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POTATO STORAGE FOR DEVELOPING COUNTRIES

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Abstract.

The need to consider potato storage as an integrated part of the total production system and its interdependence on prevailing production and marketing patterns is emphasized and illustrated. Some socio-economic factors which should be considered in addition to biological and engineering factors in making storage decisions and deriving integrated storage systems and selecting storage methods are discussed. The danger is stressed of merely transfering storage system from one region to another without consideration of or adaption to local production, marketing, and socio-economic conditions. Low-cost storage methods which are in demand in many developing countries, and factors for consideration in their design, modification, and evaluation are discussed. Particular attention is paid to the potential use of natural diffused light in simple low-cost seed stores as an alternative to controlled low-temperature seed stores. Emphasis is provided for good pre-storage tuber selection and store management as an essential to successful storage, particularly where low-cost simple stores are used.

Based on paper presented at the 3rd Regional Potato Symposium, "Potato Production in the Humid Tropics", October 13-17,1980. Bandung, Indonesia.

Introduction

Storage of potatoes, for either consumer or seed use, must be an integrated part of the total production system. Potato production aims at providing a sufficient supply of potatoes for total market demand. This can be achieved by either continuous market orientated production or by periodic production plus storage. Because continuous production is rarely possible or practicable in many countries, storage is necessary to supply market consumer demand and to provide seed tubers for planting the next crop. Consumer requirements include potatoes for human consumption, for processing, and in some countries for animal feed. Requirements of both consumer and seed tubers may be for both internal and export markets. Storage thus "moves" potatoes in a controlled fashion through a period of time to make them readily available. This helps to stabilize and reduce excessive price fluctuations.

Socio-economics

Socio-economic factors in addition to biological and engineering factors must be studied and form part of potato storage decisions. We need to know the quantity and quality of potatoes to be stored, why they are to be stored, and for how long we need or wish to store them. To answer these questions we must know present production patterns and present marketing procedures and evaluate how storage fits into this existing system and anticipate if storage will change the system in any way. For storage to work it must be acceptable to both the production and marketing parts of the total system. If it is not accepted by both, it will not be used.

Potato stores may be considered analogous to a reservoir used to control stream flow and to prevent flood damage on a river system. The river reservoir is designed to accumulate excess flood waters during the rainy season for release gradually during the dry season. By knowing when and how much water must be released from the reservoir, it is possible to

regulate the flow through the river system to prevent floods and droughts. At least a minimal flow of water is usually maintained at all times. Care should be taken, however, to only place the quantity of potatoes required to satisfy future consumer demands in the storage reservoir. Over-use of the reservoir will result in over supply, low prices, and thus increased financial loss. To best regulate the flow of newly harvested potatoes into the storage reservoir and the outflow of stored tubers from there to the market, information on the influence on prices of over-supply or under-supply is of utmost importance. Detailed information on production patterns, marketing systems, and total and varying consumer demands is necessary to determine overall storage needs for meeting either national or regional requirements.

All potato storage methods, no matter how simple, cost money. All storage systems require investments. Even if the store is used only partially or not at all, it adds to the cost of the total production system. The more complicated the store system, the higher the investment. Storage methods selected and used must be the most cost effective available. The most cost effective method may or may not be the same as the technically most effective method. For example, in a given situation storage losses may be technically reduced from 15% to 7% by installing a refrigeration plant in an existing forced draft store. But this technical improvement could only be justified if the value of the saved 8% of the stored crop was higher than the costs of installing, running and maintaining the refrigeration plant.

For the storage part of the system to be effective, operation of the storage reservoir must be thorough. Storage management is as critical to the system as are production management and marketing. This requires understanding the total production-storage demand system in addition to detailed knowledge of potato storage technology. The cost and availability of managerial skills is an important factor in the choice of technically appropriate and cost effective storage methods. Proper storage management helps make the total production system more efficient and less costly.

Storage Needs

Potato storage must form part of and be acceptable to both production and marketing patterns. Where continuous production and harvesting cannot be practiced, storage is needed and functions to move potatoes in a controlled fashion through time. Thus, particular storage needs are to a large extent determined by total and specific consumer requirements and the magnitude, duration and frequency of harvests. These factors together with variable storage costs and social conditions make storage needs location specific. There is no "best" storage system; different systems are more or less appropriate under different technical, economic and social conditions.

Some examples of ways in which production and marketing patterns influence storage needs are given below. Consumer requirements, both total and specific, may or may not be stable throughout the year or from one year to the next. Information on the magnitude and stability of these variations and demand trends is required to determine storage needs. If, for simplicity, we consider that total demand in a given location is constant, then we can see in Figures 1 to 5 how the magnitude and frequency of harvests influences storage-needs. In Figures 1 and 2 total annual production is equal to the demand. In Figure 1 there is a single annual two-month harvest which requires that 16.7% of the total production be marketed directly during those two months and the remaining 83.3% is stored and released to the market during the following ten months to provide an even supply which satisfies the demand. This situation demands large scale and long duration storage. In Figure 2 are two annual two-month harvests equal in both magnitude and frequency within the year. Each harvest produces half the quantity of that produced in the single harvest of the previous example and 33.3% is marketed directly and the remaining 66.6% stored and released evenly during the following four months. This situation requires smaller scale and shorter duration storage in which the same storage facilities can be used for the two storage seasons. Figures 3 and 4 illustrate cases of over and under production in single annual harvests and the consequential effects on

