Using Bar Code Technology for Horticultural Research and Plant Inventory Activities

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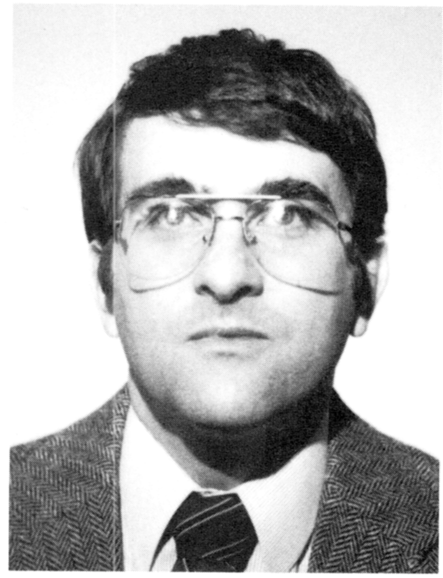

Parliman

The development and use of bar codes for automatic identification and systematic data collection is one of the most significant technological changes in American business and industry today. Most people become familiar with bar codes at the grocery store. The bar code symbol (Fig. 1) is that portion of the merchandise label with black bars and white spaces that is scanned by machines at the check-out counter. Bar codes are achieving widespread popularity because they can be incorporated into the primary-source marking of products from production to consumption (23). Bar codes are having tremendous impact on manufacturing, warehousing, and distribution activities. Bar code symbols are used for automatic identification of items as varied as hospital supplies, library books, and marathon runners; and are used to keep track of the manufacture of items as diverse as automobiles, hot steel ingots, and integrated circuits.

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Bar code technology can be adapted for numerous horticultural operations. Examples include: a) plant inventory maintenance and germplasm evaluation (arboreta, botanical gardens, repositories, seed storage facilities); b) research treatment and plant identification (field, greenhouse, laboratory); and c) commercial labeling (nursery trade, fruit and vegetable production/marketing). Bar codes can provide automatic identification for all of these applications, although the nature of the data and their processing vary. Current labeling, data collection, and inventory procedures for plants are cumbersome, inaccurate, and time-consuming. Bar code labels can reduce or eliminate these problems because they are machine-readable and may be computer-generated, and their use can be integrated with new or existing database management systems. Bar code labels on research materials improve efficiency of making repeated measurements of a wide range of agronomic and horticultural parameters such as growth, yield, and proliferation. The objectives of this paper are to provide: a) an introduction to bar codes; b) guidelines for development of bar code systems for research, inventory, and commercial data collection; c) guidelines for selection of bar code system components; and d) suggestions for bar code labeling materials that can be used safely and efficiently in typical horticultural environments.

ADVANTAGES OF A BAR CODE SYSTEM

Bar codes are popular because they provide an easy, fast, and accurate means of collecting data that is usually more efficient and economical than other systems. For industry, direct dollar savings are derived from reduced inventory, increased payroll accuracy, streamlined production, simplified inventory and maintenance record keeping, improved quality control procedures, and immediate availability of analytical data for management decisions (27, 42).

Bar code symbols are easy to scan. Little training is required to teach an operator to use scanning equipment, and operators do not have to be highly educated (10). In environments where the operator must keep the hands free for use, the scanning equipment can be stationary or it can be hung from clips on a belt (Fig. 2).

Bar codes can be scanned faster than data can be keyed by hand. Tests performed by the Intermec Corporation have shown bar code scanning speeds to be 75% faster than a secretary keying alphabetic data, 33% faster than a skilled 10-key operator keying numeric data, and 250% faster than a teletype operator keying random alphanumeric data (10).

Bar code data entry is far more accurate than keyed data entry. Substitution errors occur at a frequency of about one in every 300 characters for keyed data entry (12). In contrast, bar code data entry has a substitution error rate of <1 in every 3,000,000 characters scanned (10).

The basis of the speed and accuracy of bar code data entry is that the symbol is directly machine-readable, and there are built-in checks for data accuracy. Machine-read data can be sent to the computer for processing as soon as collected; they do not have to be processed through keypunching. For most organizations, persons collecting inventory and research data are part of the nonprofessional support staff; yet, the accuracy of the data and of the whole information system is dependent on the effectiveness of those employees. Use of bar codes increases employee effectiveness by avoiding human-assisted interpretation, transposition, and transcription errors. In addition, because there is no need to prepare and check coding sheets, keypunch, or detect and correct keypunch mistakes, errors associated with these activities are avoided. With the use of portable scanning equipment, ''point of work'' data collection becomes possible in that data are entered directly at the site of the activity, whether it is the office, laboratory, greenhouse, orchard, field plot, or warehouse.

Speed and accuracy in data collection are desirable goals in themselves, but it is the resulting cost savings that has captured the attention of American industry and the federal government. The U.S. Department of Defense (DOD) has implemented a bar code program known as LOGMARS (Logistics Application of Automation Marking and Reading Symbols), and they project that it will result in tangible savings of $113 million annually over conventional means of data entry (27).

U.S. PLANT INTRODUCTION AND QUARANTINE STATION

Before discussing development of a bar code system, it is useful to describe the application of bar codes at the U.S. Plant Introduction and Quarantine Station (USPI/QS) as a point of reference. The station functions to receive, establish, maintain-in-quarantine, conduct pathogen indexing and therapy, and propagate quarantined plant germplasm from foreign countries. The station processes an extremely diverse group of clonally propagated plants, ranging from apple cultivars grown in the orchard to sweet potato genotypes cultured in vitro. Collateral functions are to conduct horticultural and pathologic research relevant to the streamlining of quarantine procedures (34, 35). Temporary collections of quarantine-released fruit crop cultivars also are maintained. All activities require accurate and efficient methods for labeling, data collection, inventory keeping, and data analysis in a form that is accessible and understandable to all researchers and technicians working with the plant material.

USPI/QS has been computerizing its introduction, virus indexing, and inventory data over the past 4 years. Most databases are maintained on a mainframe computer, but day-to-day activities often are performed on personal computers. Computerization has had a tremendous impact on information resources, but regardless of the care with which the data were collected, errors still would infiltrate the data system through interpretation and transposition mistakes, and through keypunching errors. The end result would be frustration, some lack of confidence in the ''new'' computer system for record keeping, and tremendous amounts of time and effort expended in detecting and correcting errors. Accuracy was the major reason for implementation of a bar code system at USPI/QS. Additional reasons were to reduce labor costs by having labels prepared by an outside vendor and to improve label readability and durability.

DEVELOPING AND IMPLEMENTING A BAR CODE SYSTEM

Bar code system components and their function

There are four basic components of a bar code system: a) bar code symbol, b) scanner, c) decoder, and d) system interface to a data processing unit such as a personal computer (40). A fundamental concept in development and implementation of a bar code system is that components of the bar code system must perform well individually as well as with other components in the system. Bar code labels, scanners, and decoders cannot be chosen in isolation (9).

Bar code symbol. The bar code symbol is composed of wide and narrow black lines, called bars, and the wide and narrow spaces between the bars (Fig. 1). Different combinations of bars and spaces represent different characters such as letters or numbers. Several ''languages'', called symbologies, have been developed for different bar code user groups. The symbology used in a grocery store is different from the one used for industrial production and inventory control applications.

