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Critical Food Safety and Quality Elements in the Dry Bean Supply Chain

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1. Introduction

The concept of *quality* is associated with all aspects of our lives. A myriad of consumer goods (cars, cell phones, stereos, and more) are sold based on real or perceived notions of quality and value. However, perhaps the single most urgent and focused concern in today's public is the quality and safety of our food supply. Any number of food-related issues during the past 10 years have heightened consumer concerns. Quality has many connotations and qualifying definitions.

What wisdom have others previously provided regarding quality?

"It is quality rather than quantity that counts." (*Seneca, Roman Senator, 8 BC*)

"To do a common thing uncommonly well brings success." (*Henry John Heinz*)

"Quality is for the customer." (*W. Edwards Deming, 20th century quality guru*)

"Wherever you see a successful business, someone once made a courageous decision." (*Peter F. Drucker, recipient of the Presidential Medal of Freedom, 2002*)

"Quality has to be caused, not controlled." (*Philip Crosby, U.S. quality consultant*)

"Quality is never an accident." (*John Ruskin, English writer, Victorian polymath*)

Today's Michigan bean growers are both beneficiaries and proponents of a long legacy associated with production and supply of quality beans. This favored position requires diligence and constancy of purpose. It is important to highlight the concept of *quality* within the context of dry beans. Michigan bean growers fully recognize that quality is associated with good business and that consistent delivery of quality products is required to sustain customers. Thus, full application of the marketing axiom "It is easier to keep a customer than find a customer" is warranted. Quality foods must, by definition, be safe, wholesome, and nutritious. Dry beans possess every attribute to be fully recognized as quality foods. The dry bean is, above all, a most noble food that must be handled as such throughout production, harvest, and shipment to assure sheer delight by the customer. The purpose of this paper is to highlight the importance of food quality and safety for Michigan bean growers in the context of the complex food supply chain (Image 1).

Image 1. High-quality Michigan beans have been a staple of the industry for over 100 years. Source: Michigan Bean Commission.

Food quality and safety: Food safety and quality are real or perceived technical issues. Everyone within the food system must be alert to the sensitivity of consumers. Traditional print and broadcast media as well as social media are replete with near hysterical examples of consumer misconceptions about processed foods and perceptions about the shortcomings of the industrial food supply. Growers, processors, and distributors must be prepared to address concerns with knowledge and technical solutions.

Historically, regulatory attempts have been made to separate food safety issues from food quality concerns. However, during the past 20 years, more enlightened integration of safety and quality has occurred to address the real concerns of consumers. The food system has been viewed as the continuum from producer to consumer (sometimes referred to as "farm gate to the dinner plate"). Security and integrity of the food supply chain are essential for sound business transactions and assurance of practical programs that meet real needs. The recent initiation of the Safe Quality Food (SQF) program is a practical approach to do just as it says – deliver safe quality food to the consumer.

Attempts to define quality have been varied and many times inadequate. Quality has been defined as "conformance to specifications" or perhaps more relevant as "conformance to customer requirements." Clearly, these definitions have qualitative and quantitative elements aligned with consistency and continuity of supply. Current food-processing establishments require large volumes of uniform quality products or ingredients to operate efficiently.

The rate of product flow (speed) and volumes can be staggering.

Further, the term *quality* is frequently qualified with appropriate adjectives such as "high or low quality" and "good, bad, or poor quality." This necessitates meaningful terminology and specific standards to enable sound communication. Knowledge, communication, and integrity are essential. No one likes quality surprises in the complex marketplace.

In a complex supply chain, various roles must be linked to assure delivery of specified goods. These include the *vendors* (suppliers), *customers* (any number of intermediate receivers, such as mills, transporters, processors, and final distribution markets) and finally, *consumers* (end users). Any disconnect or communication breakdown any place throughout this supply chain is a potential for food safety or quality concerns. We do not need to look far for horrific examples of international food supply chain breakdowns that have resulted in serious health concerns.

Growers are the initial element in a sophisticated and interactive supply chain. The ability to consistently produce high-quality beans begins with the use of high-quality seed of sound genetic background (improved cultivars) and excellent management practices (the sum total of tillage, planting, pest control, and harvest and handling operations). Each phase contributes to quality aspects and as every grower knows, may, in fact, be a determining factor in overall quality and value of the crop.

Quality systems: Elements of food safety and quality programs include aspects of assurance and control. *Quality assurance* is an assessment of requirements and answers the question, "What should be done to assure quality?" *Quality control* is consistent implementation of the program to ensure compliance with needs or identified standards. Thus, both elements are essential to success. They may be distinctive entities in large organizations or may be simply and more fully integrated in a single group. Both functions must be conceptually achieved.

- ***Quality assurance:*** *Doing right things*
- ***Quality control:*** *Doing things right*

Michigan bean growers must continue to actively engage in both quality assurance and quality control activities to enable consistent delivery of high-quality bean products to both domestic and global markets.

Figure 1 outlines the dry bean supply chain where both quality assurance and quality control need to be implemented.

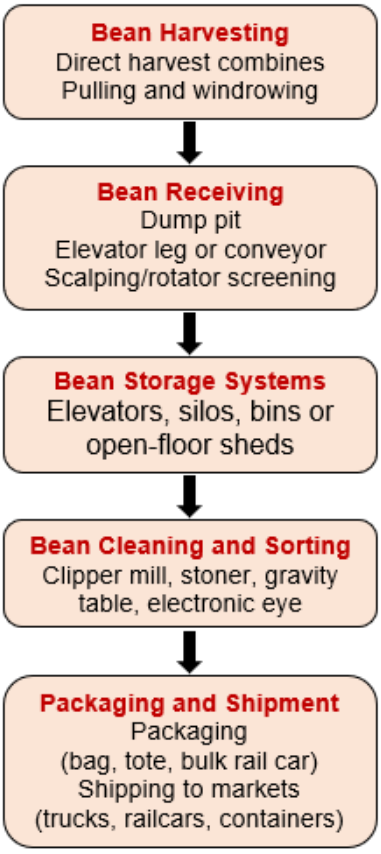

Figure 1. Continuum of the dry bean supply chain. Source: Adapted from Uebersax et al. (2022)

Specific food safety and quality concerns for dry beans by the food processing industry

- Production under Good Agricultural Practices (GAPs) and handling under Good Manufacturing Practices (GMPs) as defined by regulatory agencies and understanding of Safe Quality Food (SQF)
- Removal of foreign materials (stones, mud balls, plant materials, and extraneous materials such as glass, metal, and other materials)
- Cross-contamination of grains (soy, corn, and contrasting classes of beans) as potential allergens or as quality defects
- Excessive seed coat damage (checks and splits)
- Adverse storage and handling conditions (musty off-flavor, discoloration, and aged seed)

Michigan dry bean growers are noted for production of quality products and are distinguished for innovative practice. To continue this reputation, the principles of food safety must be clearly understood and fully implemented. Growers' role in quality control and assurance of dry beans before delivery is essential.