FIG.1

One Annual Production Season
Total Production = Demand

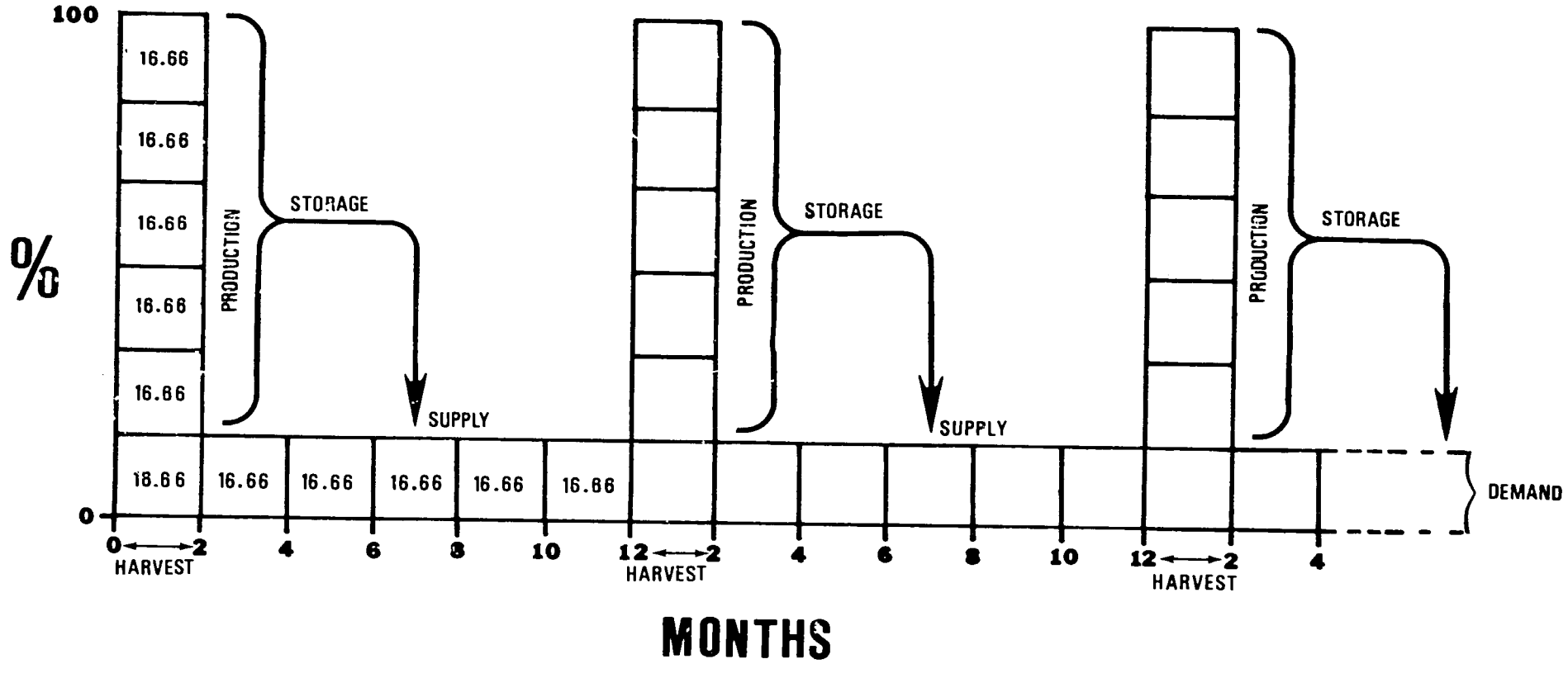


FIG. 2

Two Annual Production Seasons
Two Equal Harvest
Total Production=Demand

