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# Co-Designing Decision Support Systems for Niche Agriculture: Medjool Date Thinning

**Noy Saraf**, Institute of Agricultural and Biosystems Engineering, Agricultural Research Organization – Volcani Institute, Rishon LeZion 7505101, Israel

**Yuval Cohen,** Institute of Plant Sciences, Agricultural Research Organization – Volcani Institute, Rishon LeZion 7505101, Israel

**Noah Morris,** Southern Arava R&D, Eilat Region, Israel

**Tal Oron-Gilad**, Department of Industrial Engineering and Management, Ben-Gurion University of the Negev, Beer-Sheva, Israel

**Maia Nusinow**, Ardom Telecomputing, Israel

**Avraham Sadowsky**, Southern Arava R&D, Eilat Region, Israel

**Tamir Tikochinsky**, Southern Arava R&D, Eilat Region, Israel

*__Yael Salzer__, Institute of Agricultural and Biosystems Engineering, Agricultural Research Organization – Volcani Institute, Rishon LeZion 7505101, Israel

[*]Corresponding author:

Dr. Yael Salzer

**Email:** salzer@volcani.agri.gov.il

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**Abstract**

The adoption of agricultural decision support systems (DSS) remains lower than anticipated, particularly in small, rural sectors with unique needs. This study applies a participatory design approach to align future DSS with farmers' practices and priorities. Although relatively small, the Israeli Medjool date sector has a major role in global date production and national agricultural exports. Effective fruit thinning is critical for fruit weight, quality, and yield, yet no DSS currently supports thinning protocol decisions. To address this gap, we engaged farmers directly in the design process, integrating their expertise into system requirements. Qualitative and experimental methods were employed over three years, including open-ended interviews and annual in-field fruitlet counts. A foundational workflow was first mapped to capture the existing thinning process and highlight knowledge gaps. We then identified key factors guiding thinning decisions, evaluated farmers' perceptions of their relevance, and examined how protocol consistency influences field workers' performance. Findings show that farmers consistently prioritize fruit weight, yield, and revenue, despite differing management styles. Importantly, greater consistency in planning was significantly correlated with reduced deviations in field implementation. This suggests that DSS may foster adaptive decision-making strategies that improve protocol efficacy, though possibly at the cost of in-field precision. The study demonstrates the potential of participatory design to develop tailored DSS for niche agricultural groups. By capturing farmers' knowledge and preferences, this approach offers a pathway toward context-specific tools that enhance adoption, sustainability, and innovation in specialized crop sectors.

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**Keywords**

decision support system, digital farming, fruit thinning, knowledge elicitation, Medjool date fruit, on-farm experimentation, participatory design, yield optimization

**Abbreviations**

DSS - Decision Support System

## 1. Introduction

Farmers make complex decisions on a daily basis in a dynamic agricultural environment, often dealing with large amounts of information. Typically, the relevant data is not regularly logged or stored, and when it is logged, it is often done sporadically without uniformity. Analyzing large datasets requires time and skills farmers may lack (Fountas et al. 2006; Van Hertem et al. 2017; Gutiérrez et al. 2019). Decision support systems (DSSs) can assist farmers in manage farms by collecting, and analyzing data from multiple sources. Studies investigated agricultural DSSs for various operations, including irrigation (Navarro-Hellín et al. 2016), fertilization (Villalobos et al. 2020), pest control (Padma et al. 2017), crop management (Lorite et al. 2013), climate (Jarvis et al. 2017), aquaculture (Piplani et al. 2015), dairy farming (Oliver et al. 2017) and more (Lagos-Ortiz et al. 2019). Agricultural DSSs that manage farms by collecting and analyzing data instructions preserve farmers' autonomy in making the final decisions (Zhai et al. 2020) and are more likely to be adopted (McCown 2002).

Despite their recognized benefits, agricultural DSSs see limited adoption, partly due to the top-down approach of delivering fully developed technologies that lack adaptability to emerging challenges and farm-specific conditions (Fuglie et al. 2020; Rossi et al. 2014; Gent et al. 2013; Parker and Campion 1997; Périnelle et al. 2024). Adoption barriers include farmer traits (e.g., age, education, risk management, personal objectives, and experience), DSS relevance to specific decision-making tasks,integration with current farming practices and technologies (McCown 2002; Alvarez and Nuthall 2006; Aubert et al. 2012), and data-sharing concerns (Reissig et al. 2024). Parker and Sinclair (Parker and Sinclair 2001) found only three widely adopted UK agricultural DSSs—all developed with user participation. Systems without such engagement saw little to no regular use (Parker, 1996). Gutiérrez and colleagues (2019) reviewed 61 agricultural DSSs; aabout half aimed to aid farmers understand farm status and make informed decisions, but only eleven used participatory design methods.

Farmers and stakeholders now play a greater role in designing agricultural DSS using participatory methods (Rose et al. 2016, 2018). Participatory design combines researchers' insights with farmers' contextual knowledge—definition of challenges, environmental conditions, management options, and key indicators for the DSS—improving understanding of farm management needs (Cheriere et al. 2025). Participatory design enhances trust, acceptance, effectiveness, and uptake of agricultural DSS (McCown 2002; Lamb et al. 2008; Jakku and Thorburn 2010; Van Hertem et al. 2017; Gutiérrez et al. 2019) as shown in crop production (Parker and Sinclair 2001), beef cattle crossbreeding (Newman et al. 2000), greenhouse management (De Oliveira et al. 2022), and more (Gutiérrez et al., 2019).

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Farmers' expertise is typically practical, developed through hands-on learning and experience, and shaped by their perspectives and goals (Cornelissen et al. 2003). DSS design uses knowledge elicitation methods to capture farmers' insights. These methods help researchers understand how farmers make decisions, solve problems, and manage knowledge (Hoffman et al. 1995). Knowledge elicitation methods vary widely, with no single definitive procedure (Cooke 1999). Observing farmers in their work environment provides insights into behaviors, helps develop initial concepts, and identifies constraints (Keval and Sasse 2010). Interviews, workshops, and discussions help explore complex issues and clarify tacit knowledge. Researchers can use structured, unstructured, semi-structured, or open-ended methods to interact directly with the farmers, exploring their perspectives, experiences, and insights on relevant topics. For example, Papadopoulos and colleagues (2011) developed a fuzzy DSS for site-specific nitrogen fertilization, formulating its fuzzy rules through expert interviews and annotated scientific and technical resources. Participatory design workshops actively involve farmers and stakeholders in developing systems that directly affect them (Kusnandar et al. 2019; Cheriere et al. 2025). These workshops facilitate a deeper understanding of farmers' agricultural practices and aid in designing DSS that better assist them in achieving their objectives (Odom 2010). Oliver et al. (2017) developed a farm-scale DSS using an empirical model to assess E. Coli risk. They ensured accessibility by engaging stakeholders—including regulators, industry, academia, and farmers—through workshops and demonstrations.

Generally, commercial DSSs are designed to serve a wide user base—a cost-effective strategy that maximizes impact and development efficiency. However, some agricultural industries are region-specific and limited to a few sites, where few decision-makers control a major market share. These specialized farmers form a niche group with significant market influence. Transferring the same system between different agricultural industries is less feasible in these cases. Instead, design and development should cater to the local industry’s end-users and stakeholders.

### 1.1. Date Palm Farmers: A Specialized Niche Group

Israeli date palm farmers form a niche group of only a few dozen individuals, yet they exert significant influence over the global date production, contributing significantly to the country's agricultural export economy. In 2023, their combined turnover reaches 43,000 tons of dates, valued at 832 million USD (Central Bureau of Statistics 2023). The industry focuses on the Medjool cultivar (also called ‘Medjhool’, ‘Medjoul’, ‘Mejhul’, or ‘Mejhoul’), marketed as an elite product (Cohen and Glasner 2015). Israeli farmers are leading Medjool producers and exporters globally, producing more than 45% of the world’s Medjool dates (Cohen and Glasner 2022). Due to its status as a premium cultivar, Medjool cultivation is growing worldwide, resulting in an annual increase in production.

Cultivating Medjool date palms requires careful management and specialized labor. Farmers harvest pollen from male trees and pollinate inflorescences on female trees (February - March, in Southern Israel), thin the fruit bunches (March-May), tie up the bunches to nearby fronds, cover the fruit bunches with mesh sacks (July) and selectively and repeatedly harvest the fruit (August–October) (Cohen and Glasner 2015). As

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a a premium product, Medjool fruit is anticipated to possess an impeccable appearance, significantly impacting its pricing based on size and quality. The main quality factors are fruit size (bigger fruits are sold at higher prices) and perfect appearance. Common physiological defects that reduce quality include skin separation (Lustig et al. 2014; Cohen and Glasner 2015; Alam et al. 2023) and dry rings at the base of the fruit. The tree's fruit load affects the quantity, quality, and weight of Medjool dates.