Scanner. The bar code scanner is the device responsible for sensing the bars and spaces within the bar code symbol and converting the resulting signal into a form usable by the decoder. Scanners contain a light source, optics, a photodetector, and signal processing circuitry (40). The scanner illuminates a small portion of the bar code symbol with a light beam generated within the scanner. As the beam of light is passed over the bar code symbol, that light reflects from the symbol back to the scanner where it is collected by a photodetector (18). Signal processing circuitry amplifies and converts the resulting analog electrical signal into a digital signal, which is then sent to a microprocessor in the decoder.

Scanning devices are either fixed or handheld. Fixed scanners most often are used with rapidly moving conveyors or in systems such as the grocery store check-out station. Many horticultural applications will require handheld devices (Figs. 2 and 3) because automation is not always practical in biological systems where the bar code symbol location

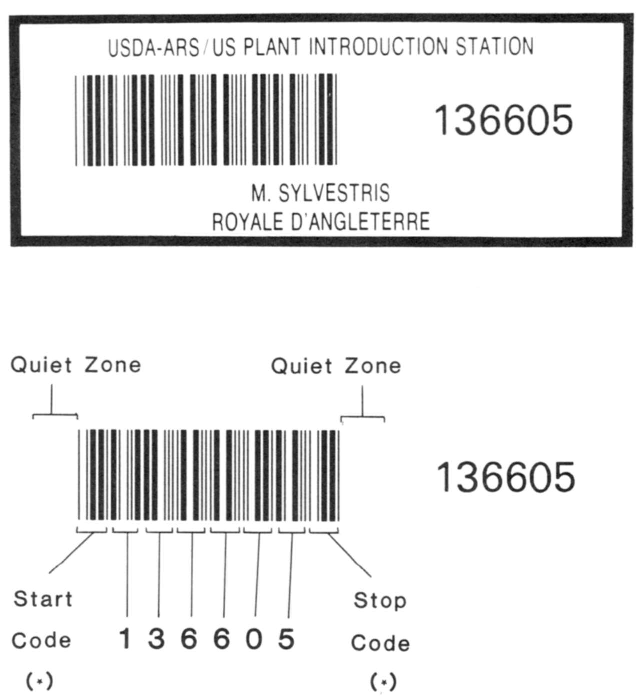

Fig. 1. (**Top**) Example of a bar code label using Code 39 symbology to encode the message ''136605'', which is the PI number at USPI/QS for 'Royale d'Angleterre' apple. The human-readable interpretation of the code is given to the right of the bar code symbol. The station name and scientific and cultivar names are additional lines of text, which are printed on the label but not encoded in bar code. This label was generated by photocomposition with photosensitive paper facestock by Computype, Inc. (**Bottom**) Bar code symbol that appears in the label above. Start and stop codes, quiet zones, and encoded characters are indicated. Each of these Code 39 characters is composed of two wide bars, three narrow bars, one wide space, and three narrow spaces.

Table 1. Comparison of major bar code symbologies.[z]

Property	UPC	Code 39	Interleaved 2-of-5	Code 11	Code 93	Code 128	Codabar
Character set	Numeric (0–9)	Alphanumeric (43 ASCII characters)	Numeric (0–9)	Numeric (0–9)	Alphanumeric (full ASCII possible)	Alphanumeric (I28 ASCII characters)	Numeric (0–9)
Special symbols	None	$ / % + – . and space	None	–	$ / % + – . space and four control characters	Full ASCII special characters	$ / + – . :
Error checking	Check sum at record level	Built in each character	Built in each character	Check digits are required	Check digits are required	Built in each character, plus addition check digit	Built in each character
Highest achievable symbol density	13.7 characters per inch	9.4 characters per inch	17.8 characters per inch	15 characters per inch	13.9 characters per inch	18.5 characters per inch	10 characters per inch
Ability to encode variable length data	No (except for UPC version D)	Yes	No (unless a length check or multiple check digits are used)	Yes	Yes	Yes	Yes
Codifed in standards[y]	UPCC, IAN	USD-3, ANSI, DOD, GSA, AIAG, HIBC, DSSG	USD-1, ANSI, UPCC, DSSG	USD-8	USD-7	USD-6	USD-4, ANSI, CCBBA
Market adoption	Retail	Industrial, health, commercial, government	Industrial, retail	AT&T	Unknown	Unknown	Blood bank industry Photo, Libraries, Federal Express

[z]Refs. 1, 5, 12, 24, and 33.
[y]Abbreviations: AIAG (Automotive Industry Action Group), ANSI (American National Standards Institute), CCBBA (Committee for Commonality in Blood Banking Automation), DOD (U.S. Department of Defense), DSSG (Distribution Symbology Study Group), GSA (General Services Administration), HIBC (Health Industry Bar Code), IAN (International Article Numbering), UPCC (Uniform Product Code Council), and USD (Universal Symbol Description).

and orientation are not fixed.

Hand-held scanning devices may be classified into two basic groups: contact scanners, such as wands (Fig. 2); and noncontact scanners, such as automatic moving-beam laser scanners (Fig. 3) (18, 23). Contact scanners must physically touch and be moved across the bar code symbol or its protective covering. Noncontact scanners can be held at some distance (usually 15 to 25 cm) from the symbol. A moving-beam laser scanner contains a moving mirror system that automatically moves the beam of light across the bar code symbol at rates of about 40 times per second (4). The decoder will produce an audible beep when a successful scan has been made with both types of scanners.

Decoder. The decoder, also known as a reader (Fig. 3), processes signals received from the scanner and converts them into appropriate character interpretations (40). The transformation from signal to decoded data is accomplished by a finite set of rules (commonly referred to as the decode algorithm) permanently programmed in the decoder memory (38). Decoding is similar to the process used by a person converting a Morse code message into readable text. For most symbologies, wide bars and spaces in the bar code symbol are interpreted as a binary "1" and narrow bars and spaces as "0". The binary ones and zeros are then converted to alphabetic and numeric characters. To transmit data, the decoder converts them into a common code format such as ASCII (American Standard Code for Information Interchange), which is usable by computers (10). Data may be stored in the decoder's memory or may be transmitted immediately to data processing equipment. Decoders may be designed to decode one or more bar code symbologies and some decoders are capable of automatically determining which symbology is in use.

System interface. The system interface includes the devices, rules, and conventions for input and output by which the decoder communicates with the data processing unit such as a personal computer. Data may be sent to the computer directly through point-to-point connections such as RS-232-C ports, or the data may be transmitted over telephone lines to a computer through the use of a modem (10). Once data have been transferred to a computer, they may be processed by the many application programs available, including database management systems.

Designing the bar code system

A bar code system should be designed from the "top down", concentrating first on the organization's needs and the requirements of the operation (13). It is important to establish

Fig. 2. Bar code symbol on a bottle scanned by an operator using a wand scanner attached to a portable decoder terminal. The decoder is hung from a belt clip to keep the operator's hands free. Note bar-coded keyboard. A wrist band menu is worn by the operator to speed data entry of typical responses. (Photograph courtesy of Intermec Corp.).

Fig. 3. (**A**) Handheld moving-beam laser scanner activated by depressing trigger switch. (**B**) Portable decoder terminal with 32-character LCD display. Note large alphanumeric keys. (Photograph courtesy of Intermec Corp.)

broad organizational objectives before becoming involved in selection of bar code equipment and materials. It is equally important to use a team approach, where a representative from each operation within the organization has input and can contribute at the planning stage. Their insight into what "will" and "will not" work assures their final support and cooperation at the time of system installation and implementation (9). The human factor is a critical consideration in a successful bar code system.