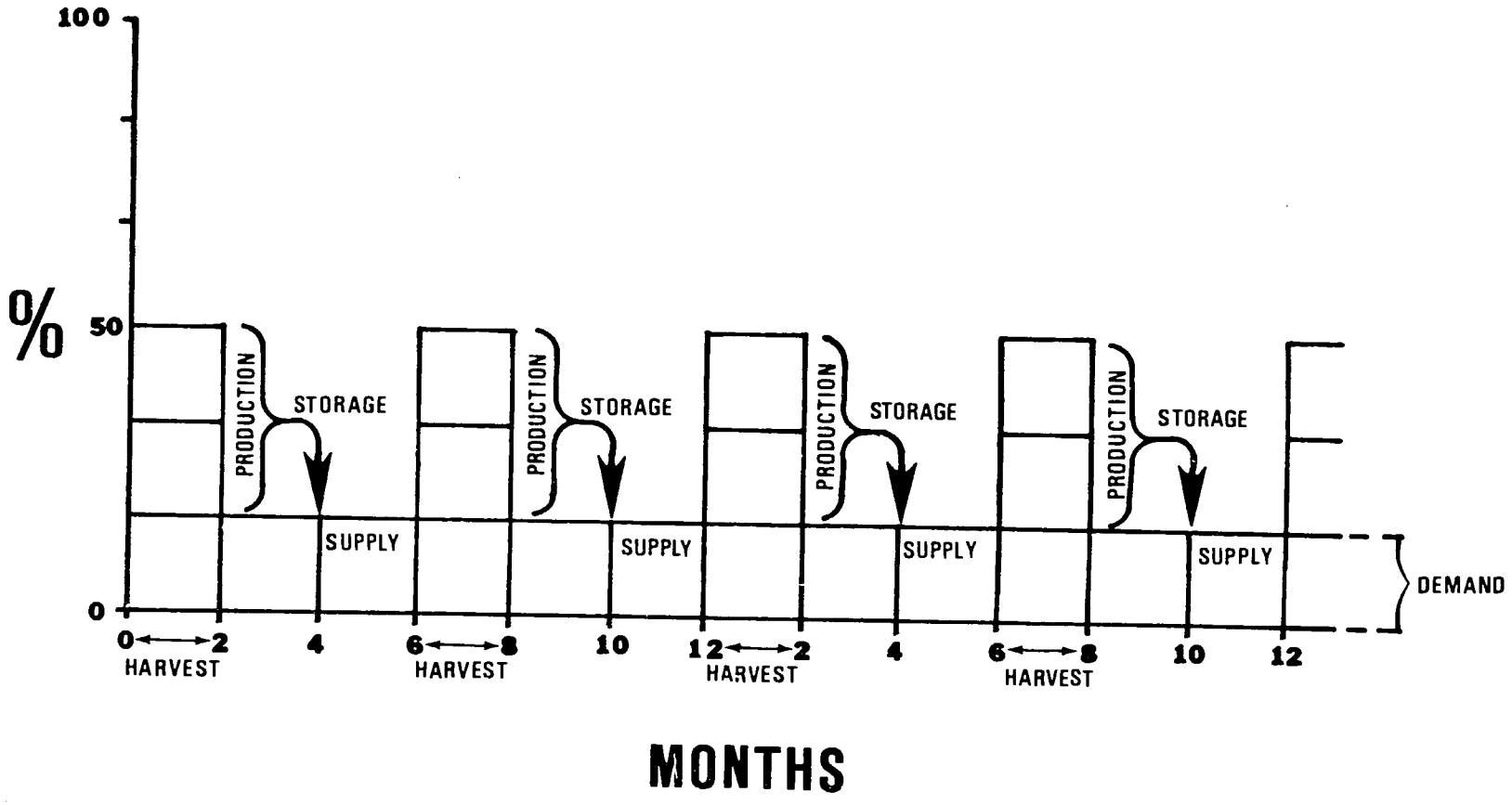


FIG. 3

One Annual Production Season
Total Production > Demand

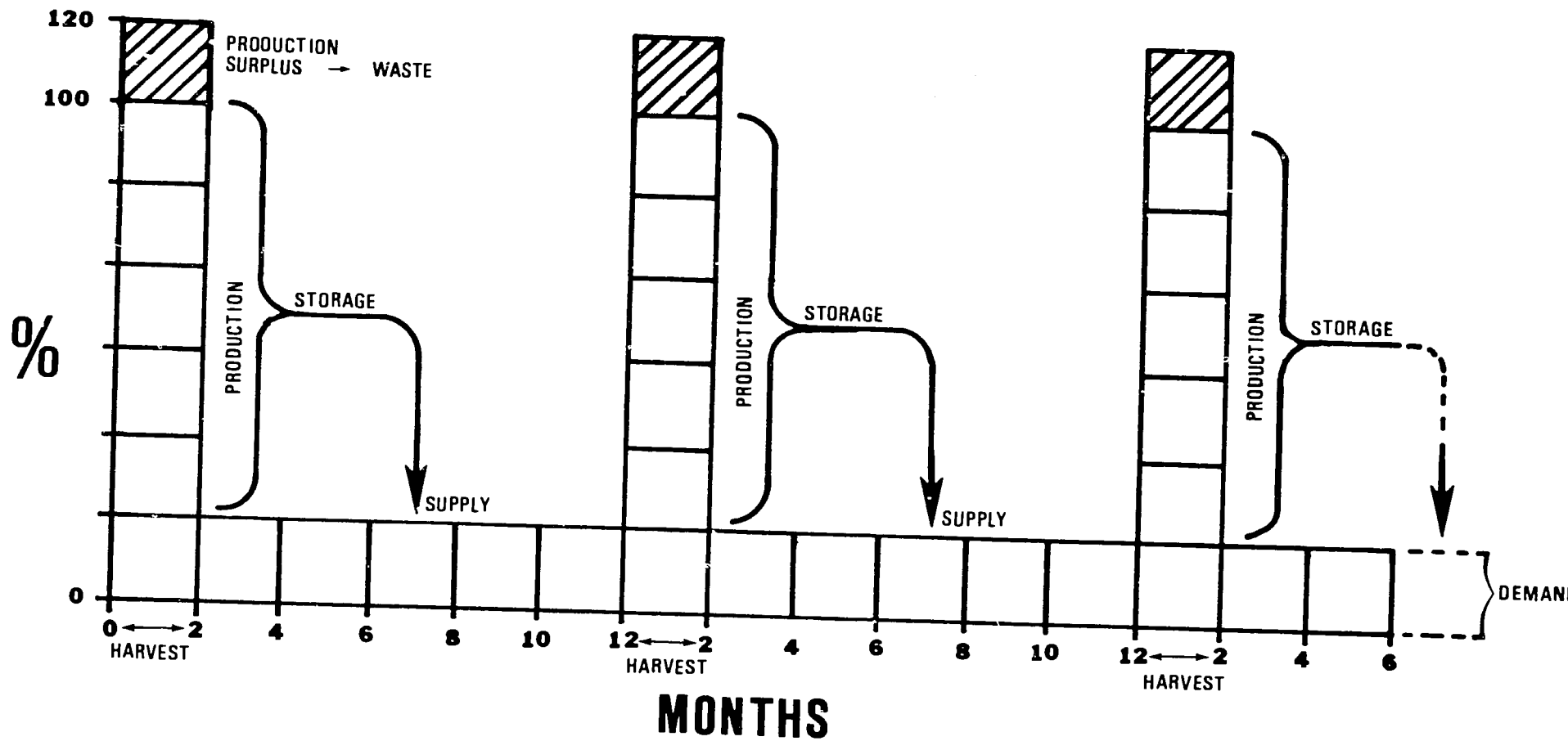
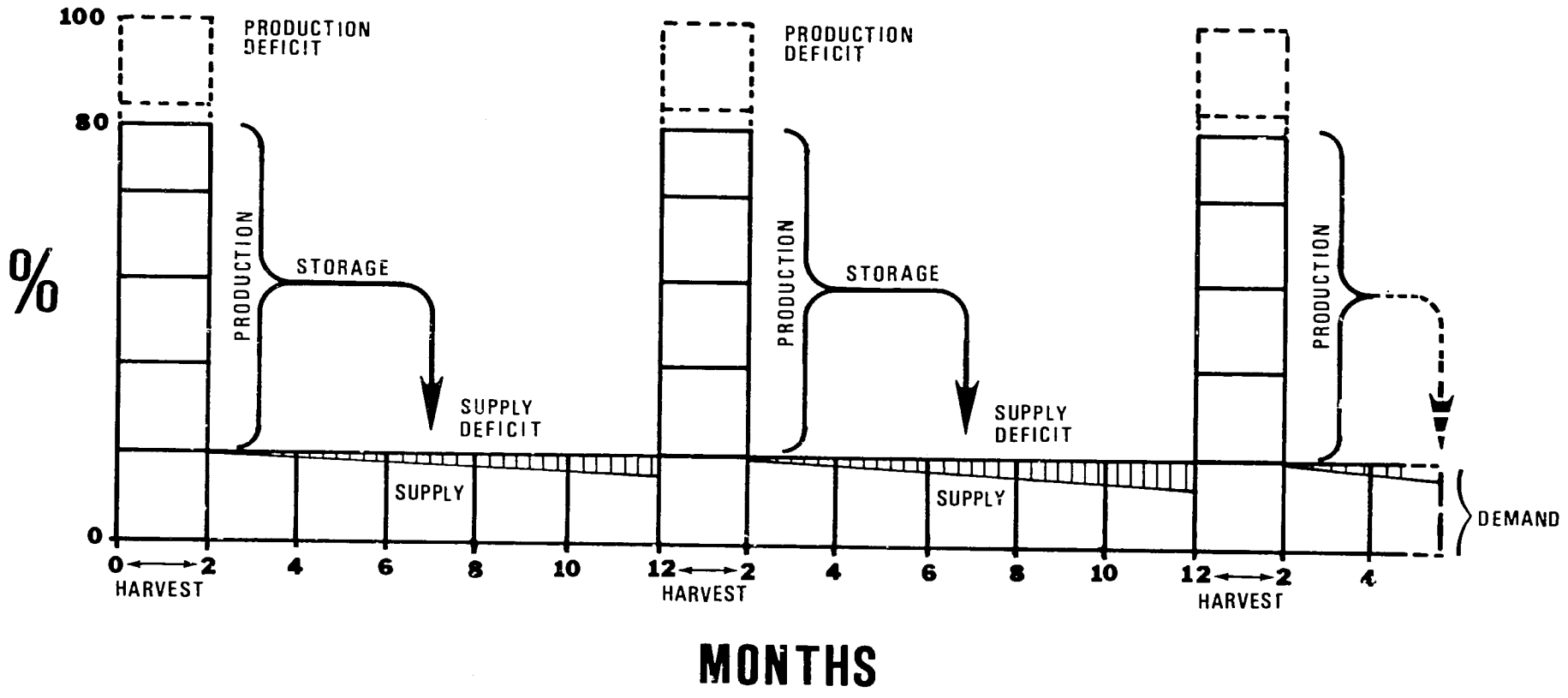