Fruit load results from fruit set and natural abscission, both influenced by climate and environmental conditions. In spring, fruit bunches develop at the axil of the palm fronds that developed in the previous season. Each fruit bunch Fruit load results from fruit set and natural abscission, both influenced by climate and environmental conditions thousands of fruitlets. Depending on climatic conditions, cultivation practices, and the tree's age, 20-30 fruit bunches develop in each mature Medjool tree. The bunches grow in three whorls—upper (6-8), center (10-16), and lower (6-8)—named by their relative height on the crown. Each bunch consists of a fruit stalk, several dozen unbranched rachilea (spikelets, strands), with 50-100 flowers on each spikelet that develop into fruitlets after pollination (Zaid and de Wet 2002; Krueger 2021; Bar-Shira et al. 2023). Only some flowers develop into fruit, while others naturally abscise, mostly at two peaks: early during fruit setting and late during the 'June drop,' though abscission continues throughout development (Ish Shalom et al. 2024).

Growing strategies and specific thinning protocols have been developed to help Medjool fruit achieve premium qualities (Figure 1). Fruit thinning is a manual practice that removes excess fruitlets early in development. Although data-logging tools are available, none directly support thinning decisions for farmers. A dedicated DSS for thinning protocols has yet to be developed. The factors valuable for formulating thinning protocols are unclear, and no models exist to predict yield and quality based on farming practices and environmental conditions. These research needs came directly from the farming community, as growers' feedback on the lack of a suitable tool prompted the development of a decision-support system for thinning, which guided its design.

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**Figure 1. Medjool date palm orchard, Sourthern Arava.** Most horticultural tasks, including thinning, are performed on the crowns of tall trees, requiring high platforms for access (Yael Salzer, 2021).

Adopting a DSS by Medjool date farmers could significantly impact global production. Designing a DSS for a niche group of experts requires early involvement to leverage their unique knowledge (Parker and Sinclair 2001). Future DSS designs should engage the end-user community to address the lack of decision support tools for thinning protocol generation. Capturing and utilizing their expertise in system design requires focused effort.

### 1.2. The Conceptual Framework for the Study

This research used a mixed-method approach to explore farmers' contextual framework, identify conceptual requirements for a future DSS, and assess its impact on current practices, ensuring the alignment with farmers' constraints and workflows. First, we first created a workflow mapping the current on-farm process to identify knowledge gaps for future DSSs. We then conducted three complementary studies. In Study 1dentified the key factors farmers prioritize when developing a thinning protocol. In semi-structured interviews, farmers discussed aspects of thinning protocol decision-making and the significance of various factors. Study 2 examined farmers' feedback on visual dashboardspresenting key factors from Study 1 relevant to thinning protocols, assessing their perceptions and acceptance during decision-making. Finally, Study 3 explored the relationship between the inclination to modify thinning protocols and field workers'

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adherence to them. Over three years, we conducted repeated open-ended thinning protocol interviews and in-field fruitlet counting. Over three years, we conducted repeated open-ended thinning protocol interviews and in-field fruitlet counting.

## 2. Material and Methods

### 2.1. Participants

The research was conducted in the Israeli Southern Arava region (Figure 2), home to twelve large date-growing establishments owned by local cooperative communities. Most farmers receive cold storage and packing services from Ardom Cooperative, a modern, local packing house. Most farmers use Tamarika© orchard management system (Ardom Communications, Israel) to manage their date orchards. The study was carried out in collaboration with the Southern Arava R&D, a regional branch of the Ministry of Agriculture and Food Security, and the Agricultural Research Organization—Volcani Institute, a governmental institute dedicated to advancing local agriculture and addressing global agricultural challenges. As researchers from the Volcani Institute and Southern Arava R&D, we maintain close, year-round contact with local growers. This ensures that collaboration with farmers is continuous and direct throughout the lifecycle of our research projects, as was the case in this study.

Regional growers hold annual meetings in which they openly discuss the previous year's performance. Costs and productivity are reported by name and without concealment as part of the regional collaboration. In the same forum, researchers working with the farmers also present the outcomes of their studies from that year. A year before this research program began, we met with the region's Medjool growers at the annual gathering, where we introduced the research and invited them to participate in our on-farm study.

Eight farmers (seven male and one female), representing 66% of the region's Medjool growers (Hunt et al. 2025), participated in the research, actively seeking innovations to improve their orchard management. All participants are active date farmers with at least fifteen years of date cultivation management experience. Participants manage orchards ranging from 73 to 122 hectares. Six of the eight participants from Study 1 continued to Studies 2 and 3, representing 50% of the region's Medjool growers.

Discussions were conducted collegially during routine meetings. The long-standing relationship between the regional R&D, Volcani researchers, and the farming community has been characterized by immediate and ongoing collaboration. Consequently, formal written consent forms would not have reflected this informal, trust-based process. At the beginning of each study, participants were informed that their participation was voluntary and they could withdraw at any time.

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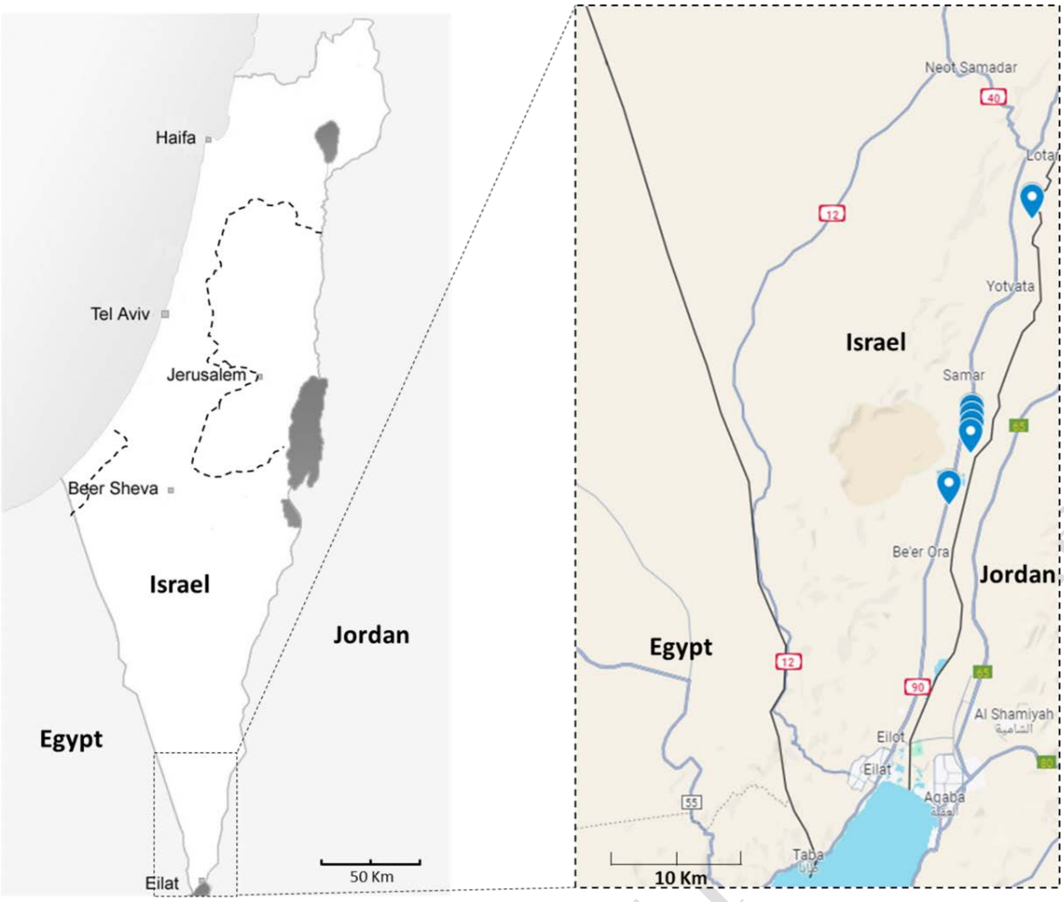


**Figure 2. Geographical overview and experimental site locations.** Left: A Schematic map of Israel. Map lines delineate study areas and do not necessarily depict accepted national boundaries. The dashed inserted box represents the enlarged Southern Arava region, with accompanying regions of Egypt and Jordan, presented in the right panel. Locations of participating farms are marked with blue pins.