The first step is to make an inventory of the organization's operations and identify all the potential bar code applications. Then, study the paper documents and manual data entry procedures currently in use in addition to the flow of data and materials (such as plants and plant parts). Plan to network the bar code system across several different operations within the organization to facilitate information sharing. Then, start with a controlled pilot program to minimize risk and allow for smoother system development later. Begin implementation of the bar code system at a point early in the material flow, such as when it first arrives. It is also wise to choose a highly visible application for the pilot program so that successful implementation will provide the necessary leverage for approval of further system development. Focus initially on the pilot program, but anticipate the needs of later stages in the system implementation (9).

It is important to consider that the bar code system serves as the interface between the work activity (such as greenhouse operations and research experiments) and the information system (data collected from the work activity and computers that process that data). The bar code system furnishes automatic identification of items used in the work activity and provides a fast and reliable method for data collection for the information system. Therefore, the bar code system must be designed to operate within the environment where the work is done and to provide the required data to the computer system in use (6).

Data encoded. One of the first issues to address is what data will be encoded in the bar code label. Identification labels for items such as plants and experiment samples should have an alphanumeric number encoded, which is used as a key to access a computer record containing information about that item. Avoid encoding extraneous information. Limiting encoded information to an identification number permits use of small labels and enhances system flexibility, because computer records can be changed more easily than labels. An example is the UPC (Universal Product Code) labels on merchandise in the grocery store. The UPC number identifies the store's computer record containing the price and description of the item. If the price were encoded instead of the UPC number, the store would have to relabel merchandise each time the price changed.

The identification number encoded in the bar code may be either "meaningful" or "non-meaningful" (13). An example of a meaningful identification number is the Plant Introduction (PI) number encoded in the bar code tags for individual trees in the orchard at USPI/QS. Several trees have the same PI number because the trees are of the same clone and considered to be identical. In contrast, a non-meaningful identification number might be a sequential number that is encoded in bar code labels and assigned to identify samples in research experiments. A sequential number does not contain any information about the treatment applied, but it uniquely identifies the sample.

Bar code labels may have additional lines of text printed on them that are not encoded in the bar code symbol (Fig. 1). This additional text, such as taxonomic and horticultural data on display labels, can be quite extensive for arboretum applications.

For ease of data collection, bar code symbols can be placed in a menu format on a clipboard or wrist band (Fig. 2) that is carried by the operator. Bar code symbols in the menu act similar to special function keys on a terminal (37) and can represent a wide range of characteristics and numeric values. Entry of descriptive data (such as leaf color or observed disease symptom) that are collected during evaluation activities can be expedited by encoding typical responses to prompted questions in a bar code menu. A different menu can be prepared for each application.

Symbology. Bar code symbologies differ in the kinds of characters that can be encoded (numeric, alphabetic, symbolic), spatial relationship of the characters within the bar code symbol, width of the bars and spaces, quantity of information encoded for a given symbol length, and presence of special characters to indicate the beginning and end of a bar code symbol (which allows encoding of variable length data). A comparison of the major symbologies is given in Table 1. About 25 different symbologies are currently available for use, but many symbologies are considered obsolete because of rapid changes in technology and movement toward standardization (23). Selection of the bar code symbology will depend on the data to be encoded, the scanning technology to be used, the amount of space available on the label for the bar code (24), and whether the particular industry has adopted a standard symbology. There are advantages and disadvantages associated with each symbology, but it is wise to select the simplest symbology possible to get the job done (42).

Symbology has become a critical issue for the horticultural nursery trade. Large chain, high-volume retailers are demanding that UPC symbols be included on labels of all the wholesale nursery stock that they purchase (15). UPC labeling is beneficial to these retailers, but it represents additional costs for the grower and is almost useless for tracking individual plants, plant lots, and labor within the nursery operation. Committees are trying to develop an industry standard, and there is debate over what information will be encoded in the UPC number.

USPI/QS has chosen Code 39 symbology for several reasons. Identification numbers at USPI/QS include numbers, letters, and the minus sign, so an alphanumeric code that includes some special symbols and can encode variable length data is required. Code 39 has widespread use and has become the dominant industrial standard symbology (5). The DOD selected Code 39 as their official symbology (12), indicating a direction for other federal government agencies. As a result of widespread use and DOD adoption, much information has become available on specifications for Code 39 bar code labels (29, 36), which eliminates guesswork when discussing requirements with vendors. Widespread use of Code 39 also means that compatible scanning equipment is available. A final consideration is the space requirement for Code 39. By conforming to recommended formats and using the high symbol density of 9.4 characters per inch, seven Code 39 characters can be encoded on a 2.9-cm bar code label, which is acceptable for tissue culture needs at USPI/QS.

Symbol placement and size. Placement of the bar code symbol is an especially important consideration in horticulture because the symbols rarely can be printed on or attached directly to the plants or plant parts as they can on cartons or paper documents. Placement will influence the size of the label, method of adherence, and material selected for the label. Bar code tags at USPI/QS (Fig. 4) are hung either directly on tree branches or secured to tall stakes placed in front of plants for orchard and field applications. Bar code labels applied either to plastic pot stakes or to plastic tags hung from short wire stakes were chosen for labeling individual plants in the greenhouse. For tissue culture applications, small bar code labels can be attached directly to culture tube caps, or surface-sterilized bar-coded aluminum tags can be placed inside culture tubes along with the plant material. In all cases, labels must be positioned so that they may be scanned easily.

The size of the tag or label, bar code symbol, and human-readable interpretation of the bar code symbol must be matched to the application. Tags for orchard use must be large enough to locate on trees, and greenhouse labels must be small enough to fit on stakes. It is recommended that the height of the bars be at least 25% of the symbol length for contact scanning because operators move wands across symbols with a natural curved motion instead of straight paths (25). Small bar code symbols are scanned more easily with moving-beam laser scanners because mirrors move the light in a straight line. The human-readable interpretation of the bar code symbol (Fig. 1), also printed on the label, must be read without difficulty. At USPI/QS, large human-readable characters were more important for the greenhouse than for orchard or tissue culture applications because employees wanted to read the text of these labels over the width of one or more benches.

Bar code labeling materials and label production

Bar codes are new for horticultural environments, so USPI/QS has been evaluating bar code labeling materials for long-term research and inventory applications. Labels and tags will be considered separately. Labels are made of flexible materials, such as paper, vinyl, or metal foil, and are attached to an item by an adhesive. Tags are made of rigid metal, plastic, or laminated paper stock and generally have no adhesive.

Durability and label cost should be matched with the lifetime and value of the item labeled and required data accuracy. Bar code labels usually are generated using data from computer databases. Once the computer's data are correct, both the data on subsequent bar code labels and information obtained from scanning those labels will be correct. This high level of accuracy alone often is sufficient to justify the cost of the labels or tags.

Label facestocks, laminates, and adhesives. The label facestock is the material on which the bar code symbol and human-readable text are printed. Typical facestocks include plain and coated papers, plastics, and metal foils (17). Facestocks should be selected on the basis of their suitability for scanning as well as for durability in the environment. It is essential to consider how the bar code symbol appears to the scanner, rather than how it appears to the human eye. The photodetector in the scanner must be able to distinguish clearly the transitions from bars to spaces within a bar code symbol to scan that symbol successfully. Bar code symbol specifications, such as MIL-STD-1189A (29), establish guidelines for surface reflectivity, facestock opacity, contrast between the bars and spaces, symbol density and dimensions, and printing tolerances. A matte or dull surface usually is recommended for the facestock. Opaque facestocks prevent patterns under labels from showing through and interfering with scanning. When contact scanning is used, the facestock must be durable enough to withstand repeated scannings without degrading reflectivity, smearing the bars, or abrading the symbol (12). Facestocks of removable labels should be sufficiently sturdy that they do not disintegrate upon removal.