FIG. 4

One Annual Production Season
Total Production < Demand



supply. In the case of over production, only that harvest surplus which is required to satisfy future demand should be placed in the storage reservoirs. Over storage will result in even greater financial losses through depressed prices than does over production. Where there is a deficit in total production the storage policy and management will determine the distribution of this deficit.

A more complex situation is illustrated in Figure 5. Although the total production of the two annual harvests is equal to the total demand an even supply to satisfy this demand cannot be maintained because the two harvests are unequal in magnitude. Thus, as illustrated in Figure 5, the production surplus of the first harvest should not normally be stored, while the second smaller harvest results in a deficit. Because in most situations stored tubers compete poorly on the market with fresh tubers, but must cost more to cover the additional costs of storage, the theoretical and technical possibility of storing the surplus from the first larger production season over into the deficit period following the second smaller production season, will rarely be feasible in practice. Of particular importance in managing such situations is a knowledge as to what extent over supply or under supply influences prices and demand.

Marketing and distribution patterns similarly influence storage needs. As an example we can examine alternative patterns of seed distribution from the seed producers to the seed users in a given location and see the influences which these have on storage needs. We can identify three major patterns by which seed tubers are distributed and which have different storage needs (Figure 6). First, the seed at harvest time may be collected and stored by one or more centralized seed agencies or merchants and then sold and distributed to users at planting time. This system demands few large scale stores. Second, the seed may be stored by the seed producers themselves and sold and distributed to seed users at planting time, either directly or through seed agencies or merchants.

FIG. 5

Two Unequal Annual Production Seasons
Total Production = Demand
Unequal Productions → Uneven Supply
(waste + Deficit)