## 2.2. Foundational Workflow Mapping for Medjool Date Thinning: Current On-Farm Practices

A schematic foundational thinning protocol decision-making workflow of the information and operations is presented in Figure 3. Thinning is crucial for optimizing fruit weight, quality, and yield, making strategy and timing essential for farmers' success (Figure 3 A-C). There is an inherent tradeoff between fruit number and fruit weight. More fruitlets generally result in smaller fruits, while fewer fruitlets result in larger, more valuable fruits. However, excessive yield reduciion can limit the tree's potential. Therefore, farmers face the challenge of identifying the optimal balance where tree yield is maximized while ensuring a skewed distribution towards higher fruit weights. Thinning the bunches can influence pest control and disease prevention, and improve harvesting efficiency. Thinning occurs at three levels: adjusting the number of bunches per tree, removing central spikelets within each bunch, and shortening spikelets to control fruitlet numbers per spikelett (Figure 3C). To support optimal growth, only a few hundred fruits should be left per bunch remain, leading to several thousand per mature Medjool tree. To complete thinning on time, must start thinning early, before they can assess fruit set (i.e., the number of rapidly developing fruits) or predict natural fruit drop (abscission) during later fruit development stages (Figure 3D). The thinning strategy (Figure 3A) is

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a key decision point for farmers, directly affecting fruit yield, quality, and revenue. Study 1 aimed to identify key factors farmers prioritize in thinning protocol development.

Most farmers maintain protocols and field performance records throughout the years (Figure 3E), with some choosing to keep these records internally and others preferring to log them on a locally developed orchard management system database. However, the existing data-logging tools do not directly assist farmers in thinning protocol decisions. A dedicated decision support system (DSS) for thinning protocols does not yet exist (Figure 3F, dashed lines). As a result, no models currently predict yield and quality based on farmers' practices and environmental conditions. Moreover, the key factors and information needed to formulate a thinning protocol remain unclear. Study 2 examined farmers' responses to the information presented during the decision-making process. We assessed their perceptions and acceptance of the key factors identified in Study 1 as relevant to planning thinning protocols.

The date farmers adhere to management protocols and cultivation techniques to the best of their understanding and experience while considering the available workforce and machinery resources. Since most of the work is performed on the crowns of tall trees, expensive equipment, including high cranes/platforms, is required for most horticultural tasks. The farmers employ different thinning strategies adapted to their target yield, which they implement at different times and with varying degrees of accuracy or speed. Some farmers adhere strictly to consistency, rarely applying changes to the thinning protocols over the years. Others adopt a dynamic approach, updating the thinning protocol based on their in-field experience and interpretation of previous records of informing factors. Once a protocol is decided, the farmer introduces the instructions to the field workers (Figure 3B). The farmers' instructions are translated into field execution, performed by a team of workers. The realized result, the implementation of the thinning protocol (Figure 3C), frequently diverges somewhat from the initial plan. In Study 3, we examined how the tendency to modify and update thinning protocols over the years affects field workers' performance, specifically in terms of implementation deviation from the instructions. Within the framework of this longitudinal study, it is hypothesized that the greater the farmer's consistency, the smaller the gap between the thinning protocol and the in-field outcome, assuming the team of workers has remained mostly unchanged over the years. Conversely, a farmer who frequently updates the thinning protocol yearly is likelier to experience field outcomes that deviate from the planned protocol.

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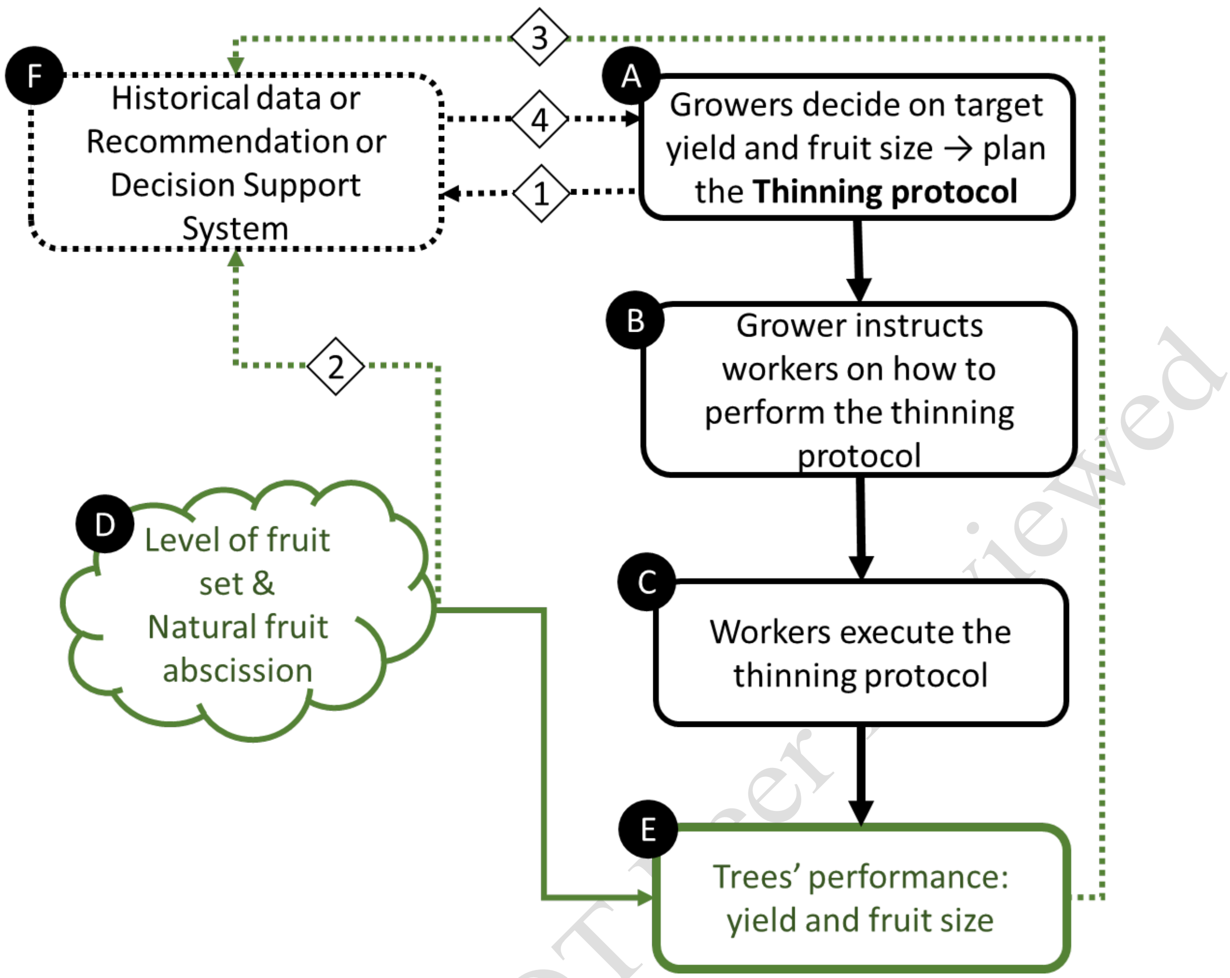


**Figure 3. Thinning protocol decision-making workflow.** Letters (A–F) represent processes or entities, while numerals (1–4) indicate the sequence of events (solid lines) and information flow (dashed lines). Each season, (A) farmers develop a thinning protocol to achieve target fruit size and yield. (B) Field workers implement these instructions. (C) The actual thinning, combined with (D) natural fruit set and abscission—factors only partially known to the farmer at the time of decision-making—affects tree performance (E). A decision support system (DSS) is not yet available (F), as indicated by dashed lines. When developed, the DSS will use historical records of thinning protocols <1>, fruit abscission <2>, and tree performance <3> to assist farmers in planning future protocols <4>.

### 2.3. Study 1: Farmers' Insights into Key Factors Affecting Thinning Decisions

Study 1 identified key factors farmers prioritize in thinning protocol. Each participant underwent a semi-structured interview. The interviews were conducted via Zoom between January and March 2020 during COVID-19, lasting 30 to 90 minutes each. Questions were shared via Qualtrics on a shared screen and were introduced verbally. The participants provided responses that the reviewer recorded, and they were encouraged to elaborate further. Participants gave their permission to record the interviews, which were transcribed for further analysis. Each interview lasted between 30 minutes and 1.5 hours.

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#### 2.3.1. **Explicit Value: Factor Ranking**

Participants ranked from highest to lowest the contribution and value, i.e., *explicit value,* of 11 expert-defined factors relevant to the thinning protocol—*number of bunches per tree, climate, available high platforms, thinning timing, revenue, market-driven requirements, desired fruit weight (gr), desired yield (kg tree*$^{-1}$*), fruit quality (i.e., skin separation, dry rings), workers' proficiency,* and *the plot's historical records*. The participants were encouraged to introduce other not-listed factors they deemed significant to the thinning protocol.

#### 2.3.2. **Implicit Value: Semi-Structured Interviews**

Participants were asked about the nature of their farm and the expected yield per typical mature tree. Then, they were asked about their perspective on the value of accurate bunch, spikelet, and fruitlet counting and the investment of efforts in this task. Further, they were asked about the value of timing and labor in thinning, thinning precision during the early and late thinning rounds, and thinning protocol decisions. Lastly, they were asked about the value of using prior data to predict natural fruit drop assessment and how prior estimates affect their thinning decision. Participants were encouraged to explain their decisions regarding the thinning process in depth.