In applications where the bar code label must withstand repeated contact scanning (more than 50 times) or is exposed to adverse environments, it should be protected by a transparent laminate. The latter is applied to the facestock after the symbol is printed and is made of a thin film of mylar, vinyl, polypropylene, acetate, or other polymeric substance having a thickness of 10 mil or less (1 mil = 0.0254 mm.). A matte finished laminate surface is preferred (12).

Durability in the environment is an important selection criterion for the label. Moisture resistance was the primary consideration in evaluation of greenhouse applications at USPI/QS. Print appeared to wash away from common paper and vinyl bar code

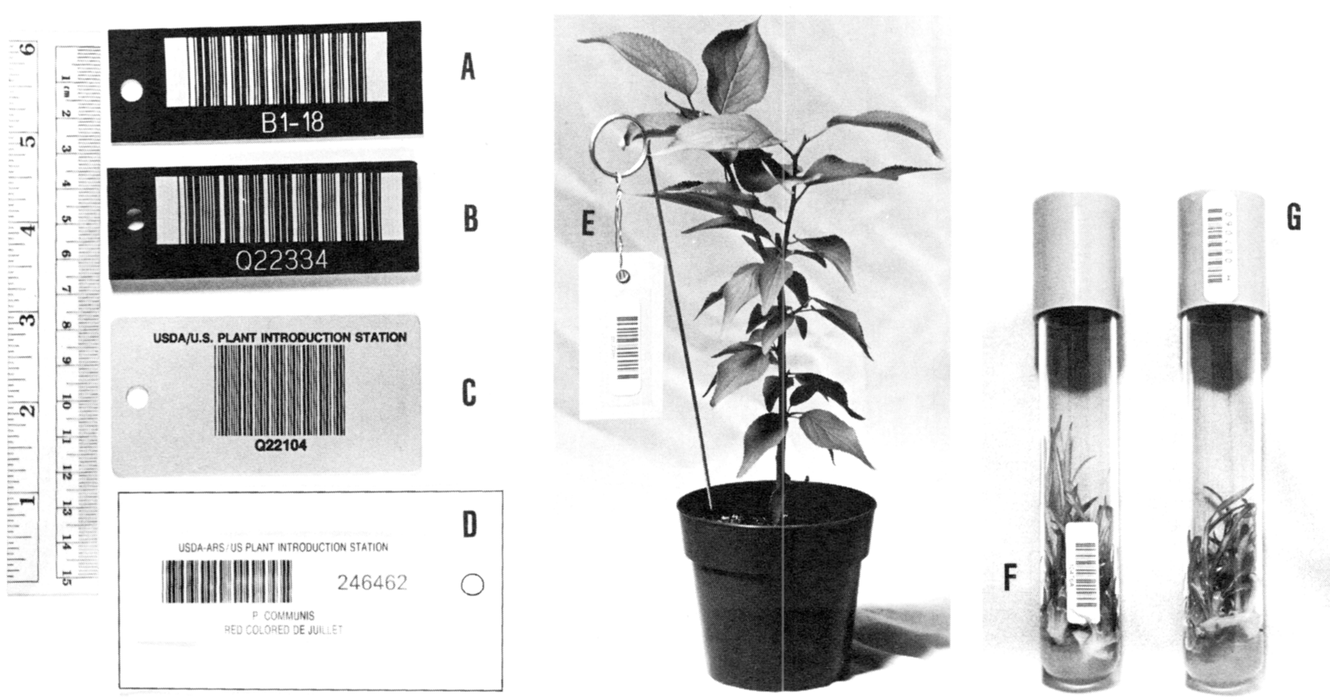

Fig. 4. Bar code labels and tags found suitable for horticultural use. (**A**) Orchard tag, generated by laser etching on 32-mil anodized aluminum (Great Lakes Laser Services). (**B**) Orchard tag, generated by laser etching on 125-mil acrylic plastic (Great Lakes Laser Services). (**C**) Orchard tag, generated by photocomposition within 20-mil anodized aluminum (Metalcraft I.D. Plates & Labels). (**D**) Orchard tag, generated by photocomposition on photosensitive paper facestock laminated between two oversized layers of 10-mil mylar (outlined in black for clarity) (Computype, Inc.). (**E**) Greenhouse label (applied to a colored plastic backing), generated by photocomposition on photosensitive paper facestock laminated with oversized 1-mil mylar (Computype, Inc.). (**F**) Autoclavable tissue culture tag (inserted in medium within culture tube), generated by photocomposition within anodized aluminum (Metalcraft I.D. Plates & Labels). (**G**) Autoclavable tissue culture label, metalized polyester with mylar laminate (Data Documents Systems, Inc.).

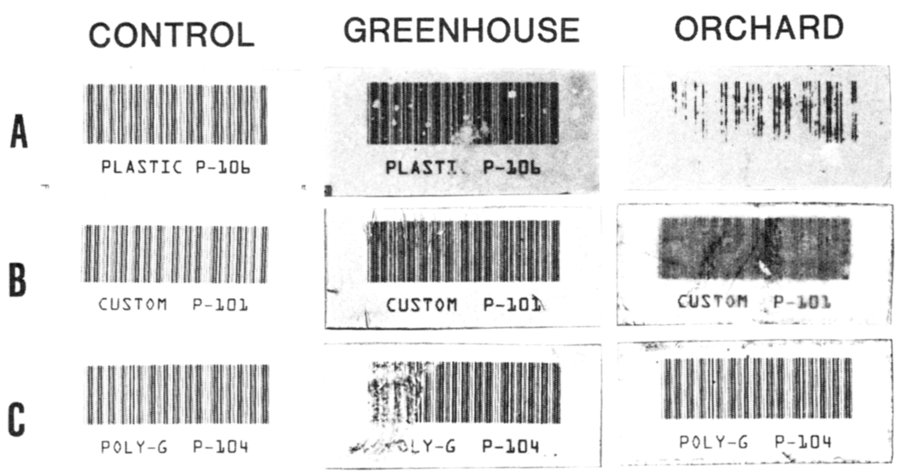

Fig. 5. Examples of unsuitable bar code labeling materials for greenhouse or orchard use. (These are excellent labels for dry environments). Labels in column marked "GREENHOUSE" were exposed to constant moisture for 16 months in the greenhouse mist benches at USPI/QS; and in column marked "ORCHARD" were applied to aluminum plates hung in trees 16 months at USPI/QS. Problems include removal of the bar code symbol image, smearing of bars within bar code symbol, and growth of mildew between facestock and laminate. (**A**) Dense polystyrene facestock with a permanently bonded chemical topcoat. (**B**) Photosensitive paper facestock and no laminate. (**C**) Photosensitive paper facestock with a clear, 1-mil polyester film laminate.

labels over time, even when protected with a chemical topcoat (Fig. 5). Labels with plastic laminates cut to the same size as the facestocks eventually developed mildew between the facestock and laminate layers. Best results were obtained with a paper facestock covered with an oversized mylar laminate (1 mil thick) that completely sealed the facestock from moisture. This label has performed well through multiple production cycles in the greenhouse and also as a temporary label (up to 1 year) in the orchard. Cost per label is about $0.08. Other labels with plastic facestocks and waterproof inks show promise for the future.