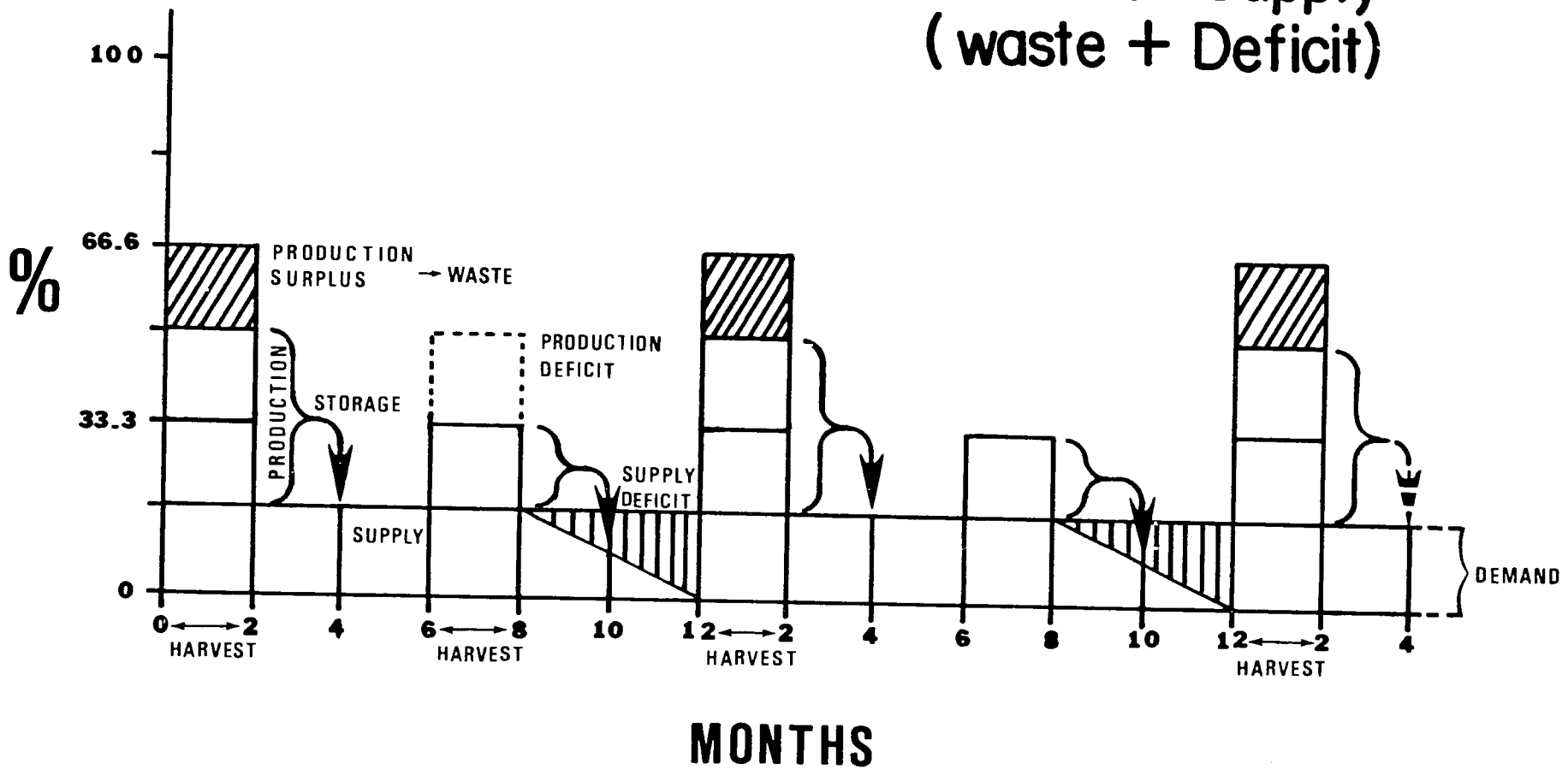


FIG. 6

THREE ALTERNATIVE SEED DISTRIBUTION PATTERNS WITH DIFFERING STORAGE NEEDS

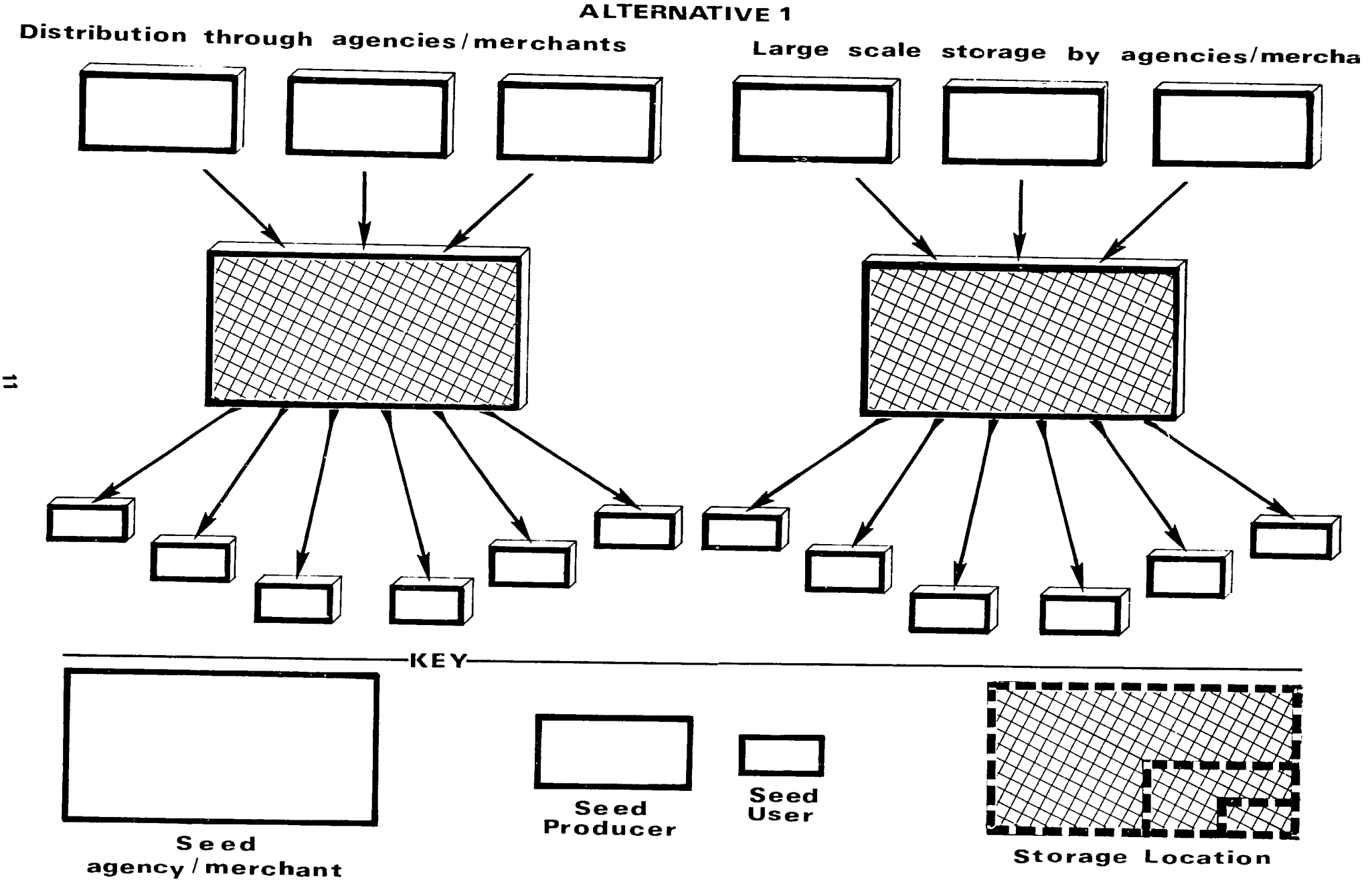