Two human factors engineering experts (N.S. and Y.S.) and one date palm expert (Y.C.) independently reviewed the transcripts. The experts were asked to determine, on a Likert scale ranging from 1 (low) to 7 (high), each one of the 11 factors' level of importance to the individual farmer as it emerged during the interviews. These scores were averaged for each factor and farmer and were defined as the factors' *implicit value.*

#### 2.3.3. **Data Analysis: Value Mapping**

Each listed factor was associated with paired explicit and implicit value scores. When both scores are high or low, the factor value is consistent. When a pair of scores are inconsistent, where the implicit value score is high, and the explicit value is low, the farmer may be unaware of the factor's significance. Conversely, when the implicit value score is low, and the explicit value is high, it is plausible that the interview session may have failed to extract additional information on a factor the farmer explicitly identified as important.

### 2.4. Study 2: Farmers' Perceptions of Visualization of Key Factors in The Thinning Decision-Making Process

Study 2 aimed to evaluate how farmers responded to the information presented during the decision-making process. The study assessed their perceptions and acceptance of interactive visual tools that linked past thinning practices to corresponding harvest results, which were identified as key factors in Study 1.

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Their feedback helped assess the practical utility and clarity of the information provided and its effectiveness in supporting informed decision-making.

### 2.4.1. Data Processing

Historical thinning protocols were derived from the documented fruitlet counts recorded in the orchard management system database (Tamarika©, Ardom Communications, Israel), while harvest results were obtained from the packing house management system. It is important to note that the orchard management system database and the packing house management system are not synchronized. Therefore, the data was consolidated and processed to enable the association of fruitlet counting with tree yield, fruit weight, and quality.

**Fruitlet Counting**

Thinning is gauged by fruitlet counting. Typically, farmers sample fruitlets count once thinning is completed, between late April and May, and again before bunch coverage in July. A farmer would assess two to four representative trees within a plot in a routine sampling procedure. However, not all farmers engage in fruitlet counting. Of those who do, some maintain their records internally, while others opt to log them on the orchard management system database.

**Yield (kg tree$^{-1}$)**

The orchard management system database maintains an annual record of the total plot yield (in kilograms), the number of trees per plot, and the trees' planting dates. The average yield per tree is calculated by dividing the total plot yield by the number of trees in a plot. The yield of date trees is influenced by age, with younger trees producing less fruit than mature ones. For consistency, tree yield was normalized per plot using an expert-endorsed method.

**Individual Fruit Weight and Quality**

The dates are transported to the regional packing house during the harvest period between August and October. The dates are processed and sorted into one of 37 predetermined categories based on fruit size and quality. The packing house annually records the total farm yield (kilograms), and yield according to the categories used by the marketing cooperative that sells the dates. Each category defines a specific combination of fruit weight fraction and quality (i.e., level of skin separation and the presence of dry rings). For instance, a category might be linked to a fruit weight fraction of 18 to 23 grams with no skin separation, while another category with the same weight of 18 to 23 grams includes up to 15% skin separation. The warehouse raw data was consolidated and processed into two sets of orthogonal meaningful category classifications: four fruit weight categories (small fruit < 15 gr, 15 gr < 18 gr, 18 gr < 23 gr, larger than 23 gr) and four skin separation categories (no skin separation, 5-15%, 15%-40%, above 40% skin separation). Critically, the packing house consolidates yields from multiple plots within the same farm and evaluates the total yield and fruit categories at the farm level.

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**Database Consolidation**

The information shared with the farmers stemmed from the consolidation of databases, including 106 data points of fruitlet counting upon thinning completion (mid-May), fruitlet counting before bunch coverage (mid-July), and average tree yield spanning from 2015 to 2021 across 31 plots associated with nine farms. One hundred thirty-seven records covered the yearly farm yield and yield corresponding to 37 fruit size-quality categories of 26 distinct farms between 2012 and 2020. The intersection with the fruitlet counting data concluded in 22 records of average fruitlet counting and yield associated with nine farms between 2015 and 2020.

### 2.4.2. Visualizationt Setup

Microsoft Power BI was employed to showcase the average tree yield contrasted with fruitlet counts per tree upon thinning completion and before bunch tying, the percentage distribution of yield based on the size-quality category at the commercial farm level, and the percentage distribution of yield based on fruit weight, and the percentage distribution of yield based on skin separation level, as outlined in Table 1. The Microsoft Power BI interactive dashboards on a 55’ screen provided unified displays to the farmers for interaction and exploration by the farm, plot, or years they wished to view.

<Table 1 here>

### 2.4.3. Interviews: Introducing Dashboards to the Farmers

Individual one-hour meetings were conducted with each of the six farmers in March 2022. Five sessions were conducted at the farms' central offices, and one was carried out through video conferencing. With the farmers' consent, all meetings were recorded and transcribed for further anaylsis. Farmers who do not routinely record their data on the orchard management system database were introduced to General Dashboards 1, 2, and 3, presenting all available historical records of all sites, albeit anonymized. Farmers who had their thinning records logged on the orchard management system database were presented with three additional Site-specific Dashboards, 4, 5, and 6, displaying the data explicitly linked to their plots and farm records. The meeting started with an overview of its objective and an introduction to the interactive dashboards, emphasizing farmers' interpretations and insights on the displayed information. The content of the dashboards that would be presented to them was then explained. The farmers were invited to share their thoughts and give feedback freely at every step, creating a space for open discussions. Dashboard-related themes were extracted from the farmers' responses to the presented dashboards. General themes were also identified from statements and references unrelated to specific dashboards, but focusing on data presentation and its potential influence on thinning decision-making were noted.

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### 2.5. Study 3: The Influence of Thinning Protocol Consistency on In-Field Implementation

The longitudinal study examined the interdependence between the consistency of farmers' thinning protocols and the accuracy of workers' adherence to these instructions. Over three years, 2021, 2022, and 2023, repeated open-ended thinning protocol interviews and in-field fruitlet counting visits were conducted (Figure 4). It was hypothesized that a farmer who is more likely to update the thinning protocol every year will experience a more significant gap between the planned protocol and its in-field implementation. The six farmers who participated in Studies 1 and 2 also participated in Study 3.

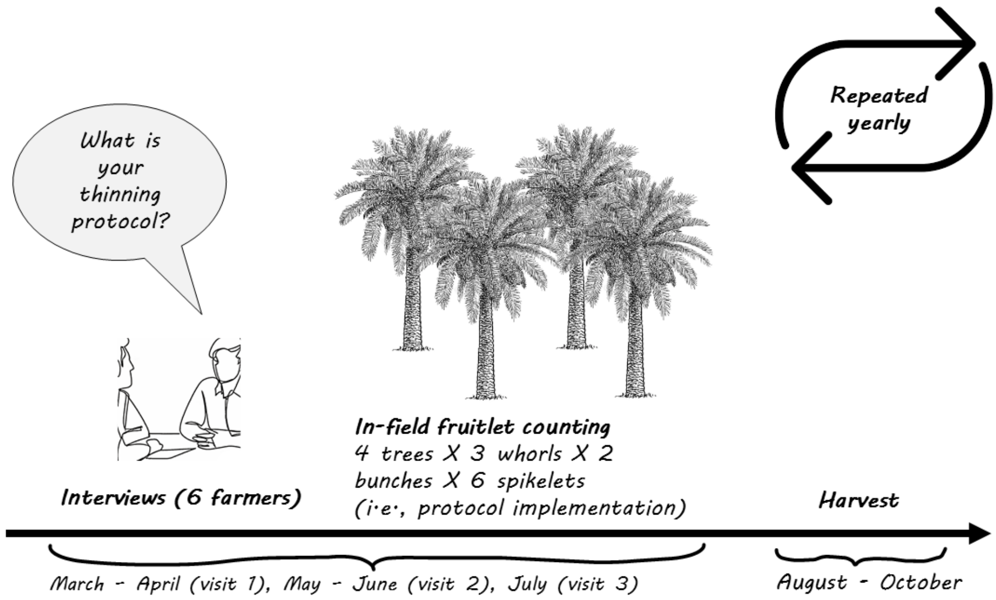


**Figure 4. Overview of the three-year longitudinal study (2021–2023).**

#### 2.5.1. Data collection

**Thinning Protocols Instructions: Findings from Open-Ended Interviews**

The primary objective of the open-ended explicit thinning-protocol interviews was to gain insights into the strategic planning of the thinning processes and to gather information about the farmers' instructions to field workers. The interviews were conducted twice or three times a year. The interviews were timed to coincide with the in-field fruitlet counting following the first round of thinning and/or after the completion of the thinning of the trees. Most of the interviews were carried out in person. Farmers were asked about the thinning protocol decisions and to estimate the number of bunches in each whorl (upper, center, lower), spikelets, and fruitlets expected to remain on these bunches, in alignment with the counting visit date. Farmers were encouraged to explain their decision on the specific thinning protocols. The interviews fostered in-depth discussions about the instructions issued. They delved deeper into the decision-making processes behind these directives, such as the effect of specific weather conditions and the expected percentage of fruit that will fall during the growing period (i.e., abscission). Critically, the farmers were encouraged to assess

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how the instructions were translated into field execution and how the resulting thinning was monitored. Most of the interviews took place in person. During the COVID-19 pandemic, some interviews were conducted by phone or video-conference application (Zoom ©). Explicit permission to document the proceedings was obtained from each participant before the interviews.