Tolerance to autoclaving is the major factor for tissue culture applications. Some plastic facestocks shrink to minute squares (Fig. 6). Label laminates often have different shrinkage rates than facestocks, creating unreadable warped and wrinkled images. A metalized mylar facestock with a mylar laminate cut the same size as the facestock withstands the rigors of repeated autoclaving and costs about $0.08 per label. Very thin aluminum labels (the thickness of heavy paper card stock) perform equally well, but are relatively expensive. Autoclavable latex-impregnated paper labels used in blood-bank applications perform very well, but few vendors are able to encode variable data (such as nonsequential identification numbers).

Each application has unique adhesive requirements. A water-resistant adhesive that forms a permanent bond on smooth metal and plastic surfaces as well as slightly textured plastic surfaces is required for most applications at USPI/QS. Adhesives for autoclavable labels must be moisture- and high-temperature-resistant. Adhesives for removable (transferable) labels are available for most labeling environments, including the autoclave.

Materials for bar code tags. Long-term field and orchard applications require durable labeling materials. Conventional paper bar code labels will not survive for extended periods under the adverse conditions of high heat, high moisture, ultraviolet light (UV) exposure, chemical/solvent attack, and abrasion. Bar code tags currently are produced by three major methods: a) photographic image suspension within an anodic layer of aluminum (a form of photocomposition), b) surface printing on aluminum or steel, and c) chemical or laser etching directly on metal or plastic (14).

The photocomposition process produces a high-quality, UV-resistant symbol within anodized aluminum. The tag has a smooth finished surface that permits contact and noncontact scanning methods, and is resistant to abrasion, chemicals/solvents, moisture, dirt, oils, and lubricants (14). These tags are used in the USPI/QS orchard; the cost per tag is about $1.90.

The surface printing method uses a heavy-duty dot matrix printer head to print the symbol and text on an aluminum or steel tag that usually is coated with paint, ceramic, or epoxy prior to printing (2, 14). The resulting printed image has a lower resolution than other permanent methods and remains exposed on the surface of the tag. The tags are relatively inexpensive, but tests at USPI/QS determined that they were subject to abrasion by tree branches in the orchard (Fig. 7). Once the abrasion problem is solved, and more permanent inks are used, this tag could become cost-effective for horticultural use.

The laser etching process involves the use of a laser beam to engrave a bar code symbol into material such as anodized aluminum or acrylic plastic. For aluminum tags, the laser removes the black anodized coating and exposes a bare aluminum surface to create the symbol and text. For acrylic plastic tags, heat of the laser beam causes the surface to "boil" up white, thus serving as a white space in the bar code when a black background is used (16). Laser etching produces a clear symbol, but the etched surface has a disadvantage in that it may collect dirt or other contaminants and does not permit contact scanning. Both aluminum and acrylic laser-engraved tags are used in the orchard at USPI/QS, with the cost per tag of about $2.10.

USPI/QS also is evaluating the performance of a paper facestock laminated between two oversized layers of 10-mil mylar that give a complete seal. This tag is less expensive ($1.11) than others used in the orchard and is light-weight. More time will be required to determine whether the lamination will withstand prolonged buffeting by tree branches. However, even if it proves to be less durable than other types of tags, this laminated tag may be a cost-effective product for labeling items with short time requirements.

Another consideration is how to attach bar code tags to tree branches in the orchard. Past experience has shown that birds will pull off labels that are loosely attached with

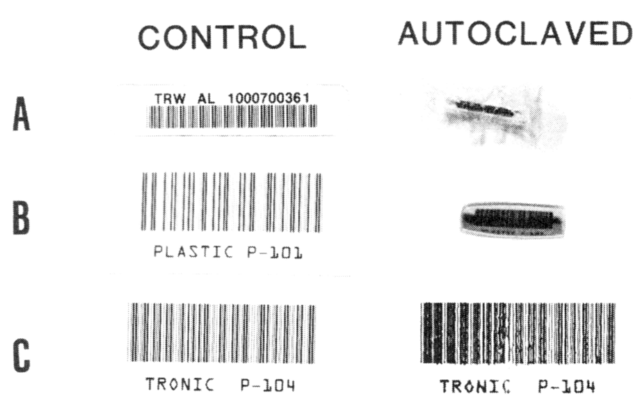

Fig. 6. Examples of unsuitable bar code labeling materials for tissue culture applications involving autoclaving. Labels in column marked "AUTOCLAVED" were autoclaved (15 min at 1.05 kg·cm^{-2} and 120°C) 30 times. Problems include shrinkage of facestock, differential shrinkage between facestock and laminate, and smearing of bars.(**A**) Polystyrene facestock with a mylar laminate. (**B**) Polystyrene facestock with a permanently bonded chemical topcoat. (**C**) Polystyrene facestock with a permanently bonded chemical topcoat (designed for printed circuit board manufacturing applications).

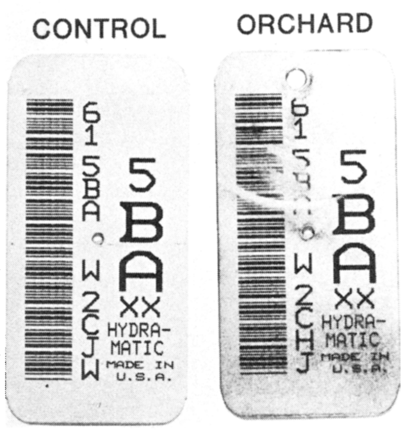

Fig. 7. Bar code tags generated by surface printing on coated aluminum found unsuitable for orchard use. Right tag after 11 months abrasion by tree branches. Resulting voids in symbol preclude scanning.

thin wire or twist-ties. USPI/QS currently uses nylon cable ties commonly found in electronics applications. Such ties must be weather-resistant and contain an UV light inhibitor. As with more traditional orchard and field identification methods, bar code labels and tags can be affixed permanently to trees themselves or to large stakes.

Bar code label production. In developing the bar code system, a decision must be made whether to produce the labels ''in-house'' (within the organization) or ''off-site'' (by an outside vendor). Methods for in-house label production include impact dot matrix, impact formed font, thermal printing, thermal transfer, and laser xerography (Table 2). Methods for off-site label production include flexography, offset lithography, letterpress, silk screen, hot stamping, laser xerography and etching, photocomposition, and ion deposition (Table 3). Selection criteria for choosing between in-house or off-site label production include label characteristics (amount and variability of data encoded, symbology, symbol accuracy, size, durability, and format), volume of labels needed, scanning method, applicability of industry standards, and cost (20, 28). The overall decision process involves analysis of the application requirements, evaluation of the technologies and resources available to produce the required label, and comparison of the cost for each viable option.

The amount and variability of encoded data are primary considerations. Data such as weights, quantities, and dates that are to be encoded in bar code symbols at the time of measurement cannot be predicted ahead of time and therefore require in-house label production. Applications with predetermined data requirements, such as sequential numbers or data from computerized inventories, can use off-site production methods. The ability to encode variable information (sequential and nonsequential) is desirable for most horticultural applications, which means that laser, ion deposition, and photocomposition techniques are the most appropriate of the off-site methods. The paper labels currently used at USPI/QS are printed using photocomposition methods. Several of the off-site methods involve the use of film masters, printing plates, and screens, and are generally reserved for printing UPC symbols and direct printing on containers where thou-

Table 2. Comparison of major in-house bar code printing methods[z].