Quality control and assurance in dry beans begins with the grower and is continued through the supply chain: (1) dry beans are inspected by the grower during harvest (splits, checks, moisture, foreign material), (2) each load than is inspected and graded at the elevator prior to unloading, and (3) while being weighed, once approved to unload, material is visually monitored for the duration of unloading by elevator staff. Image 2 depicts quality control and assurance from harvest to elevator.

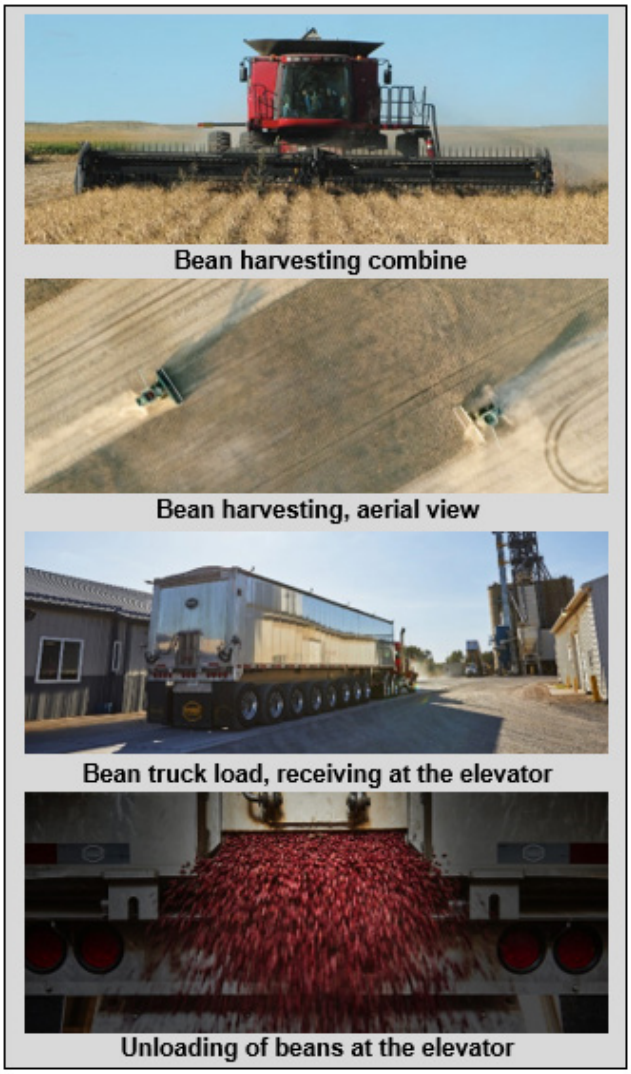

Image 2. Field harvesting, transportation and receipt/unloading of beans at the elevator. Source: Original images by Scott Bales and Michigan Bean Commission.

2. Food safety and quality concerns for dry beans by the food processing industry

Food regulation has a long history steeped in tradition that aims at reduction of health hazards and economic fraud. All moral codes are directed to assure safe food and water supplies. These laws and regulations have done much to improve the overall health and well-being of entire populations throughout the world. These date from a wide range of Biblical laws and further include Roman concerns for deception such as the watering of wine. In fact, the common use of the "baker's dozen," the practice of adding an extra item to the dozen for a total of 13, was a response to the medieval times practice of giving the death penalty to those who cheated consumers by giving them less than what they paid for.

Our modern food laws were initiated by the 1906 Pure Food and Drugs Act, which was designed to provide wholesome food devoid of deleterious substances. This law was enacted during President Theodore Roosevelt's administration in response to abhorrent conditions in the meat processing industry. Thus, the action was taken against foods that contained poisonous substances.

Proof of adulteration was ascertained through detection of the poisons within the food. This approach had many limitations. In 1938, Congress enacted the Food, Drug, and Cosmetic Act. This New Deal legislation under Franklin Roosevelt was much more effective in assuring food safety based on the provision within the act that stated, "Food is deeded to be adulterated if it was processed or handled under conditions whereby it may have become contaminated." Thus, the environments in which food is handled, stored, distributed, and processed is essential to assuring food safety. Facility sanitation and personnel practices are key elements. This food law provided for inspection of facilities. The promulgation of Good Manufacturing Practices (GMPs) provided clear, yet basic guidelines, for establishing sanitary facilities and acceptable personnel hygiene practices. In today's competitive marketplace, much of the food industry is working under much stricter practices that may be regarded as *excellent manufacturing practices.*

The most recent developments have been focused on prevention rather than detection of food safety hazards. Great effort has been placed on hazard analysis critical control points (HACCP). This program was developed during initial stages of the U.S. space

program for the prevention of foodborne illnesses in astronauts and focuses on prevention and control rather than inspection and detection. It involves the documentation of all hazards within the food system and the essential (critical) controls necessary to reduce the risk of that hazard. It establishes a comprehensive program focused on the *vital few elements* that if out of control will result in a public health issue. The Food Safety Modernization Act of 2011 (FSMA) utilizes HACCP concepts as well as thorough traceability as key components to significantly reduce public health hazards in the food supply. FSMA is comprehensive, and specific details must be reviewed by recognized experts. Guidelines may be reviewed at the Food and Drug Administration site (http://www.fda.gov/Food/GuidanceRegulation/FSMA/default.htm).

Foreign material contamination is particularly detrimental in dry beans. It is common to all agricultural commodities but warrants special attention by bean growers. Foreign material (commonly referred to as FM by the food industry) may be composed of native materials (for example, stones, mud balls, sticks, and stems) and induced substances such as metal, glass, and plastics. Freedom from foreign material requires diligence at all levels from field production to harvest to transport. Reliance on post-harvest removal, although important, should not be a substitute for good practices to avoid foreign material.