**Quality of Thinning Implementation: Field Data Assessment**

Quantitative data was collected through in-field counting to evaluate workers' performance. Four adjacent trees per farmer, left unmarked to prevent worker bias, were selected each year for evaluation. Visits were coordinated with farmers, and counting was performed immediately after the first round of thinning, post-completion of thinning, and two months later, around mid-July, when the fruit bunches were covered with nets in preparation for the harvesting period. On each visit, the research team followed the thinning process by randomly selecting two bunches from each whorl, six bunches in total per tree. The research team marked the clusters for future reference on each visit. The team counted and recorded the number of spikelets in each of the selected bunches. The team randomly selected six spikelets within each bunch to count and record the number of fruitlets. On the last visit, the research team determined the total number of bunches per tree. Field counting produced a dataset comprising three-dimensional data samples: fruitlets per spikelet, spikelets per bunch, and bunches per tree.

### 2.5.2. Data Analysis

The interview data were analyzed to quantify farmers' tendency to modify thinning protocols over the years, referred to as *Protocol Planning Consistency*. The in-field counting and interview data were assessed to quantify discrepancies between the intended thinning and the actual actions taken, termed *Protocol Implementation Deviation*. These two metrics were correlated to estimate their interdependence.

**Protocol Planning Consistency Index**

*Protocol Planning Consistency* index is a quantitative assessment of farmers' tendency to modify thinning protocols over the years. *Protocol Planning Consistency* was determined by calculating the Euclidean distance between yearly and averaged protocols, as expressed in Equation 1. A lower *Protocol Planning Consistency* value indicates that the planning activities are carried out according to a structured and uniform approach, while a higher value suggests variability in the planning methods.

Equation 1. Protocol Planning Consistency (PPC), index of farmer's level of consistency

$$PPC_{g,v,w} = \frac{\sum_y \sqrt{(B_y - \bar{B})^2 + (S_y - \bar{S})^2 + (F_y - \bar{F})^2}}{no.of\ years}$$

Where:

$g = \text{farmer} \in \{A, B, C, D, E, F\}$

$v = \text{counting visit} \in \{1, 2, 3\}$

$w = \text{whorl} \in \{\text{upper}, \text{center}, \text{lower}\}$



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$y = \text{ year} \in \{2021, 2022, 2023\}$

B = Quantity of bunches by protocol

$\bar{B}$ = Quantity of bunches by protocol averaged over three years of study

S = Quantity of spikelets by protocol

$\bar{S}$ = Quantity of spikelets by protocol averaged over three years

F = Quantity of fruitlets on a spikelet by protocol

$\bar{F}$ = Quantity of fruitlets on a spikelet by protocol, averaged over three years

**Protocol Implementation Deviation Index**

The *Protocol Implementation Deviation* index measures the gap between the farmer's planned protocol for each whorl and visit time —specifying the desired quantity of bunches per tree, spikelets per bunch, and fruitlets per spikelet—and the actual in-field implementation by the workers. Euclidean distance between in-field counting and the protocol was calculated, as detailed in equations 2 and 3. High *Protocol Implementation Deviation* indicates significant differences between the planned protocol and actual implementation

Equation 2. Single data point deviation from protocol. The Euclidian distance (deviation, Dev) between a single in-field three-dimensional data point and the specified protocol associated with specific whorl and visit.

$$Dev_i = \sqrt{(B - b_i)^2 + (S - s_i)^2 + (F - f_i)^2}$$

Where:

i = sample, in-field count

B = Quantity of bunches by protocol

b = Quantity of bunched counted

S = Quantity of spikelets by protocol

s = Quantity of spikelets counted

F = Quantity of fruitlets on a spikelet by protocol

f = Quantity of fruitlets on a spikelet, counted

Equation 3. Protocol Implementation Deviation (PID). The Euclidean distances averaged across all years and trees for each grower, visit, and whorl.

$$PID_{g,v,w} = \frac{\sum_y \sum_t \ \sum_{i=1}^{n} \sqrt{Dev_{g,v,w,y,t}}}{no.of\ year * no.of\ trees * n}$$

Where:

$g = \text{ farmer} \in \{A, B, C, D, E, F\}$

$v = \text{ counting visit} \in \{1, 2, 3\}$

$w = \text{whorl} \in \{\text{upper}, \text{center}, \text{lower}\}$

$y = \text{ year} \in \{2021, 2022, 2023\}$

$t = \text{ tree} \in \{1,2,3,4\}$

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n = samples, in-field counts

## 3. Results and Discussion

This research used a mixed-method approach to explore the farmers' contextual framework, identify the conceptual requirements for a future DSS, and assess its potential impact on current practices, ensuring the system aligns with farmers' constraints and workflows. To that end, the sector experts were involved in the process from the early stages.

Understanding the factors influencing thinning practices, horticultural and managerial, required meetings with farmers over three years; detailed horticultural results were presented in Cohen et al. (2025). First, the researchers and experts reached out to the farmers to define the thinning process flow. A foundational workflow mapping the current on-farm process was created and then used to identify knowledge gaps for future DSS. The gaps that emerged included the need to identify the factors farmers consider valuable in formulating protocols, study their compliance with visualizing these factors in the decision-making process, and explore the impact of their tendency to update decisions on the in-field implementation.

### 3.1. Study 1: Farmers' Insights into Key Factors Affecting Thinning Decisions

For each factor, the paired scores—explicit and implicit value—were mapped on a scatter plot, as shown in Figure 5. These maps identify four value categories based on quadrant location (Yousaf et al. 2023). Each quadrant represents a distinct attribute. In quadrants 1 (upper right) and 3 (lower left), the farmers' explicit and implicit assessments of the factor's value are consistent—*high* and *low*, respectively. Quadrant 2 (upper left) represents cases where the scores are incongruent, with high implicit and low explicit values. This suggests the farmer may not recognize the factor's significance , i.e., *unaware value*. Quadrant 4 (lower right) represents incongruent scores, with low implicit and high explicit values. This suggests that the interview session may have failed to extract further information on a factor the farmer explicitly identified as important, i.e., *missing information on a factor.* A factor was classified as h*igh value, low value, unaware value,* or *missing information* if at least half of the paired assessments fell in the same quadrant.

No factor received unanimous agreement, but clear patterns emerged. Notably, farmers' explicit ranking and experts' interview assessment agreed that *desired yield (kg tree$^{-1}$), desired fruit size (gr),* and the *number of bunches per tree* were significant factors for the farmers' thinning protocol decision-making. Conversely, most farmers considered *available height platforms, market-driven requirements, workers' proficiency, fruit quality, and climate* less relevant. The farmers ranked high significance for the timing of thinning, i.e., *thinning date* and *revenue.* However, the interview session failed to extract further information that would have allowed the interviewers to agree on the level of importance. Therefore, these scores fell within quadrant 4. The *plot's historical records*' significance to the thinning protocol decision-making is ambiguous; some farmers assess it as important, while others did not; there was no majority to one quadrant. One farmer skipped ranking *revenue* and *climate* but introduced new factors: *fruit shedding* (ranked 4), *density* (6), and *plantation tree count* (10). Another farmer added *thinning end date* (ranked 1, low value). As

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these were suggested in interviews with only specific farmers, they were not included in the analysis. Figure 6 shows the mean explicit values (M) and standard deviations (SD) for each factor. *Revenue* had the highest mean ranking score (M=10, SD=3.3), followed by *desired fruit size* (gr) (M=8.5, SD=2.4) and *desired yield (kg tree$^{-1}$)* (M=8, SD=2.3).