Property	Impact dot matrix	Impact formed font	Thermal printing	Thermal transfer	Laser xerography
Typical substrates	Paper, vinyl, polyester, metal	Paper, vinyl, polyester	Heat-sensitive coated stock	Paper, vinyl, polyester, metal	Paper
Relative print speed (per min)	30–50 labels	40–100 labels	10–18 labels	30 labels and higher	12 pages (<3000 labels)
Graphics capability	Yes	No	Yes	Yes	Yes
Flexibility	High	Low	Low	High	High
Noise level	High	High	Very low	Very low	Low
Consumables	Ribbon	Ribbon	None	Ribbon	Toner
Minimum bar width	10–20 mil	7.5 mil	8–10 mil	6.5 mil and smaller	7.5 mil
Dispense one label	No	Yes	Yes	Yes	No
Cost of material/m²	\$3.06 (high-volume dot-matrix)	\$3.06	\$2.71	\$3.82	\$3.06
Cost of labor/m²	\$11.25 (high-volume dot-matrix)	\$15.17	\$16.63	\$22.01	\$7.34
Equipment cost	\$9000.00 (high-volume dot-matrix)	\$9000.00	\$8000.00	\$6000.00	\$34,000.00
Advantages	Prints multi-part forms Infinitely variable formats	High quality print High, medium, or low density Preprinted stock Many accessories	Quiet Inexpensive	Permanent high quality print Quiet	Fast Superior quality
Disadvantages	Fair print quality No high density Does not print to all specifications	Dedicated to one symbology Cannot rearrange format	Labels may fade in bright light or heat Special paper required	Expensive	Expensive, limited Only certain adhesives available

[z]Refs. 11, 12, 28, 31, and 41.

Table 3. Comparison of major off-site bar code printing methods.[z]

Property	Flexography	Offset lithography	Silk screen	Letter press	Hot stamping	Laser xerography	Laser etching	Photo-composition	Ion deposition
Typical substrates	Paper, vinyl, polyester, corrugated	Corrugated, paper, vinyl, polyester, metal, glass	Wood, plastic, metal, glass, plates, fabric	Paper, vinyl, metal	Paper, vinyl, polyester, foils	Paper	Metal, coated metal, acrylic plastic	Retro-reflective material, photosensitive-label stock, paper, vinyl, metal	Paper, vinyl, polyester
Variable information	Requires a rotary numbering wheel (sequential)	Requires a rotary numbering wheel (sequential)	Requires a rotary numbering wheel (sequential)	Requires a rotary numbering wheel (sequential)	No	Yes	Yes	Yes	Yes
Production speed	High	High	Low	Medium	Medium	High	Medium	High	High
Graphics capability	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Flexibility	Low	Low	Low	Low	Low	High	Medium	High	High
Special requirements	Film master & printing plate	Film master & printing plate	Film master & screen	Film master & printing plate	Film master & printing plate	None	None	None	None
Minimum bar width	20 mil (on corregated) 7.5 mil (labels)	20 mil (on corregated) 7.5 mil (labels)	13 mil	6.5 mil (variable)	10 mil & smaller	7.5 mil	6 mil	4 mil	8-10 mil
Symbol density capability	Medium	Medium	Medium	Medium	Medium	High	Very high	Very high	Medium to high
Advantages	Many label sizes, many substrates multicolor	Direct printing on containers, many sizes and colors	Variety of substrates, print on odd-shape surfaces	Many label sizes, multicolor	Excellent quality multicolor prints	Fast, superior quality, flexible	Etches many surfaces, durable, direct marking	Superior quality, flexible durable	Multicolor graphics, flexible
Disadvantages	No random numbers, limited flexibility	No random numbers, limited flexibility	No random numbers, limited flexibility	No random numbers, limited flexibility	No random numbers or high density, plates expensive	Expensive, certain adhesives available	Expensive, slow, no contact scanning	Expensive substrates	Expensive

[z]Refs. 11, 12, 19, 20, 30, 41, and 43. 1 mil = 0.0254 mm.

sands of the same bar code symbol are required.

Symbology and symbol accuracy are important. Simple symbologies such as Code 39, Interleaved 2-of-5, and UPC may be produced with both in-house and off-site methods, but more complex symbologies such as Codabar, Code 128, and Code 93 require off-site methods (28). In-house methods may be used when there is a lower requirement for sharp, precise bars and spaces, print contrast, and character formation. Much greater symbol accuracy is possible with off-site methods.

The physical space on an item that is available for label application is a factor in determining label size, and therefore determines symbol density and production method. If there is a large area to apply the label, then medium symbol densities of 5 to 7 characters per inch are acceptable and are available with both in-house and off-site technologies. Small labels, which require much higher symbol densities ($\geq$ 9.3 characters per inch), usually require off-site methods.

Selection of production methods also will depend on the durability requirements. Labels of short durability (scanned a few times, lasting 90 days or less, and not exposed to adverse conditions) can be printed in-house with inexpensive label facestocks and printer ribbons. Labels of medium durability (scanned up to 100 times and lasting up to 3 years) require more expensive label materials, ribbons, and printing equipment. These labels may be printed with both in-house and off-site methods, but generally off-site methods are more efficient. Labels and tags of long durability require permanent images that resist adverse conditions. Most of these labels and tags are produced only off-site (28). There is far more flexibility in the design and construction of the labels with off-site methods due to the wide range of facestocks, laminates, adhesives, packaging (physical size and format), finishes, and graphics available (12, 43).

The volume of labels required also will influence production site decisions. Low volume requirements may be satisfied in-house, whereas high volume requirements usually dictate off-site production. Off-site systems are very efficient, with speeds for some printing processes attaining 328 $m \cdot min^{-1}$ (12). In-house systems are considerably slower.

Additional costs are incurred with in-house methods for printing equipment, equipment maintenance and operation, maintenance of supplies of label materials and ribbons, personnel, training, and verification (20). Bar code printing equipment can be expensive because usually there is a computer to drive the printer. Personnel must be available and trained to enter the data, and often additional software must be purchased. Verification of bar code symbols (routinely checking that the bar code symbols are in specification for encoding, dimensional tolerances, and optical characteristics) also must be done in-house. For example, potential problems associated with dot matrix printing include bar width growth and shrinkage, irregular bar edges, voids in bars, split bars, poor print contrast, and distorted bar/space dimensions (7). Use of manual or automatic quality control methods should be considered as a part of the in-house printing decision (20). In contrast, vendors assume responsibility for quality control to ensure compliance to standards and verification of symbols produced with off-site methods.

Employing off-site label production will make use of the expertise of vendors specializing in bar code printing; therefore, it is important to choose the vendor carefully. Make sure the vendor has experience in the required specialization (such as forms manufacture). The vendor also must have experience in bar code manufacture and various quality control procedures. Check for membership in an organization such as AIM (Automatic Identification Manufacturers), which actively participates in the bar code field. Affiliation will indicate an in-depth knowledge of bar code technology and a commitment to stay informed (44). The vendor should prepare samples to test compatibility with the scanning equipment that will be used before the bar code labels are printed.