2.1. Good Agricultural Practices

Michigan bean growers and processors form a vital link in the food supply chain. Adherence to food laws and regulations are within the best interest of all parties (growers, transporters, processors, customers, and the consumers). Growers should be using Good Agricultural Practices (GAPs) for the production of dry beans. These guidelines were developed, in part, as a response to health hazards associated with fruit and vegetable production destined for the fresh market. Many of the elements of GAPs are directed toward good soil and water management techniques, which are intuitively endorsed by growers. The Food and Agricultural Organization (FAO) of the United Nations uses GAPs as a collection of principles to apply to on-farm production and post-production processes including animal care practices. From a global perspective, the objectives are designed to result in safe and healthy food, with consideration for economic, social, and environmental sustainability. Therefore, under GAPs, food should be economically and efficiently produced to provide 1) sufficient supply (food security), 2) assurance of safety (food safety), and 3) wholesome and nutritious food (food quality).

Pre-harvest interval: The appropriate use of all pesticides and herbicides is directed by the Environmental Protection Agency through product label declarations. Instructions dictate the permitted compounds and proper application of approved treatments. These products are an important tool for proper management during the production of quality beans. They must be used as directed. Particular attention must be paid to application rates and timing. The pre-harvest interval (PHI), that is, the time from application until harvest (number of days following application until harvesting is initiated), must be strictly observed to avoid residue carryover in the dry bean. Growers are particularly aware of the need for plant desiccants to assist with dry-down of green plant materials at harvest. The strict observance of PHIs for these compounds is essential.

2.2. Food supply chain support programs

With the advent of increased food safety incidents (that is, foodborne illnesses and recalls), industry (private enterprise, retail distributors, and trade associations) has worked to provide meaningful quality systems and controls.

The Global Food Safety Initiative: The Global Food Safety Initiative (GFSI), an industry-initiated program, has demonstrated an enlightened means of strict self-regulation. These guidelines are based in part on principles of the International Standards Organization of Geneva, Switzerland, which include the sound integrity principle: “Say what I do and do what I say.” Thus, document your procedures (detailed protocol to assure HACCP standards) and demonstrate (through actions and records) that you have achieved them. GFSI has been implemented in the United Stated through the previously mentioned SQF program This program certification serves to ensure that food processors and suppliers meet both safety and quality standards. A review of the SQF Institute’s website will provide clarity of the program requirements (http://www.sqfi.com/). Certification is provided for producers (SQF 1000) and processors (SQF 2000) after fully implemented facilities and procedures with trained staff are in place. Many large corporations in the food industry and, in particular, the retail distribution sector, have placed a high priority on supplies being SQF certified as a major component of their vendor and supplier criteria.

Food safety and quality can never be taken for granted but rather requires continuous improvement and diligence. Additional topics that affect dry bean quality and safety include removal of foreign materials (as discussed previously), cross-contamination of grains (soy, corn, and contrasting classes of beans) as potential allergens or as quality defects, excessive seed coat damage (checks and splits), and adverse storage and handling conditions (musty off-flavor, discoloration, and aged seed). Figure 2 demonstrates what type of quality defects can be removed at various stages of the commercial dry bean cleaning process.

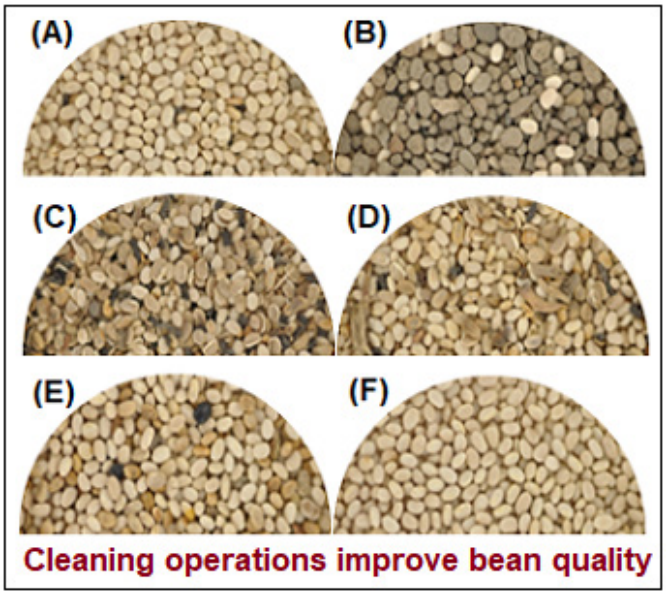

Figure 2. Bean cleaning and sorting operations — samples show the appearance of (A) Field run (unsorted beans), (B) Stoner rejects, (C) Clipper mill rejects, (D) Gravity rejects, (E) Electronic eye rejects, and (F) Final/clean beans. Source: Original images Mark A. Uebersax.

At the forefront of their marketing strategy, Michigan dry bean growers have consistently demonstrated an active concern for establishing quality and safety of beans and bean products. This takes uniformity of commitment and institutionalization of best practices. Principles of food safety must be clearly understood and fully implemented. Cross-contamination of grains as potential allergens or as quality defects can have dramatic impacts within the food supply chain.

Quality and zero defects: Assessing the defects within a lot is another view of quality. Quality standards can sound imposing but have real consequences when placed in the context of everyday life. Generally, we tend to feel that a high percentage of acceptance is adequate for success. Thus, if things were done right 99.9% of the time, initially sounds acceptable but this situation changes dramatically as the frequency and numbers increase. (See text box.)

Why isn't 99.9% defect-free good enough? Is it truly necessary to go for zero defects?

If things were done right 99.9% of the time, we'd have to accept:

- 1 hour of unsafe drinking water every month.
- 2 unsafe plane landings per day at O'Hare International Airport in Chicago.
- 16,000 pieces of mail lost by the U.S. Postal Service every hour.
- 20,000 incorrect drug prescriptions per year.
- 500 incorrect surgical operations each week.
- 50 newborn babies dropped at birth by doctors every day.
- 22,000 checks deducted from the wrong bank accounts each hour.
- 32,000 missed heartbeats per person per year

Source: Jeff Dewar, QCI International of Red Bluff, CA. Cited by Martha E. Mangelsdorf. (https://www.inc.com/magazine/19890401/5589.html) (Mangelsdorf, 1989)

In perspective, the quest for zero defects makes a lot of sense, particularly, when considering these clearly unacceptable frequency rates. How does the concept of zero defects apply to dry bean safety and quality? The regulation of food-based allergens and the management of consumer quality-based product complaints has dictated a new approach to quality assurance. It is noted that 99.9% is equivalent to one part per thousand defects. The concerns for food allergen detection is in fact a concern at the level of one seed among 100 pounds of beans and thus, approaches the parts per million level on a seed basis. The safety and quality concept are rapidly approaching zero defects. Various steps in the supply chain outlined in Figure 3 are both opportunities to promote safety and quality as well as critical points of concern when done improperly.