FIG 6

THREE ALTERNATIVE SEED DISTRIBUTION PATTERNS WITH DIFFERING STORAGE NEEDS

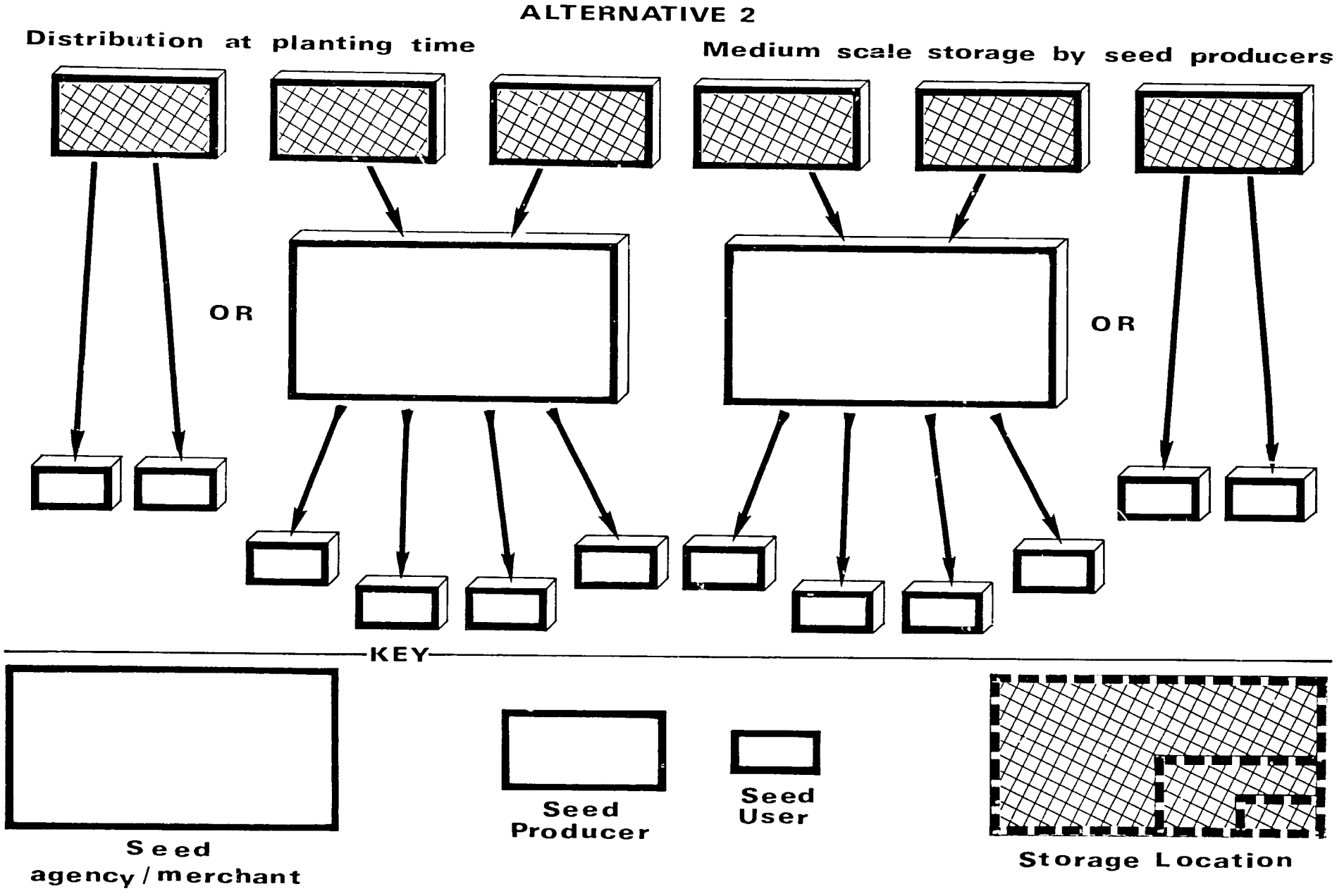
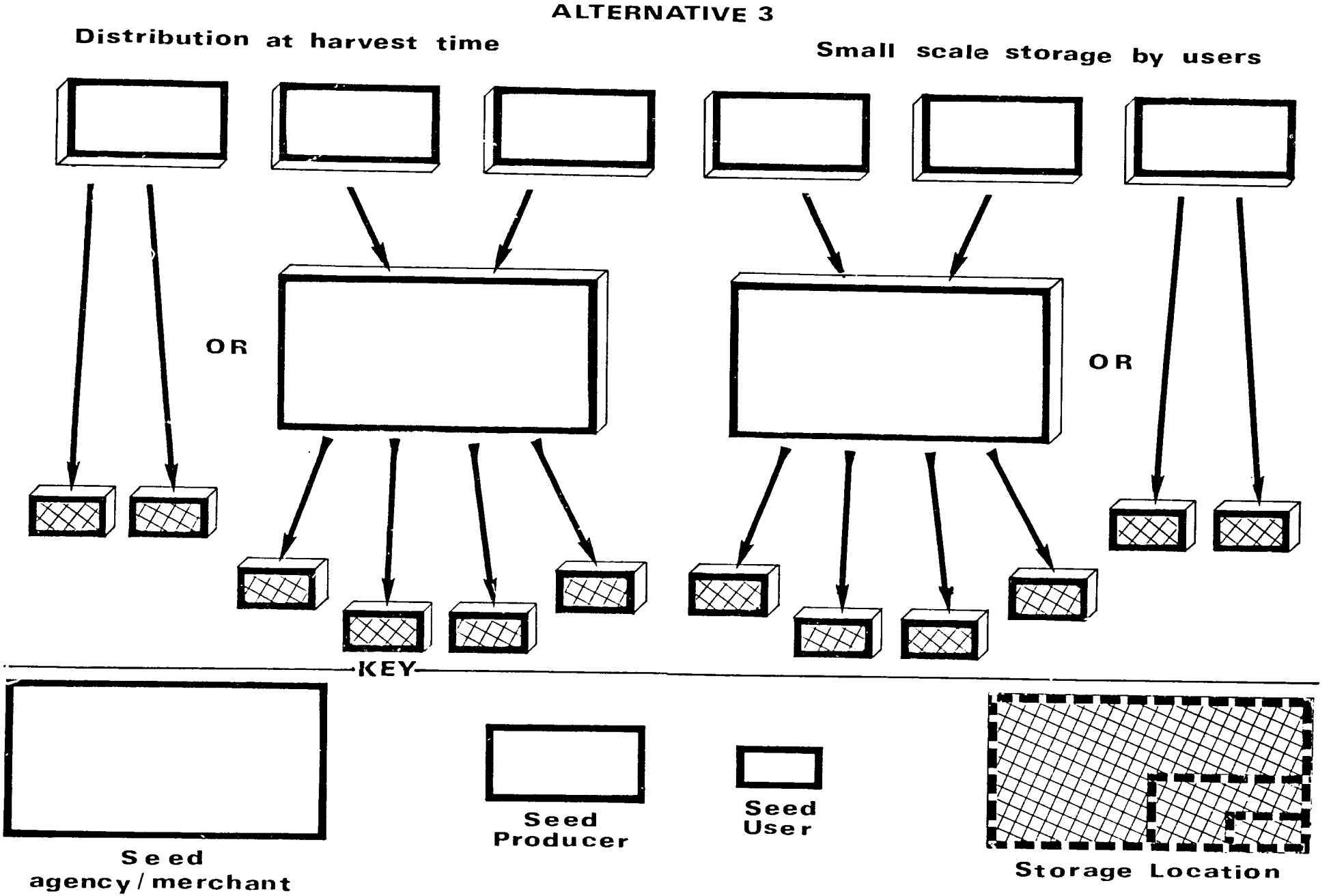