If variable information (other than sequential numbering) is to be encoded, it is important to consider how the data will be transmitted to the vendor. Data should *not* have to be keypunched by the vendor, as this introduces additional errors. Data are transmitted from USPI/QS to the vendor electronically. These data (including identification numbers to be encoded in bar code symbols and additional descriptive text) are derived from the USPI/QS computer database and are stored on computer tape or diskette for shipment to the vendor.

Selecting scanners and decoders

Scanner selection. The choice of bar code scanning equipment is an important decision in the design of the system. Only wands and moving-beam laser scanners will be discussed here. Other hand-held scanners include fixed-beam laser scanners and charged couple devices. Selection criteria include contact vs. noncontact scanning requirements, symbol characteristics, operational considerations, human factors, and cost (18, 39).

Contact scanning may be appropriate when the bar code symbol is on a clean, flat, smooth, nonflexing surface that is easy to reach. Noncontact scanners are used when symbols are hard to reach, or are affixed to rough, uneven, curved, or flexible surfaces (25). Noncontact scanning also is used in cases where contact scanning causes excessive symbol abrasion. Moving-beam laser scanners (Fig. 3) were selected at USPI/QS because wand scanning was not feasible with either laser-etched orchard tags or high-density symbols attached to curved tissue culture caps.

Symbol characteristics are perhaps the most important criteria for selecting scanning equipment. These characteristics include resolution, printing ink, symbol covering, symbol quality, and symbol length. Resolution [the narrowest bar or space within a symbol that the scanner can detect accurately (39)] is a much greater concern for wand scanners because the wand is a contact scanner and must read the symbol in a single pass (12). Scanner resolution must be matched to the width of the narrow bars in the symbol. Recommended wand resolution is 5 to 8 mil for narrow bars <9 mil, and is 8 mil or more for narrow bars ≥ 10 mil (25).

The wavelength of light emitted by the scanner must be matched with the ink used to print the bar code symbol (18, 22). Scanners that use infrared emitters (900 to 930 nm) usually require the use of carbon-based ink, while visible-red emitters (633 to 720 nm) can be used with carbon-based inks, dye-based black inks, or colored inks (other than red). Near-infrared emitters (820 nm) usually are used with carbon-based inks, although many dye-based inks may be used successfully (12). Moving-beam laser scanners have a low-power, visible red helium–neon laser. The light source in wand scanners is either a visible red light emitting diode or an infrared laser diode (25).

Symbol covering, quality, and length are important considerations. Most wands can scan through laminates that are 10 mil thick. Laminates or protective coverings >40 mil thick require the use of noncontact scanners (18). Moving-beam laser scanners can scan symbols under transparent film, plastic, and glass (including test tubes) (12). Moving-beam laser scanners also read marginally printed, dirty, or damaged symbols more quickly than wand types because of their automatic redundant scanning. These scanners have an extremely high "first-read rate" (capacity to read the symbol correctly with the first scan), which results in greater operator acceptance. Symbol length must not exceed the beam width for moving-beam laser scanners.

Operational considerations include scanner durability, operating temperature range, power consumption, and ambient light conditions (12, 18, 39). Considerations for scanner durability include impact resistance, cable pull strength, cable bend relief, and tip wear (wands). Moving-beam laser scanners are complex devices with moving parts and are therefore less rugged than wands. Scanners are designed to operate over a broad range of temperature, but they are not designed for extremes of hot or cold. Most scanning equipment probably will not operate at temperatures below 0° or above 50°C without special modifications. Storage temperatures above 70° may physically damage internal scanner components. Power consumption is a factor for portable equipment, and moving-beam laser scanners consume more power than wands. Equipment should also be selected based on normal ambient light conditions. Wands are available for operation in light conditions varying from darkness to direct sunlight or high-intensity artificial light. Moving-beam laser scanners are generally more tolerant of ambient lighting due to their monochromatic, coherent light source.

Human factors in scanner selection include the size, weight, shape, balance, and texture of the scanner (18, 39). Scanners should be comfortable to hold and should not cause arm, wrist, or hand cramping with prolonged use. One disadvantage of moving-beam laser scanners is that they are heavier and bulkier than wands. The operator also should be able to get a good grip on the scanner, especially in applications where the operator's hands may be moist or oily.

Moving-beam laser scanners are significantly more expensive than wands, often costing more than 10 times as much (12). Moving-beam laser scanners also are less durable and are more expensive to repair and replace.

An additional selection factor for wands is the construction of the tip that contacts the symbol (10). Closed-tip wands have a hardened jewel ball, which is pressed into the wand barrel and seals the wand from dirt. Open-tip wands are not sealed at the end and are therefore subject to clogging, which means the tip must be removed and cleaned. These removable open tips may become worn, which could change the wand's focal point. Open-tip wands may also be more abrasive to the symbol surface.

An additional selection factor for moving-beam laser scanners is laser safety. Scanners that use helium–neon laser tubes or laser diodes must conform to the requirements of the Bureau of Radiological Health (18). These lasers should have ratings of either Class I, Class IIa, or Class II, with Class I being the safest.

Decoder selection. General selection criteria for decoder include the capacity to interfere with the existing host computer system, fixed or portable requirements, the need for operator feedback, and symbologies and scanners to be used. If the bar code system is being developed to interface with an existing computer system, then decoder configurations that include personal computers will be the most adaptable. The choice of decoder equipment is less restricted if the bar code system is being designed as a part of a new computer information system. For specific applications, decoders can be selected with autodiscrimination, a feature that allows the decoder to read and distinguish up to 11 different symbologies automatically (38). Autodiscrimination does, however, make the decode algorithm more complex and introduces the possibility of scan error.

There is a wide range of products available to serve as the decoder in the bar code system. Decoders are either fixed or portable. Fixed decoders generally fall into three classes: a) basic "read and beep", b) wedge, and c) full feature bar code data entry terminals (25). The basic "read-and-beep" decoders operate in an on-line operation mode and transmit data directly to a host computer. This decoder provides an audible ''beep'' or a visual light (for noisy environments) to indicate a successful bar code scan. The simplest models have no display, although some have one-line displays to allow for short messages (prompts) to be sent to the operator from the computer. Wedge decoders serve as keyboard emulators and are installed between the keyboard and central processing unit (CPU) of a personal computer (8, 32). This decoder receives input from the scanner and sends data to the CPU in a form that appears identical to direct keyboard entry. There are numerous wedges available for popular personal computers, including some in the form of plug-in printed circuit boards (3). Full-feature bar code decoder terminals are equipped with displays and keyboards. These decoders may be interactive on-line or interactive intelligent devices (25). With an on-line decoder terminal, the host computer stores and executes data collection programs, provides prompts, and acknowledges data transactions as they occur. In contrast, an interactive intelligent decoder terminal may be programmed directly from the keyboard or have programs downloaded from the host computer. Once programmed, this decoder runs independently of the host computer until the complete data file is collected and is ready to be transmitted to the host.

Read-and-beep decoders usually are found in large-volume industrial settings. Both wedges and full-feature decoder terminals would be very useful for relatively static laboratory applications such as tissue culture research and seed germination testing. A wedge is an economic way to incorporate a decoder into an existing data processing system.

Portable decoders may be moved from place to place and function independently of the host computer. They are usually full-featured, with display, keyboard, and adequate memory (25). These decoders generally store and execute a data collection program, store collected data, and then transmit these data to a host computer in batches.