Figure 3: Various stages within the supply chain where safety and quality can be both at risk if not done properly, and where with proper mitigation techniques overall safety and quality can rapidly approach zero defects. Source: Original images by Michigan Bean Commission.

2.3. Food allergens and unintended ingredients

Food safety encompasses identification and labeling of food allergens. Food allergies are the immune response to ingestion or inhalation by susceptible individuals to specific proteins.

The Federal FDA regulates foods and food ingredients used in the United States. Congress passed the Food Allergen Labeling and Consumer Protection Act of 2004 (FALCPA). The law requires labeling of known allergens. The eight foods included in food allergy labeling account for an estimated 90 percent of allergic reactions. These eight foods are 1) milk, 2) eggs, 3) peanuts, 4) tree nuts (such as almonds, cashews, walnuts), 5) fish (such as bass, cod, flounder), 6) shellfish (such as crab, lobster, shrimp), 7) soy, and 8) wheat (Food Allergen Labeling and Consumer Protection Act of 2004).

Clearly, the bean growers' major interaction with known food allergens will be with soy and wheat. The entire food supply chain is sensitive to these concerns. Thus, we frequently view food product label statements that indicate "manufactured in a plant that also processes wheat" or "may contain soy" and similar statements.

The allergic response to soybean proteins

Soy proteins are common ingredients in many foods. Many allergic reactions begin early with a sensitivity to soy-based infant formula. Although most children will outgrow a soy allergy, this allergy may persist into adulthood. The typical symptoms may include a wide range of topical conditions (for example, swelling, hives, redness of skin, or itching) as well as systemic conditions (for example. breathing difficulties, nausea, diarrhea).

Life-threatening allergic reactions (anaphylaxis) are rare and are more likely to occur in people coinciding with asthma or other food allergies. Extreme anaphylaxis causes constriction of airways with difficulty of breathing, shock, (severe drop in blood pressure), racing pulse, dizziness, or loss of consciousness.

Food labeling laws must be critically adhered to, thus requiring identification of all ingredients used in the food. Product recalls occur when the presence of allergens is omitted from the label. Known food allergens must be identified, even in very small amounts, when the allergenic product is contained as an ingredient. Thus, the single largest allergen concern for dry bean producers is the cross-contamination with soybeans. These known allergens are difficult to separate and inherently cause negative response to sensitive individuals. Entire loads of dry beans have been rejected based on detection of soybean contamination.

2.3.1. Soybean cross-contamination.

Processors are concerned about accepting lots of beans that contain even small traces of soy. (See Image 3.) Extensive sampling plans to detect soy at parts per million (ppm) levels are used to define levels of soybean contamination. (Many use up to 100-pound samples for trucks and 300-pound samples for rail cars.)

Clearly, the most common grain contaminants in dry beans are corn, soy, and wheat. The dry-cleaning processes applied to beans will readily remove wheat, but soy and corn are difficult to remove due to the similarity of size and weight, and apparent density.

The canning process for dry beans does not inactivate the allergenic components of soy; therefore, soybeans must be eliminated from the dry beans prior to dry-cleaning or thermal processing.

Image 3: Soybean cross-contamination in navy beans in harvest sample. Source: Original image by Evan Wright.

2.3.2. Corn cross-contamination

The cross-contamination of corn kernels in dry beans is a problem because the corn seed becomes hard during canned-beans processing. Corn seed that has undergone the canning procedure is dark brown, hard, and brittle. Typically, canned corn products are prepared from immature, succulent sweet corn rather than from mature seed possessing high levels of starch, oil, and protein. Dry mature corn kernels can only be prepared for canning following alkali (lye) pre-cooking to form the familiar soft-textured consistency of hominy. This is a physical detriment and the cause for consumer complaints and product liability from consumer tooth fractures and related dental damage. The hardened dark corn kernels appear more like a stone than a seed. (See Image 4.) The reader may associate this hard characteristic with the familiar crunchy snack, corn nuts, with its intentional hard texture. This is not at all acceptable in a smooth texture of a fully cooked baked bean and thus, elicits strong negative consumer reaction.

Image 4: White kidney beans with less than 1% contamination of volunteer corn before (1) and after the canning process (2). While this is highly viable in white beans, this creates a significant food safety hazard in black beans after processing due to the rigid texture of field corn and little variation in color. Source: Original image by Evan Wright.

2.3.3. Contrasting bean classes

The mixing of commercial classes of beans is not uncommon and results in less desirable graded products. Contrasting classes of beans is a grade standard. Generally, large-seeded beans are more readily separated from smaller types during cleaning. The major cross-contamination exists between black beans and navy beans due to their relative similar size and shape. This is a quality issue that can only be reduced through diligent handling of bean lots. The principles of segregation of beans at all stages of harvest, handling and transfer, and storage and shipping must apply. Combine and hopper cleaning are

essential. Assure that fields are not planted with cross-contaminated seed in transfers at the seed tender and planter. Seed-handling equipment should also not be used in harvest activities to eliminate the risk of contamination from seed treatments used for the protection of seed from insects and disease. (See Image 5.)

Image 5: Navy beans contaminated with treated navy bean seed resulting in the use of seed-handling equipment at harvest. Source: Original image by Evan Wright.

2.3.4. Growers' role in reduction of cross-contamination

The grower plays a vital role in reduction of cross-contamination of soy, corn, and contrasting bean classes. The grower should take every precaution to eliminate cross-contamination:

- Assure that all combine headers, conveyors, augers, and tanks are cleaned of soybeans. (The first pass of dry beans [50–80 lbs] should be segregated or dumped to eliminate contamination.)
- Clean all trucks and wagons to assure removal of soybeans, corn, and contrasting classes particularly from corners and gates.
- Attempt to schedule harvest sequences to reduce changeovers among bean types (including soy and contrasting classes).
- Be certain that the planter hoppers, seed tenders, and other equipment are clean of all seed when changeover is undertaken to avoid mixed plantings. (See Image 6.)
- Note that volunteer corn in a bean field may increase the incidence of corn seed contamination during harvest and should be rogued or avoided.