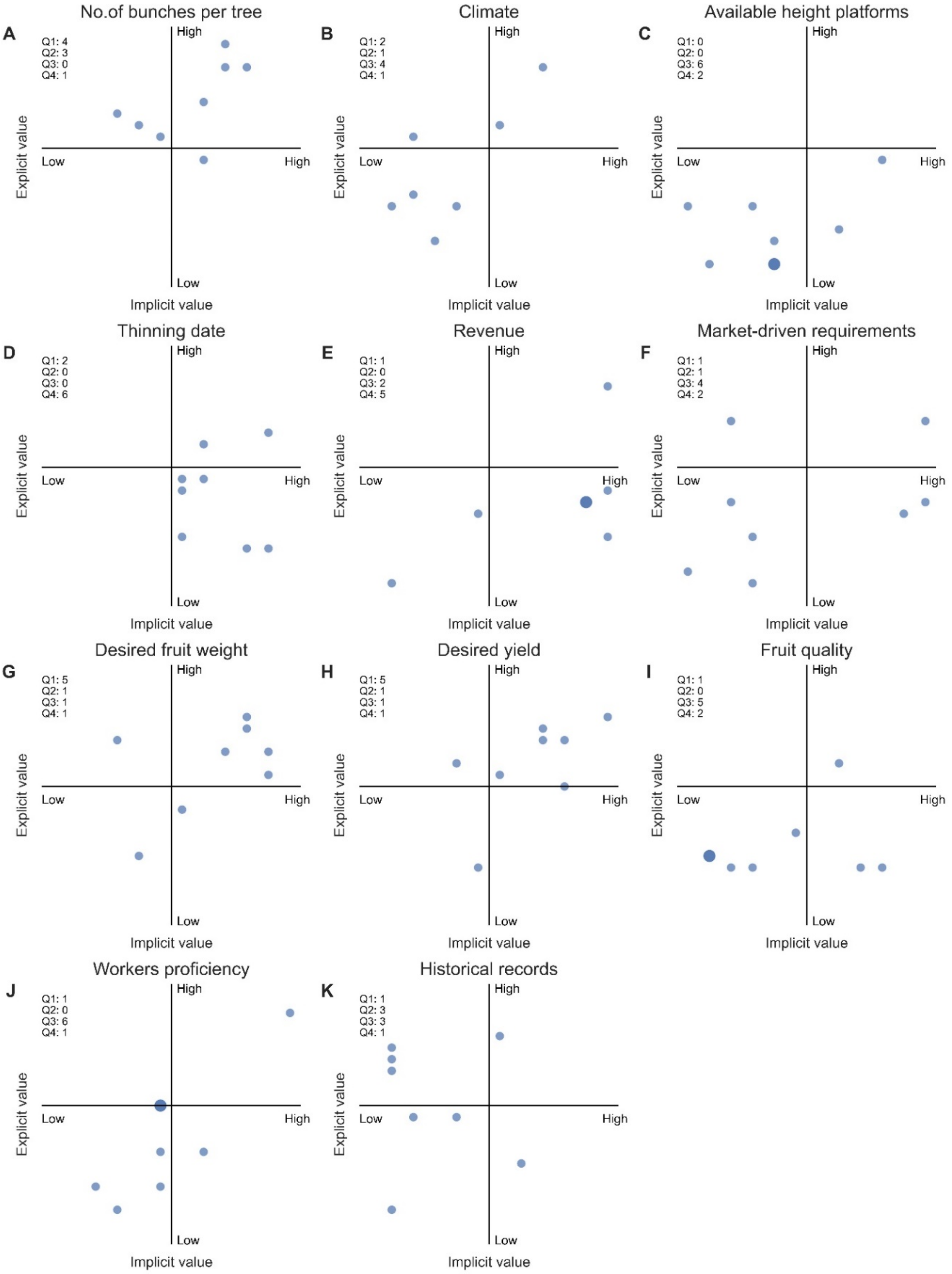


**Figure 5. Comparison of explicit (x-axis: farmer-provided questionnaire scores) and implicit (y-axis: expert interview evaluations) value scores for key factors:** (A) number of bunches per tree, (B) climate, (C) available height

platforms, (D) thinning date, (E) revenue, (F) market-driven requirements, (G) desired fruit weight (g), (H) desired yield (kg tree$^{-1}$), (I) fruit quality, (J) workers' proficiency, and (K) historical records. Data point size represents the frequency of farmers reporting the same value. The sum of data points within each quadrant is indicated as Q1, Q2, Q3, and Q4.

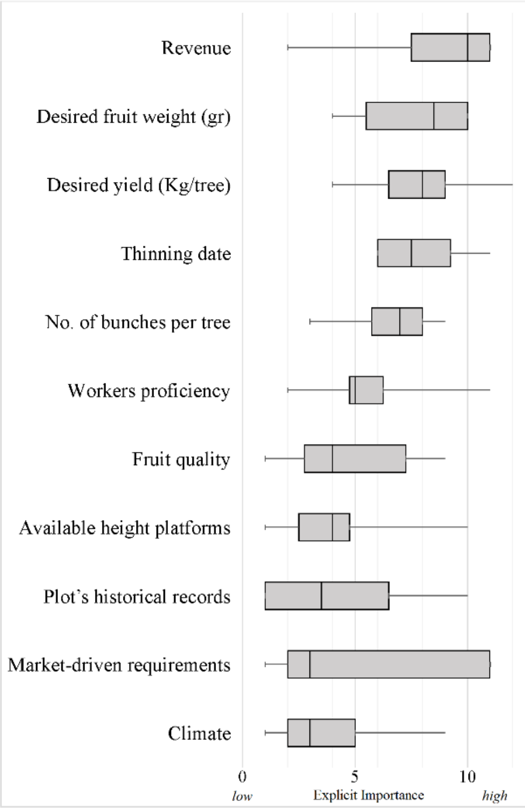


**Figure 6. Explicit thinning factors' value (median and quantiles)**

Medjool fruits are highly prized in global markets (Al-hajjaj and Ayad 2018; Zaid and Oihabi 2022). Thus, it might come as a surprise that the farmers did not rank *market-driven requirements* as important, and *revenue* scores fell in quadrant 4, suggesting that although most of the farmers openly ranked *revenue* high, *revenue* per se was not stressed during the interview.  The discrepancy is explained by the main factors affecting the market value and revenue—yield, fruit weight, and quality (e.g., skin separation, dry rings)—the former was ranked important, but the latter was not. Even though evidence from Wadi Araba, Jordan (44 km north of the northern site participating in this study) suggests that certain thinning protocols reduce skin separation as well as improve yield and fruit weight (Ahmad et al. 2023), the Israeli farmers consider fruit quality to be irrelevant to their thinning strategies. The Israeli farmers adhere to the notion that skin separation is not affected by thinning practices but rather by climatic factors (Lustig et al. 2014, 2021). Tyagi and colleagues (2017) reviewed the potential impact of several pre-harvest environmental and physiological factors and cultural practices in different crops on enhancing postharvest fruit quality and subsequently improving farmers' profitability. Cohen and Glasner (2015) surveyed the climatic factors and cultural practices unique to Israeli Medjool date production. While the reviews cover multiple cultural practices—pruning, thinning, planting density, and more — they do not address the factors' weight when decisions are made, as was done in the present research. Thus, while not directly prioritized by the date palm farmers

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participating in this study, market-driven factors undoubtedly play a significant role in shaping farmers' practices and profitability (Siddiq and Greiby 2013). Farmers' value of desired fruit weight (gr) and yield (Kg tree$^{-1}$) formulating thinning protocols highlights the farmers' shared objective of maximizing profit despite variations in their approaches to achieving this goal.

The significance of a plot's *historical records* in making thinning protocol decisions received mixed responses; while some farmers considered them important, others did not. However, it is plausible to assume that if *historical records* from multiple sources were effectively maintained, collected, analyzed, and presented, farmers might become more inclined to explore and adopt them for their benefit. Successful DSS must be well-designed (Parker and Sinclair 2001; Gutiérrez et al. 2019), as adequate information visualization empowers farmers to make informed decisions (Rossi et al. 2014).

### 3.2. Study 2: Farmers' Perceptions of Visualization of Key Factors in the Thinning Decision-Making Process

Visualization methods like time series, bar charts, histograms, pie charts, radar charts, and heat maps, can be employed to represent information (Gutiérrez et al. 2019). Users prefer visualizations that aid task completion and goal achievement (Saket et al. 2019). In the dashboards (Table 2), catterplots correlated past fruitlet counts with yield; Pie charts showed fruit weight and quality distributions; numeric values represented single data points. Researchers initially selected the visualization techniques applied in this study were based on their understanding of the subject matter; however, they may not align with the farmers' perception, understanding, and mental organization of the data.

Table 2 ummarizes themes from farmers' statements. Three farmers without routine orchard system records, were introduced only to the General Dashboards 1, 2, and 3, which presented all available historical records of all sites, though anonymized. One farmer found General Dashboard 1 (Yield per plot vs. fruitlets per tree upon thinning completion and before bunch tying) effective in illustrating fruitlet count-yield correlation. He found it striking that tripling fruitlets raised yield by just 30%. Another farmer found Dashboard 1 hard to interpret. All three ignored General Dashboard 2 (Packing house size-quality category at the commercial farm level). The farmers reacted differently to General Dashboard 3 (Yield percentages by fruit weight and skin separation). One farmer supported categorizing fruit size and quality separately. He suggested adding *fruit count* per *weight category*. The farmer expressed a desire to understand the fruit weight-skin separation correlation. However, he mentioned that skin separation alone is less interesting in the thinning strategy planning and suggested that it relates to climatic conditions post-thinning during fruit development and ripening. The second farmer expressed interest in knowing the average fruit weight. The third farmer struggled with General Dashboard 3 and preferred tables to pie charts.