Portable decoders are most applicable to horticultural applications and must be selected on the basis of several specific criteria (12, 26, 32). Features to consider include the decoder's power system, operating system and software development, memory type, keyboard, display, interface, and durability.

The portable decoder will furnish power for itself and for the attached scanner. The power system can be relatively sophisticated in that it may have two or three battery levels to protect memories from loss of data and programs. The duty cycle for the application will determine power requirements. Consider the amount of time the decoder will be used each day and the time require for recharging the batteries.

Unlike many personal computers, there is currently no standard operating system for the various portable decoders. Manufacturers, having developed their own systems, vary in providing software and software tools to allow user programmability. Many of the early decoders were developed specifically for the grocery market, where there is no need for user programmability, and generally these units are inappropriate for horticultural needs. If prewritten data collection programs are to be purchased from the manufacturer, make sure the programs to be used are available for the decoder being considered. Software is available also from software vendors specializing in bar code equipment. Many manufacturers will develop custom programs to suit particular applications, but they can be quite expensive. For example, in a survey of scanning and decoding equipment for use at USPI/QS, one company offered a package where the total cost of the scanner and decoder was $4000, but the cost for required custom software development was an additional $5000. Furthermore, to learn the decoder's programming language, USPI/QS employees would have had to attend a training program for an additional $8500. The equipment was excellent, but the operating system was not suitable for a small, independent application. An evaluation of the user programmability is critical if programs are to be written in-house. The programming language should be easy to use, well-documented, and should at least include operator prompting, self-editing capability, arithmetic capability, and output formatting. Since portable decoders have small displays and keyboards, it is desirable for them to accept programs written on personal computers.

Memory size for portable decoders varies from 8 to 256 K (26). Most models contain 32 to 64 K of memory in the form of NMOS or CMOS semiconductor chips. CMOS chips are more expensive, but they are preferred because they require considerably less power than NMOS chips. The memory size required will depend on the space required to store and execute the data collection program and store the collected data. As with personal computers, the nature of the memory can be ROM (read-only memory), RAM (random-access memory), EPROM (electrically programmable ROMs), and EEPROM (electrically erasable programmable ROMs) (12, 26, 32).

The keyboard and display are important considerations because they allow communication between the decoder and the operator, and they are major factors in determining the overall size of the portable decoder. The keyboard should contain all of the numeric, alphabetic, and special characters required to handle the data (12, 26, 32). It is also desirable that the keyboard provide feedback to the operator in the form of feel and/or audible tone when the keys are touched. Evaluate the size and placement of the keys. Large keys with adequate spacing are important if the operator must wear gloves or work under adverse conditions.

Portable decoder displays must be easy to read. The two basic displays are the LED (light-emitting diode) and the LCD (liquid crystal display) (12, 26, 32). LED displays have been in use longer and the characters are generally more readable than LCD characters, but they consume a great deal of power and cannot be used in direct sunlight. The LCD is difficult to read in dimly lit environments, but backlighting is available. The size of the display should be matched to the length of the prompts and the data input (such as plant names). LCD displays usually have two lines displayed with 16 characters per line. Larger and smaller displays are available.

Successful transfer of data from the portable decoder to the computer will require the correct interface. This interfacing is accomplished by using a direct connection, transmission of data over conventional telephones (with a modem), or wireless communication (26, 32). Direct connection is used in applications where the operator collects data at a remote site and then brings the decoder to a work station to transfer data to the computer. The most common direct connection interface for communication is RS-232-C (21). The 25-pin connector used for RS-232-C is commonly installed in data processing equipment, but just because two devices have a RS-232-C connector does not mean that they can communicate with each other. In addition, they must be compatible at all levels of the communications protocol, such as transmission speed, parity, duplex, word length, stop bits, and asynchronous or synchronous communication modes. Remote communication between the decoder and the computer is accomplished by transmitting the data over conventional telephone lines using a modem. The transfer rate with a modem is rather slow (1200 bits/sec or slower with voice grade telephone lines); hence, it may be desirable to be able to transmit data unattended during off-duty hours to save on telephone and computer charges. Wireless communication, commonly through radio links, is useful in warehouse environments. It has the advantage that data transfer does not disrupt the job and the operator does not have to return to a work station to transfer data. Wireless communication also will allow the portable decoder to function interactively with the computer.

Portable decoders must be durable. They should be purchased with the expectation that they will be used in fields, orchards, or greenhouses, and will be subjected to harsh environmental and physical abuse. Many models will not withstand this abuse and are not environmentally sealed.

Designs for decoders are changing rapidly and some emphasis is being placed on software. Future projections include combination decoder/scanners for computer packages, portable computers with scanners, and combination decoder/scanners with displays (8).

Financial considerations in bar code equipment selection should go beyond the purchase price. In addition to comparing initial costs, evaluate vendor qualifications with regard to consistent product quality, on-time delivery, and long-term support (18, 39).

Information resources

There are many sources of information available on bar codes, but these are not generally known to the bar code novice. Useful sources include publications, seminars (such as "Scan-Tech"), and trade shows sponsored by Automatic Identification Manufacturers, Inc. (AIM, 1326 Freeport Rd., Pittsburgh, PA 15238), which is an independent trade association with strong educational goals. Many useful documents also have been prepared by the DOD in relation to their LOGMARS program. These documents are available from Director, AMC Packaging, Storage, & Containerization Center, ATTN: SDSTO-T, Tobyhanna, PA 18466. Most of the major bar code equipment and label manufacturers also have published helpful reports. Other useful references include the journals: *ScanJournal*, published by AIM; and *ID Systems* (formerly *Bar Code News*, published by North American Technology, Peterborough, NH 03458. Useful books include: Reading Between the Lines: An Introduction to Bar Code Technology, by C.K. Harmon and R. Adams, North American Technology, Inc., Peterborough, NH 03458; and Bar Coding Principles & Applications (Symbology '82 Seminar Proceedings), T.D.A. Publications, Inc., Hollywood, FL 33020.

Consulting firms. Bar code technology is expanding rapidly and often is outside and beyond the time, capabilities, and/or interests of research scientists, small businessmen, or curators of arboreta. As a result, bar code system consulting firms have arisen to meet the needs of these groups. Such firms have the capability to survey the needs of an organization, determine requirements for bar code labels and equipment, develop software, and provide a continuing source of information. These consultants are not a replacement for a basic in-house understanding of a bar code system and its components, but they can expedite the decision-making, procurement, and implementation operations. Names of bar code consulting firms are available through AIM.

SUMMARY

Bar codes have had a tremendous impact on American industry and can be used successfully in many horticultural applications. Many factors must be considered in developing a bar code system for a specific application. These factors include how the bar code system will function in relation to the work being done and who will operate the system. Using a "system approach" in the design stage will yield the greatest return for the effort and resources invested. All components of a bar code system must be evaluated closely in terms of how they will function together and their suitability for the environment in which they will be used. Selection criteria for the bar code symbol, scanner, decoder, and system interface to the host computer have been presented. Evaluation of bar code labeling materials for horticultural applications determined that best results were obtained with rigid aluminum and plastic tags for long-term orchard use, paper labels with oversized clear mylar laminates for greenhouse use, and metalized mylar labels with clear mylar laminates for tissue culture use. With proper planning and execution, the bar code system can provide vast improvements in the efficiency and accuracy of both labeling and data collection, and, as a result, allow an organization to work more effectively.

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