Dry bean food safety and quality practices need to be fully integrated into the standards used throughout the food supply chain and require continuous improvement and diligence.

Image 6: Harvest sample resulting from cross-contamination of black beans in navy bean field as a result of equipment contamination at planting. Source: Original image by Evan Wright.

2.4. Customer specifications

The bean canning industry generally has quality standards that exceed the U.S. Department of Agriculture grades for dry beans. These customer-based tolerances are established according to their product quality expectations. Dry bean processors must work with their canner customers to understand the specifications and to assure adherence within tolerances particularly for foreign material and allergens. Further, all aspects of the supply chain (fields, harvesters, handling and transport, and receiving and processing facilities) must be maintained to assure compliance to standards. Customer, or more commonly, third-party audits of facilities are routinely and consistently required. The audit constitutes inspection of the physical facility and the review of procedures used to handle beans. Audits serve as "score cards" used to provide the customer and facility management with an understanding of requirements and standards and the status of compliance. The food industry is rapidly adopting certification programs and establishing preferred suppliers based on adherence to safety and quality criteria.

Traceability: Bean lot identity is an increasingly important element associated with the *traceability* of the product. "Two-way traceability" or "one up and one down" within the food supply chain is a common

expectation. Thus, in the event of a product recall, a product can be appropriately and rapidly traced. Can it be traced from the consumer package code back to the elevator, and can it be traced from the elevator back to the grower source? Conversely, if a problem is identified in the elevator, can the elevator trace the customer path for that product? (Note: the Michigan agricultural community vividly recalls the consequences of contaminates in the food supply through the inadvertent introduction of poly-bromotated biphenols, or PBB, during the 1970s.) The entire grain and dry bean industries are challenged by identifying lots because of the comingling of sources within a bin or silo. It is current practice that the grower lot can be confidently traced to the storage bin or elevator. Thus, the adage "one bad apple can spoil the barrel" applies whereby each grower must make every effort to assure that the beans delivered are of safe origin. The expanded use of *identity preserved lots* is perhaps a niche market for the future based primarily on assurance to the customer.

3. Seed coat damage: A primary critical quality factor in the processed bean supply chain

Most grains (corn, soy, wheat) are appropriately processed into *value-added* products in which the seed is milled, fractionated, or extracted to yield specialty components or ingredients (flour, oil, starch, protein, fiber). This is dramatically contrasted with dry bean markets where the most valuable form of dry beans is within the intact whole seed. In the promotional world of whole grains, dry beans are the most distinctive.

This wholeness attribute of dry beans is noteworthy and requires special attention. The distinguishing attribute of whole intact seed coats enable marketable differentiation in both the dry packaged as well as the canned bean categories. The level of split, cracked, or checked seed coats is a significant quality factor for dry beans.

3.1. The checked seed coat problem for the customer

***Impacts of excessive mechanical damage**:* Customers of dry beans maintain appropriate and specific bean quality standards for splits and checks to enable effective communication and efficient transactions within commercial commerce. Thorough sampling and systematic inspection of each bean lot must be conducted to assure compliance with seed coat damage quality specifications. The individual bean grower and the entire bean industry have vested interests to consistently provide sound whole beans with limited seed coat damage to maintain a sustainable customer base.

Dry packaging: Beans with damaged seed coats must be removed to assure appropriate visual quality appeal for consumers. The dry bean packager must present a product possessing a whole clean appearance within the package. Extensive cleaning and polishing will decrease yield and add to costs. Beans possessing cracked or checked seed coats must be removed to provide acceptable visual appearance.

Canned beans: The amount of split, cracked, or checked beans present within a given lot directly influence overall canning quality. During preparation, beans are typically soaked or hot water-blanched to enable the bean to adequately hydrate and swell. These operations change the dimensions (weight and volume) and, thus, the density of the beans. The intact seed coat allows controlled water migration initially through the hilum (seed attachment scar) and subsequently directly through the seed coat as it softens and becomes permeable. The seed coat becomes pliable and stretches as the starches and proteins within the cotyledons (internal halves of seed) (Figure 4) absorb water. If the seed coat is cracked, water will rapidly hydrate the cotyledons and displace the relatively brittle seed coat. The dislodged seed coat is frequently termed a *free skin*. This results in increased levels of loose seed coats, or free skins, and increased broken beans in the can. For canners, these free skins are a problem that must be removed prior to can filling, thus deceasing *canners' yield* (number of processed product cases produced per bag of dry beans). The presence of excessive free skins will directly impact quality characteristics of the product (appearance, sauce viscosity, and mouthfeel during chewing). Further, excessive free skins have implications on the internal can-heating characteristics of the product during thermal processing and, thus, become a safety factor associated with canned product sterility.

3.2. Excessive seed coat damage (splits and checks)

All edible dry beans have a thin seed coat layer, easily damaged during harvesting, handling, or drying. The brittle seed coat, the *testa*, is composed of high levels of fiber (cellulose, hemicelluloses, and lignin). It protects the seed and imparts color, sheen, and overall appearance. Seed coat checking and splitting must be minimized during the physical handling of dry beans. Seed coat damage is cumulative during all handling procedures.

The required conditions for dry bean harvesting include physiologically seed maturity and a bean seed moisture content (<18%). Further, sufficient desiccation of bean plant vegetation must be achieved to assure adequate movement through the harvest equipment. High bean moisture levels (>18%) will result in fungal spoilage during storage.

The intact bean, which is characterized by minimal cracking or splitting, is a highly desired quality attribute. Give strict attention to eliminating aggressive mechanical abuse that causes seed coat cracking or splitting and shattering. Assessing the susceptibility of dry beans to mechanical damage has received much research attention. Mechanical damage is most readily associated with dropping and shattering during the numerous transfers required from field to customer.

3.2.1. Harvest conditions and harvester operations

Most beans are harvested with combines, which result in direct mechanical damage to the beans as they undergo direct impact while they traverse through the equipment from header to the bin. Mechanical damage can result from bean impact velocity, moisture content, temperature, and the size of bean. Harvest system type (*direct cutting* or *pull/windrow/thrash*) and perhaps to a greater extent, harvester operation, influence seed coat cracking. Generally, gentle handling of beans is prerequisite to reduce seed coat damage. Harvester ground speeds and cylinder speeds must be monitored to assure bean stability. Higher speeds mean increased seed coat damage (Image 7).