Three farmers with records logged in the orchard management system database were shown General Dashboards 1, 2, and 3, which display all historical records, followed by three Site-Specific Dashboards 4, 5, and 6, linked to their individual plots and farm records. All three farmers focused on the Site-Specific Dashboards (4, 5, 6) and did not allocate considerable time or attention to General Dashboards 1, 2, and 3.

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One farmer found General Dashboard 3 useful for financial comparisons among Medjool farmers. One farmer mentioned that his team is already familiar with the figures on Site-Specific Dashboard 4 (Yield per plot vs. fruitlets per tree upon thinning completion and before bunch tying) as they calculate them internally. Nonetheless, he finds Site-Specific Dashboard 4 to be clear and intriguing. A second farmer remarked that they are also accustomed to calculating these figures internally. Therefore, unlike the first farmer, he perceives Site-Specific Dashboard 4 as adding little value for him. He pointed out that it is common for farm managers to conduct further thinning corrections after most of the operation is completed. However, because ad-hoc corrections are not logged, he is concerned that the numbers presented as 'after thinning completion fruitlet counting' do not accurately reflect reality. The farmer also proposed to add the count of bunches per tree.

The farmers overlooked Site-Specific Dashboard 5 (Packing house size-quality category at the commercial farm level). One farmer managing multiple farms found Site-Specific Dashboard 5 insightful for between-farm comparisons.

Regarding Site-Specific Dashboard 6 (Yield percentages by fruit weight and skin separation), one farmer suggested introducing the relative percentage of each category, not just the total value in kilograms. Multiple farmers valued the yield percentages based on fruit weight but found skin separation irrelevant. Farmers preferred tables over pie charts for year-over-year comparisons.

The farmers offered general comments unrelated to specific dashboards but related to data presentation and its potential impact on thinning decision-making. One farmer expressed significant enthusiasm for the displays, praising them as precisely the information he would have chosen for planning the upcoming season. Additionally, he recommended including details about abscission levels and providing quantitative information about the fruits after harvest. One of the farmers generally commented that he conducts fruitlet counting simply to verify that the work is done according to his instructions. The thinning protocol implemented on his farm is mainly predetermined and unlikely to change. Since he primarily examines his records to monitor and observe trends, he does not anticipate relying on the featured data to develop a thinning plan in the future.

<Table 2 here>

Study 2 evaluated the visualization and relevance of dashboards designed to aid farmers in thinning decision-making. Theme extraction was employed to analyze the interview data. Farmers emphasized distinguishing fruit weight from quality. They saw fruit weight data as useful but skin separation as irrelevant to thinning, viewing this factor as beyond their control. The farmers preferred the widely used and familiar table format over pie chart visualizations for displaying the separated distributions of weight and quality. This aligns with the general tendency of users to favor tables and bar charts, even when these may not be the most effective formats for specific tasks (Saket et al. 2019). While pie charts are particularly effective for conveying part-whole relationships and facilitating proportional judgments—especially for small datasets

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(Hill 2024)—percentages and simple frequencies are better suited for presenting prediction probabilities and event likelihood (Bhatt et al., 2020).

The farmers were primarily interested in figures displaying data related to their farms and plots, with less concern for general figures that include other farms' anonymized data unless these figures allowed for financial comparison. The general data can promote understanding of climate and environmental effects and improve practices in the long run. However, currently, for the individual farmer, it does not provide an immediate broader insight for improving his thinning protocol.

Most farmers count fruitlets seasonally to monitor orchards' conditions. However, they typically do not use historical counting and yield records to update the next season's thinning protocol. Scatterplots, accompanied by a line of best fit, were the efficient visual method to depict a trend (Harrison et al. 2014) and, thus, were the best candidates to display the correlation between fruitlet count and yield (kg tree$^{-1}$). While some farmers felt comfortable with scatterplots, as they mirrored their own familiar records, others found this visualization method confusing. Since most farmers are not experts in visualization and data analytics, early involvement was crucial. It provided us with a better understanding of which visualization methods foster a sense of familiarity, which are easy to interpret and comprehend, and which are less so, thereby improving the visualization of the future recommendation system. While most agricultural DSS studies have focused on analyzing responses to an existing system (Jarvis et al. 2017; Gutiérrez et al. 2019), this study engaged with farmers at the very early design stages. Study 2 highlighted the need for interactive dashboard design. As Gutiérrez et al. (2019) noted, the interactive dashboard helped farmers to select and compare information of interest, become familiar with the visualizations, and understand complex data. The farmers showed interest in features allowing for customization and comparison of data relevant to their farms and plots.

This study introduced a simplified version of the future DSS, presenting data to farmers in a meaningful manner, allowing them to derive previously unavailable insights. Notably, the dashboards did not include a prediction model or allow for exploring what-if scenarios. Farmers frequently highlighted the need for such models.Further data collection is needed to develop models predicting abscission, fruit setting, skin separation, fruit weight, and yield, considering management and climate factors. Predictive models may be limited by outliers like extreme weather conditions or pest outbreaks, which are crucial for making informed thinning decisions. Given agriculture's inherent dynamism, predicting unseen data from future seasons will present a critical challenge for predictive algorithms.

The data presented to the farmers in this study were sourced from the orchard management system database, which aggregates farmer records and reports, as well as the packing house records. This has two important implications. First, understanding the data source fosters trust in the system, especially since the current presentation avoids assumptions or predictions whose accuracy might be questionable (Cheriere et al. 2025). Visser and colleagues (2021) emphasize the critical role farmers play in shaping the accuracy of digital technologies, whether through calibration or validating decision support system advice. The farmers' trust underscores the need for continued cooperation between farmers and orchard management system

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databases to keep data current. Even with trusted data, DSS prediction models will likely remain imperfect. This limitation stems from the inherent uncertainty and limited predictability of uncontrolled seasonal and environmental factors. Further research is needed to assess farmers' compliance with the recommendations provided by the thinning support system and to determine the level of reliability required for its effective adoption (Starke and Baber 2020). Second, the study employed a bottom-up approach; automatic machines collected some data at the packing house, while other data were gathered manually by farmers without advanced technologies. This site-specific adaptation requires ongoing collaboration with farmers and experts to integrate field data into the system, reinforcing the adaptability of agricultural systems for small interest groups (Aragó Galindo et al. 2012). Currently, our approach is focused on a DSS for thinning protocols, but the central database has the potential to expand the study and maximize other aspects of Medjool cultivation.

### 3.3. Study 3: The Influence of Thinning Protocol Consistency on In-Field Implementation

The longitudinal study results are aligned with the expectation that lower protocol planning consistency would be associated with an increased gap between the thinning protocol and the in-field outcome. Figure 7 illustrates the correlation between *Protocol Planning Consistency* and *Protocol Implementation Deviation*, with $R^2 = 0.14$, $p = 0.02$. This indicates a significant positive linear correlation, where *Protocol Planning Consistency* accounts for 14% of the variability observed in *Protocol Implementation Deviation.* The results suggest that farmers who will utilize a future DSS to enhance decision-making processes may adopt a more adaptive strategy, potentially improving the protocol's efficacy at the cost of reducing workers' accuracy. However, it is important to note that multiple uncontrolled factors in the present study could also explain the workers' accuracy and adherence to instructions. These factors include the workers' experience, age, physical fitness and capacity, cumulative fatigue, heat exposure, and competency (Tiraieyari et al. 2010; Kenny et al. 2016; Karthik and Rao 2019). Sutherland et al.'s (Sutherland et al. 2012) conceptualization of management change at the farm level provides valuable insight into the mechanisms underlying farmers' decision-making. While farm managers tend to maintain consistency, they may make major alterations to their farming practices or business structures primarily in response to triggers, with minor changes happening incrementally. Considering this dynamic, integrating DSS into their decision-making processes could empower farmers to respond more effectively to catalysts, enabling them to make informed decisions that align with their long-term goals while adapting to changing circumstances.