FIG 6

THREE ALTERNATIVE SEED DISTRIBUTION PATTERNS WITH DIFFERING STORAGE NEEDS



This system requires a larger number of medium scale stores. Third, seed tubers may be sold and distributed, again either directly or through seed agencies or merchants, to the users at harvest time and then stored by the individual farmers until planting time. This system requires a still larger number of small scale farm stores. Additionally, both seed producers and users may store seed tubers for their own future planting. The above alternatives are not exclusive and in any one location one or more of the alternatives can operate side by side provided adequate flexibility is in the pricing system. A rigid pricing system based on a single marketing and distribution pattern will automatically exclude alternative distribution and storage systems.

Thus, it is seen that detailed information on production patterns, marketing and distribution systems, and total and different consumer demands are required before overall storage patterns and needs can be established either on a national, regional or individual basis. Such information will not only influence the overall storage needs but also detailed technical decisions because, for example, large scale and longer duration storage facilities generally require different storage methods with higher levels of storage sophistication.

Storage Methods

Storage methods may be characterized as either field storage or storage buidings. Field storage may be delayed harvest or inground storage or variable types of clamps or pits. Storage buildings are either multipurpose and adapted buildings or purposely built potato stores.

As harvested and stored potato tubers continue to respire they produce heat and therefore all potato stores require ventilation. The type of ventilation system selected depends on various biological, technical and socio-economic factors. Ventilation systems use either cool ambient air when this is available or artificially cooled air when it is not. Refrigeration is the most common means of cooling air although evaporative cooling may also be considered in regions of low ambient relative humidity. Ventilating air is distributed through stored tubers using either natural convection or forced draft systems. These different ventilation systems dictate different store designs. For the efficient design of store ventilating systems an understanding of the thermodynamic properties of air (psychrometrics) is required.

In conjunction with ventilation, all stores require insulation. The degree of insulation required will depend upon the selected internal storage temperature and the outside ambient temperatures. Store design and construction should always make use of local experience and materials. Selected construction materials must provide weather protection, adequate strength for retention of the potatoes and adequate insulation.

In selecting storage methods it is always important to realize that the most efficient method of storing and handling potatoes is not absolute, but is relative to a large number of continuously changing technical, social an economic factors and conditions. Therefore, different methods are more or less appropiate in different circumstances, even within different periods of the same storage season. In any particular situation, the methods should be selected in terms of acceptability to the total production-storage-demand system in operation and so as to yield maximum returns on the investment available and to keep both quantitative and qualitative storage losses as low as possible. Thus, instead of simply selecting one storage method, frequently involving large, sophisticated and costly storage units, greater benefits may be obtained by choosing several different storage methods and structures. These should fit together to form an integrated storage system in which each individual method yields maximum returns for the different periods within the total storage season and/or for different end uses.