Image 7: Excessive splits in dark red kidney beans incurred from harvest and handling at low levels of seed moisture (12-15%). Source: Original image by Evan Wright.

3.2.2. Seed moisture and temperature conditions

Unless specific handling equipment is available, most growers should not consider moving beans to a market if the moisture content is below 12% or above 18%. Low moisture beans (<10%) are particularly susceptible to mechanical seed coat damage.

Under adverse weather conditions, beans may be carefully dried in a manner to reduce moisture and produce limited seed coat damage. Beans may be subsequently air-dried to less than 18% moisture under gentle conditions to assure stable seed coats and storage stability.

Handling of stored beans at low temperatures, particularly during winter, results in excessive mechanical damage as the seed coat is very brittle and highly susceptible to shattering. Beans should not be handled at temperatures less than 20 °F. Bean storage is a balancing act among seed moisture, humidity, and ambient temperature. The risk of mold, yeast, and insects is elevated when moisture content and temperature are high. *When temperatures are relatively colder (<20 °F) and/or moisture contents are very low (<10%), mechanical seed damage is much more likely during transfers or seed cleaning*.

3.2.3. Bean transfers (harvesters, trucks, and elevators)

The magnitude of bean dropping has a profound influence on the degree of seed coat damage occurring in the lot. The transfer of beans from the initial combine hoppers into subsequent wagons or trucks, as well as truck unloading at the elevator, can result in severe bean seed coat damage with a negative quality impact. Mechanical augers and poorly designed or maintained bucket lifts are particularly detrimental, resulting in high levels of checked seed coats. This is primarily the result of mechanical shearing action and frictional abuse of the seed.

To reduce the seed coat damage, implement and maintain a continuous flow of beans from the vehicle bean-receiving pit. This prevents each of the individual beans from directly striking the floor or grates when the beans are emptied. The length of drop into the receiving bin is critical to reduce seed coat damage. To reduce the free fall of beans when they are filled into the storage facility, internal bean ladders are used. Maintain minimum drop distances in all areas of bean transfer.

Conveyor belts, which allow aggregated beans to remain in a stationary state during conveyance, are

superior to systems in which individual beans are dynamic and subject to abrasive forces. Auger-handling methods of transfer are generally more aggressive than conveyors due to the inherent bean-to-bean and bean-to-auger contact and abrasion. These modifications to use belt conveyors are generally more expensive than conventional grain-handling augers. The enhanced quality of beans transferred using conveyor belts may provide market incentives for making this investment.

4. Specific pre-harvest quality and food safety concerns for the grower

Quality and safety are paramount. Quality of beans are subject to agronomic stresses throughout the growing season. Generally, the highest quality of beans are produced by vigorously growing plants. Stress that negatively influences plant growth will result in decreased seed quality. These stresses may be classified as *abiotic* or *biotic* and both influence seed quality. *Abiotic stress* is generally associated with environmental or climatic facts such as rainfall (soil moisture) or temperature. Water stress (drought and water logging of soil) results in decreased yield. Temperature stress is generally manifested as above average high temperatures at various stages of growth. (Note: This is particularly impactful to yield during blossoming and resultant pod abortions, or during sustained high temperatures, which results in misshapen pods and reduced pod fill.) Many of these stresses on seed quality are not well understood but may result in hard seeds that are more difficult to cook or process during canning. Although this variability is difficult to control, resultant changes in bean water hydration capacity and softening rates diminish overall bean quality within a lot.

Biotic stress is associated with plant pests (Image 8), diseases, or weed competition. Diseases such as anthracnose will result in discolored seeds. Insects that infect plants, such as bean weevils, will result in spotted damage to seedcoats. Small-sized (for example, "pewees" within a pod) or deformed seeds will appear as shriveled seed or grossly damaged malformed seed (for example, "fish mouth"). Weed seeds of many species (for example. lambsquarter, pigweed species, and others) accumulate within harvested beans and can produce discoloration or impend airflow during bin storage. Discoloration or staining from green weed stems or green stems of actively growing beans will be evident as stained seedcoats.

Although much of the field-induced damage can be removed during cleaning at the elevator, it remains in on-farm storage and may result in further quality degradation with storage time.