The current research identified different types of farmers: some are flexible and modify thinning protocols over the years, while others adhere strictly to established protocols. In Figure 7, in which each color represents data a single farmer, the color distribution suggests that most farmers maintain a certain level of consistency in their practices. Some farmers adhere closely to established protocols (e.g., the farmer represented by purple), while others demonstrate more flexibility (e.g., the farmer represented by orange). These variations reflect the diversity in farmers' approaches. This variability affects both field workers' performance and the potential adoption rates of the DSS among farmers. The technology adoption profiles of Medjool date farmers, ranging from innovators to laggards (Rogers, 2003), have yet to be classified. The

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future system should be adaptable to different types of users and their evolving expectations as they gain experience with it. A partnership paradigm between developers and decision-makers can help overcome these barriers (Matthews et al. 2008). This approach fosters mutual knowledge exchange, leading to a shared understanding that enhances adoption and ensures successful implementation. Maintaining farmers' active involvement throughout the development process is essential

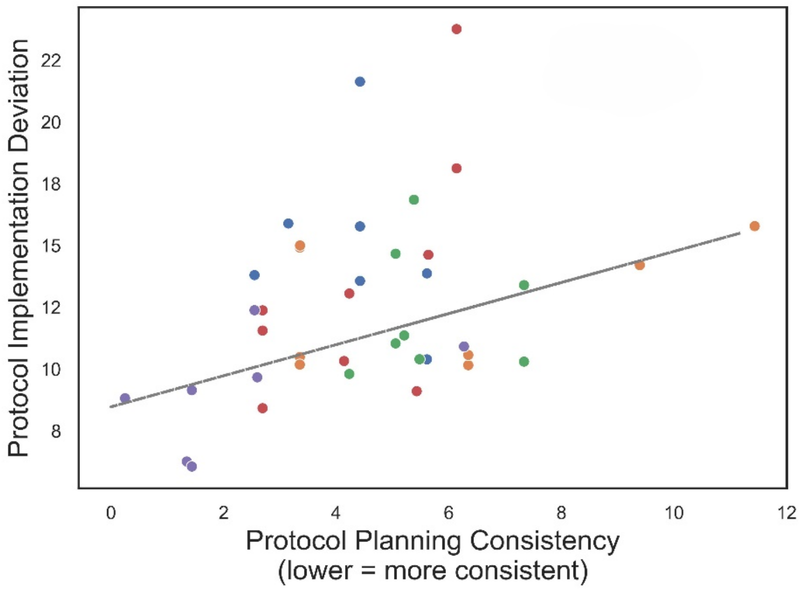


**Figure 7. Correlation between farmers' Protocol Planning Consistency (PPC) and workers' deviation from instructions, estimated by Protocol Implementation Deviation (PID), across whorl, visit, and grower.** Colors represent data for each of the six farmers.

## 4. Conclusion

The adoption of agricultural DSS is lower than anticipated, potentially due to the insufficient inclusion and application of user-centric methods during the system development stage. The farmer-participatory approach introduced in this study demonstrates significant potential for developing specific systems tailored to agricultural niche sectors, enhancing the understanding of farmers' needs and preferences, and identifying existing limitations. The future adoption and effectiveness of such systems will depend on the farmers' readiness to embrace advanced technologies and the tangible benefits these systems will provide.

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*This manuscript has not yet been peer-reviewed. A revised version may be submitted to a journal.*

## Declarations


### Funding

This work was supported by the Chief Scientist of the Ministry of Agriculture and Food Security [grant number 20-07-0043]


### Conflicts of interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

### Ethics approval

Not applicable

### Consent to participate

Verbal informed consent was obtained from all individual participants included in the study.

### Consent for publication

Verbal informed consent was obtained from all individual participants included in the study.

### Data/Code availability statement

Data available on request from the authors. Contact: Dr. Yael Salzer, salzer@volcani.agri.gov.il


### Acknowledgments

We wish to thank the participating farmers for their collaboration in the research. We thank Or Inbary for his contributions to the data collection of the first study. We thank Mira Khoury for her contribution to the dashboard design and data collection in the second study.


### Author contributions

Conceptualization: Y.S., M.N., T.O.G., N.M., Y.C., N.S.; Methodology: Y.S., A.S., M.N., T.O.G., N.M., Y.C., N.S.; Software: Y.S.; Validation: Y.S., A.S., M.N., Y.C.; Formal analysis: Y.S., N.M., Y.C., N.S.; Investigation: Y.S., T.T., A.S., N.M.; Resources: Y.S., T.O.G.; Data Curation: Y.S., N.M., N.S.; Writing - Original Draft: Y.S., Y.C., N.S.; Writing - Review & Editing: Y.S., T.O.G., N.M., Y.C.; Visualization: Y.S., N.S.; Supervision: Y.S.; Project administration: Y.S.; Funding acquisition: Y.S., A.S., N.M., Y.C.

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## Tables

**Table 1. Dashboards Visualization Setup**

| Dashboard Description | Inputs | Visualization (information received, and how) |
|---|---|---|
| **General – Dashbord 1**<br>Yield per plot vs. fruitlets per tree upon thinning completion and before bunch tying | Year | ▪ A scatterplot showing paired data points of yield per plot and the plot's average number of fruitlets per tree counted upon thinning completion.<br>▪ A scatterplot showing paired data points of yield per plot and the plot's average number of fruitlets per tree counted before bunch tying. |
| **General – Dashbord 2**<br>Packing house size-quality category at the commercial farm level | Year | ▪ A pie chart illustrating the distribution of fractions across packaging house categories, along with their respective percentages of the total for the entire year. |
| **General – Dashbord 3**<br>Yield percentages by fruit weight and skin separation | Year | ▪ A pie chart depicting the distribution of yield percentages based on fruit weight and their proportion relative to the total for the entire year.<br>▪ A pie chart illustrating the yield percentages categorized by skin separation level and their representation in the total yield for the entire year. |
| **Site-specific – Dashbord 4**<br>Yield per plot vs. fruitlets per tree upon thinning completion and before bunch tying | Farm<br>Plot<br>Year | ▪ A scatterplot showcasing paired data points of yield per plot and the plot's average number of fruitlets per tree counted upon thinning completion.<br>▪ A scatterplot presenting paired data points of yield per plot and the plot's average number of fruitlets per tree counted before bunch tying.<br>▪ A numeric value indicating the total yield per plot over a year(s). |
| **Site-specific – Dashbord 5**<br>Packing house size-quality category at the commercial farm level | Farm<br>Year | ▪ Pie chart illustrating the breakdown of fractions by packaging house categories, showcasing their respective proportions relative to the total annual yield.<br>▪ A numeric value representing the total yield for the specified farm(s) across the designated year(s).<br>▪ A numeric value indicating the average farm yield per tree (s) throughout the specified year(s).<br>▪ A numeric value representing the average number of fruits per tree for the farm(s) during the indicated year(s), post-thinning completion, and pre-bunch tying. |
| **Site-specific – Dashbord 6**<br>Yield percentages by fruit weight and skin separation | Farm<br>Year | ▪ Pie chart illustrating the distribution of yield percentages categorized by fruit weight, highlighting their proportions relative to the total yield.<br>▪ A pie chart displaying the distribution of yield percentages categorized by skin separation level, demonstrating their proportions relative to the total yield.<br>▪ A numeric value representing the total yield for the specified farm(s) and year(s).<br>▪ A numeric value indicates the average farm yield per tree (s) for the indicated year(s).<br>▪ A numeric value representing the average number of fruitlets per tree for the farm(s) during the indicated year(s) after thinning completion and before bunch tying. |

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848 **Table 2. Farmers' Insights and Themes from Dashboard Presentations**

| Dashboard Description | Insights and Themes |
|---|---|
| **General – Dashbord 1**<br>Yield per plot vs. fruitlets per tree upon thinning completion and before bunch tying | ▪ The dashboard effectively illustrates the clear correlation between the fruitlet counts before tying and the resulting yield<br>▪ The dashboard has the potential to support decision-making.<br>▪ Dashboards should present the farmers with their farms and plot information<br>▪ Other farmers' data are of little interest and cannot support thinning protocol decision-making<br>▪ The dashboard was difficult to interpret |
| **General – Dashbord 2**<br>Packing house size-quality category at the commercial farm level | No themes extracted |
| **General – Dashbord 3**<br>Yield percentages by fruit weight and skin separation | ▪ Independent categorization of fruit weight and skin separation is beneficial<br>▪ Fruit weight categories are highly relevant to thinning protocol decision-making<br>▪ Skin separation categories are of minimal relevance to thinning protocol decision-making<br>▪ Useful for comparing personal revenue with the date farmers' community<br>▪ Additional desired data:<br>o Number of dates in each fruit weight category<br>o Average fruit weight within each category<br>o Correlation between fruit weight and skin separation |
| **Site-specific – Dashbord 4**<br>Yield per plot vs. fruitlets per tree upon thinning completion and before bunch tying | ▪ Figures are familiar because they are calculated internally by farmers<br>▪ The dashboard is easy to interpret<br>▪ The plots have little added value<br>▪ Data useful to observe historical trends<br>▪ Additional desired data:<br>o Counts after thinning correction work<br>o Abscission |
| **Site-specific – Dashbord 5**<br>Packing house size-quality category at the commercial farm level | ▪ Pie charts for each farm individually are insightful |
| **Site-specific – Dashbord 6**<br>Yield percentages by fruit weight and skin separation | ▪ Fruit weight categories are highly relevant to thinning protocol decision-making.<br>▪ Skin separation categories are of minimal relevance to thinning protocol decision-making.<br>▪ Preference for a table format over charts to facilitate multiple years comparison<br>▪ Additional desired data:<br>o Fruit size distribution<br>o Continuously updated real-time data during harvest |
| **General Themes** | ▪ The data is sufficient to assist in determining the thinning protocol |

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- Despite available data, there is no intention to change the existing protocol
- Preference for a table format over charts
- Data can always come in beneficial
- Additional desired data:
  - Climate contrasted with yield and fruit quality
  - Pests
  - Other farmer's data is of less interest unless used to compare revenue

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