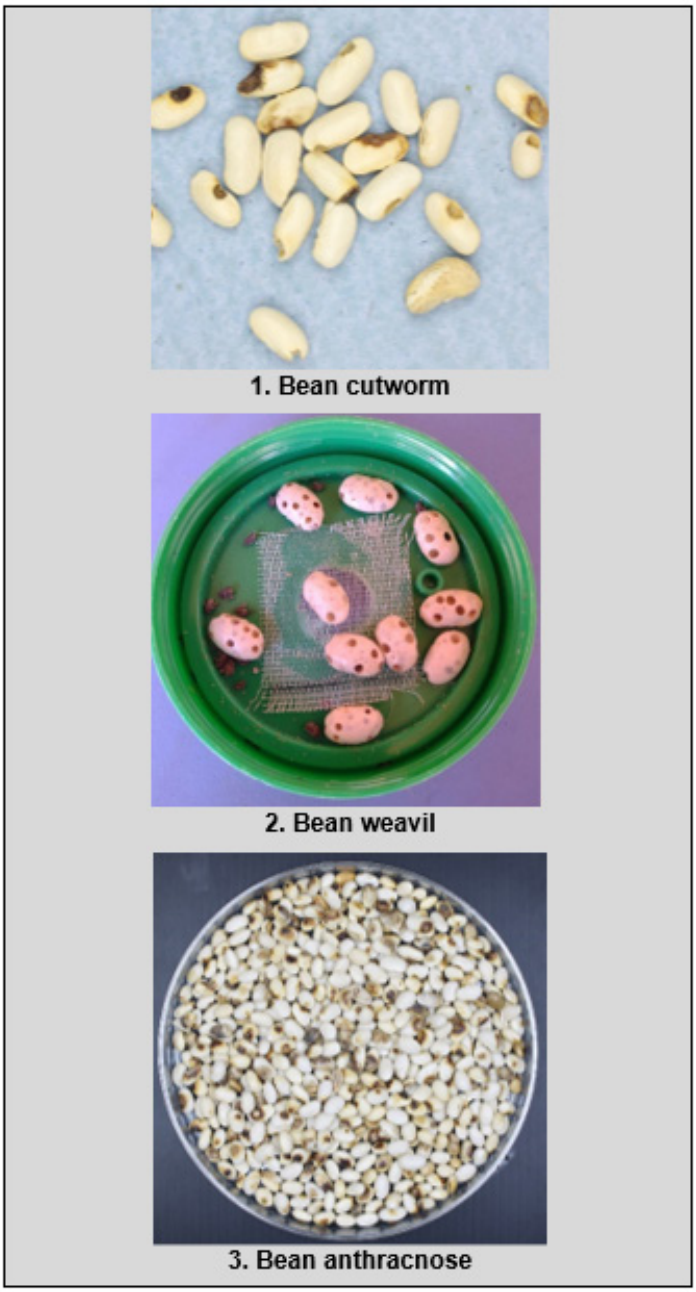

Image 8: Biotic sources of reduced quality including insect damage in the field from western bean cutworm (1), in storage from bean weevils (2), and bean anthracnose (*C. lindemuthianum*) in the field (3). Source: Original image by Evan Wright.

4.1 Strictly adhere to pre-harvest intervals

The *pre-harvest interval* (PHI), defined as the time from application until harvest (that is, the number of days following application until harvesting is initiated), must be strictly observed to avoid residue carryover in the dry bean (as previously discussed).

Growers are particularly aware of the need for plant desiccants to assist with dry-down of green plant materials at harvest. The strict observance of PHIs for these compounds is essential.

4.2 Minimize foreign materials

At the point of delivery, growers are assessed for the presence of foreign material (stones, mud balls, and plant materials) (Image 9). This "pick" loss is a direct cost. Make every effort to reduce this extraneous contamination, which will need to be removed during various cleaning procedures (aeration, gravity table separation, sieving, and other procedures).

- Growers should operate equipment in a manner that will reduce pick up of stones, mud balls, and excessive plant materials. This requires appropriate ground speeds and appropriate header lift heights. The recent innovative use of field rollers has contributed notably to a reduction of stones.
- Further, extraneous materials including glass and metal pieces and fragments can be a major problem to food processors. Assess all equipment for loose bolts and fittings.
- Roadside areas are particularly susceptible to discarded contaminants and trash. Walk the roadside edges to remove glass bottles and other debris. It is far more effective and efficient to remove a single intact bottle than to be challenged with the removal of numerous glass fragments and shards. These items are direct food safety hazards best solved at the point of harvest.

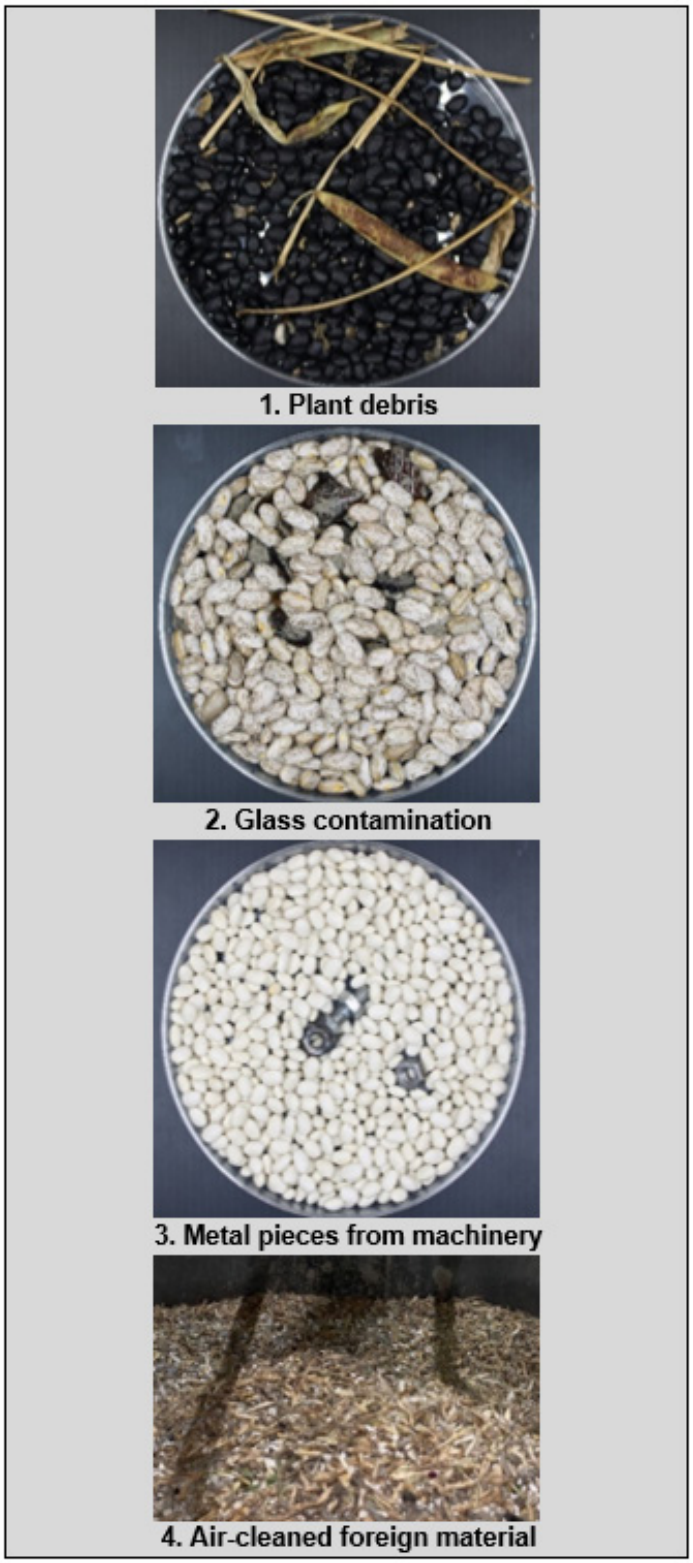

Image 9: Unacceptable presence of foreign materials including plant debris (1), glass from roadsides (2), metal from equipment failure (3) foreign material removed by air aspiration during receiving at point of delivery (4). Source: Original images by Evan Wright and Michigan Bean Commission.

4.3. Assure absolute minimum cross-contamination of grains

Cross-contamination of grains is a real potential health hazard that has received much attention in recent years. There is zero tolerance for soy in dry beans because it is a potential allergen and thus, a major concern to food processors. Labeling requirements state that known allergens are to be declared. The cross-contamination of corn and contrasting classes of beans is viewed as a quality defect that diminishes the appearance quality and palatability of beans. Corn is a particular problem because it will become firm under the canning processes, making the hard seed much like a stone in canned beans.

Growers should exercise strict controls to assure no cross-contamination. This is particularly important at the combine level to assure no carryover of seeds within augurs and conveyors. When changing from soy harvest to dry bean harvests, it is recommended to completely clean out the first-cut product (soy) and segregate that from the subsequent cuts. Select harvest sequence to minimize changeovers from different bean types. Rogue out volunteer corn prior to harvest to eliminate this source.

The grower plays a vital role in reduction of cross-contamination of soy, corn, and contrasting bean classes. The grower should take every precaution to eliminate cross-contamination. Consider the points of concern that were addressed in section 2.3.4.

4.4. Reduce excessive seed coat damage

Dry bean markets establish the most valuable form of dry beans as whole intact seed. This wholeness attribute is greatly influenced by bean moisture content and mechanically handling conditions during harvest. The extent of split, cracked, or checked seed coats is a significant quality factor for dry beans. Growers should be mindful of the following harvest conditions and harvester operations:

- Growers must minimize seed coat checking and splitting during all stages of physical handling of dry beans. Bean seed coat damage is cumulative during each stage of handling from harvest to final distribution and preparation.
- Mechanical damage is most readily associated with dropping and shattering during the numerous transfers required from field to customer. Mechanical damage can result from bean impact velocity, moisture content, temperature, and the size of bean. Harvest system type (*direct cutting* or *pull/windrow/thrash*) and perhaps to a greater extent, harvester operation, influence seed coat cracking.
- Most beans are harvested with combines. This results in direct mechanical damage to the beans as they undergo direct impact while they traverse through the equipment from header to the bin.
- Means to mitigate seed coat cracking, splitting, and shattering due to aggressive mechanical abuse requires strict attention. Generally, gentle handling of beans is prerequisite to reduce seed coat damage. Harvester ground speeds and cylinder speeds must be monitored to assure bean stability. Higher speeds mean increased seed coat damage.
- Under adverse weather conditions, beans may be carefully dried in a manner to reduce moisture and produce limited seed coat damage. Beans may be subsequently air-dried to less than 18% moisture under gentle conditions to assure stable seed coats and storage stability.

4.5. Reduce adverse storage and handling conditions

Adverse handling and storage may result in moldy beans (musty off-flavor) and discolored beans (bin burn and aged seed). (See Image 10.) Such damage is most detrimental to quality and economic marketability of beans. Seed moisture and temperature conditions must be managed to assure efficient handling during harvest and subsequent storage stability.

- Maximum bean moisture for storage is 18%. Under adverse harvest conditions, beans may be air-dried under gentle conditions to achieve 18% moisture with a minimum of seed coat damage.
- Appropriate monitoring of bin aeration and temperature is important to assure stability. Adverse storage conditions can rapidly deteriorate beans and result in catastrophic losses.
- Unless specific handling equipment is available, most growers should not consider moving beans to a market if the moisture content is below 15% or above 18%.

Image 10: Excessively darkened pinto beans from long-term bin storage (1) moldy dark red kidney beans from high moisture at harvest and lack of aeration (2). Source: Original image by Evan Wright.

5. Summary and recommendation

Food quality: The concept and reality of quality in dry beans is fundamental to the Michigan bean grower, the customer, and the consumer. Specific planned approaches and attention to details can make all of the difference toward achieving consistent high-quality beans. Michigan growers know that the reputation associated with being a high-quality supply source is long in the making and can be rapid in the decline. The grower must strive to deliver on the promise that Michigan beans are, in fact, of high quality and safe. Many aspects of overall quality are directly weather dependent. However, growers must exercise approaches within their control to assure delivery of sound, safe, and high-quality products.

Food safety: Dry bean production is undertaken using GAPs and all handling must be conducted under GMPs as defined by regulatory agencies. Further, specific programs used by customers within the food industry delineate special requirements to enable quality control including traceability of ingredients and products. An important and commonly used program is SQF. Increasingly, the food industry is employing these third-party programs to provide certifiable action plans for food safety and quality. A review of the guideline requirements can provide an enhanced understanding of this program (http://www.sqfi.com/).

Growers' opportunities for excellence in quality & safety: Today's Michigan bean growers are both beneficiaries and proponents of a long legacy associated with production and supply of quality beans. This favored position requires diligence and constancy of purpose. Concerted and united efforts to assure high quality will benefit everyone within the Michigan bean industry.

References:

Food Allergen Labeling and Consumer Protection Act of 2004 (FALCPA) Public Law 108-282, Title II. § 202 (2004). https://www.fda.gov/food/food-allergensgluten-free-guidance-documents-regulatory-information/food-allergen-labeling-and-consumer-protection-act-2004-falcpa

Mangelsdorf, M. (1989, April 1). Why 99.9% just won't do. *Inc.* https://www.inc.com/magazine/19890401/5589.html

In addition to the above references, some of the information in this document comes from:

Uebersax, M. A., Siddiq, M., Cramer, J., & Bales, S. (2022). Harvesting, postharvest handling, distribution, and marketing of dry beans. In M. Siddiq & M.A. Uebersax (Eds), *Dry beans and pulses: Production, processing, and nutrition* (pp. 81–104). John Wiley and Sons, Hoboken, NJ.

Additional Resources:

ADM (Archer Daniels Midland). (2017). *Handbook For better edible bean production*. https://www.adm.com/globalassets/products--services/services/farmer-services/seedwest-seed-profile-catalog/adm-edible-bean-2018.pdf/

Jones, A. L. (1999). *Phaseolus bean: Post-harvest operations*. Food and Agriculture Organization of the United Nations. http://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_Phaesolus_beans.pdf

Kandel, H., & Endres, G. (Eds.). (2019). *Dry bean production guide* (A1122-20). North Dakota State University Extension. https://www.ndsu.edu/agriculture/extension/publications/dry-bean-production-guide

Maddex, R. L. (1978). Handling and storage. In *Dry bean production: Principles and practices* (E-1251) (pp. 196–201). Michigan State University Extension.

Roberston, L. S., & Frazier, R. D. (1978). *Dry bean production: Principles and practices* (E-1251). (p. 225). Michigan State University Extension.

Sprague, C. L., & Burns, E. (2024). *Weed control guide for field crops* (E0434). Michigan State University Extension.

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