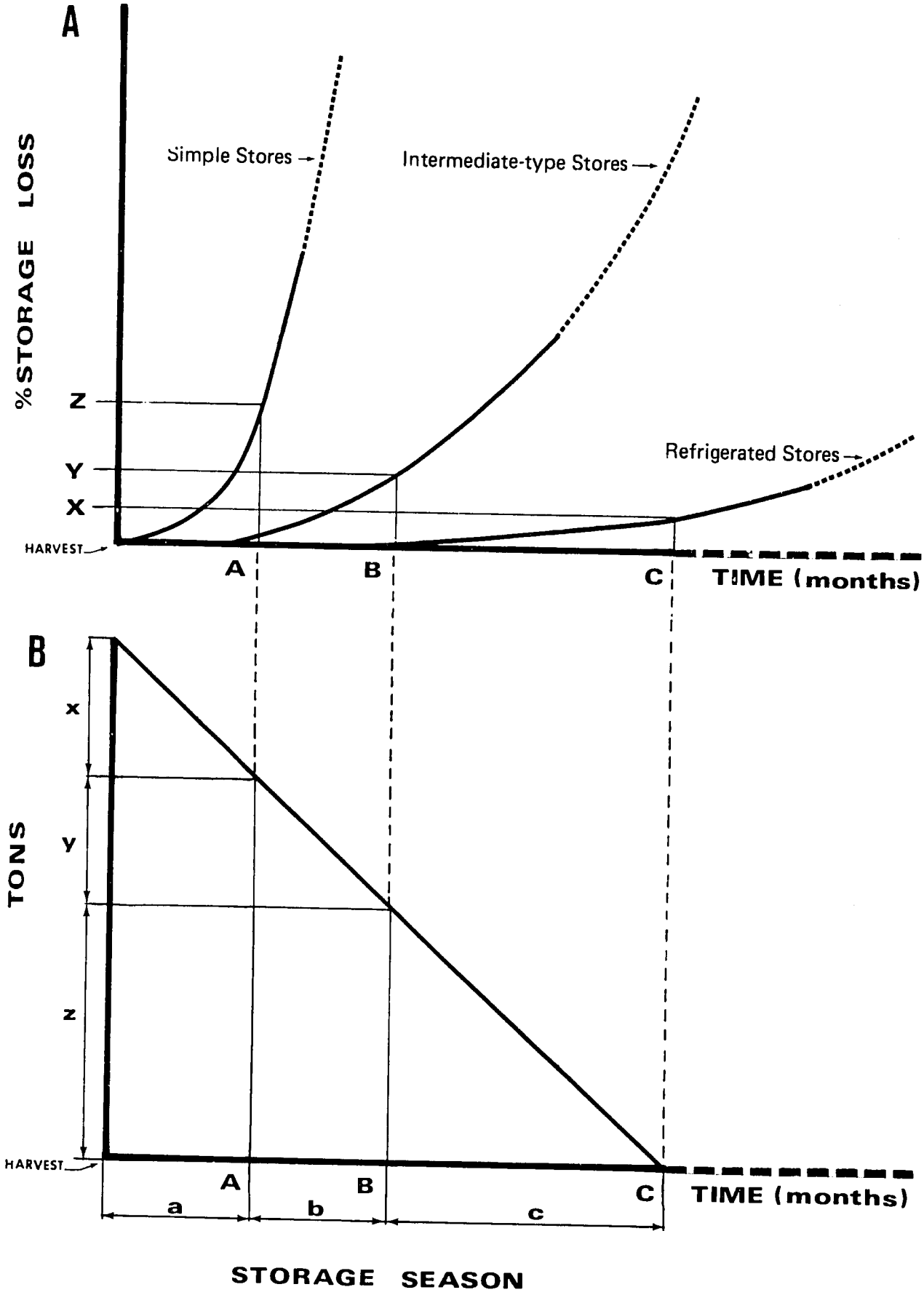
An example of such a storage system using three different storage methods is illustrated in Figure 7b. In this example the tonnage "x" required during the first portion "a" of the total storage season is stored in simple field clamps, the tonnage "y" required during period "b" is stored in naturally ventilated intermediate type stores, and only the tonnage "z" which is required in the final period "c" is stored in sophisticated refrigerated stores. Before such integrated systems can be derived, information is required on how long potatoes can be economically stored using different methods under the prevailing local conditions. When information on storage losses is available (Figure 7a) this together with socio/economic and marketing data can be utilized to derive an integrated system illustrated in Figure 7.

In selecting particular storage systems take note of the total market value of the crop to be stored and consider this when deciding on how much to invest in storage systems to protect that sum. Too frequently vast efforts and expense are placed into producing the crop which is then stored under inadequate conditions resulting in substancial losses. Commonly such losses could be reduced by a relatively small additional investment.

Great attention must be placed not only on the technical and economic perfomance of selected methods but also on their acceptability to both the production and marketing parts of the total system. If selected methods are not accepted by both, they will not be used. Too many examples of such storage "white elephants" can be found in developing countries where technically sound stores are not used because of their inappropriateness to the prevailing total system. Such examples are commonly found where storage methods were directly transfered from other regions of similar climate without any effort being made to adapt or develop the technology to the prevailing production, marketing, and socio-economic systems. In short a storage method must be selected and developed within the total system and not simply transfered from outside from some other system for which it was evolved.

FIG 7

DEVELOPMENT OF INTEGRATED STORAGE SYSTEMS



Low-cost storage methods

The demand from a majority of developing countries is for low-cost storage methods. Some of the factors influencing the appropriateness of these and other storage methods have been discussed. The technically most-efficient storage method may not be the most cost effective method. Similarly remember that low cost storage methods need not necessarily be the most cost effective.

Low-cost storage methods generally consist of field storage systems, modified or adapted existing buildings or purposely-built, generally small scale, rustic stores. However, when appropriately designed and constructed, using local experience and materials, the cost of more sophisticated and generally larger scale storage buildings, can commonly be lower than anticipated.

Where improvements in storage methods are being considered a thorough knowledge of existing practices is first required. Frequently, valid reasons exist for use of prevailing systems although these systems may initially appear inferior to the technologist. Any changes made in the storage part of the total production system need to be evaluated against existing practices, not only at the research or experiment station level but also at "farm" level, and within the total system. Three levels of evaluation can be recognized: technical, economic and acceptability.

Technical evaluation involves a comparison of the technical perfomance of the "improved" with existing storage method. In the case of stores for consumer potatoes this effectively means comparing storage losses. With the storage of seed tubers both storage losses and subsequent perfomance of the seed in the field need to be evaluated. Economic evaluation involves comparative cost benefit studies carried out in the context of the total production-storage-demand system. These studies should take into account such factors as cost and availability of differing capital requirements, construction costs, running and maintenance costs, labor costs and availability, management costs and availability, interest charges, and alternative cash uses and needs.

Acceptability evaluation is the most important because if the "improved" system is not accepted and used it is not justified to expound its technical and economic merits. Thus an understanding of major local socio-economic constraints on technology transfer together with a monitoring of the adoption of the new system is required.

A knowledge and understanding of these three levels of technology evaluation is also helpful in designing purposely built stores for a specific location and in carrying out meaningful problem solving storage research.

Major factors to be considered in the improvement of design of low-cost stores for consumer potatoes are ventilation and insulation. Insulation of existing buildings to be used to store potatoes is commonly inadequate and can usually be readily improved with cheap locally available materials. When building or modifying a store remember that the insulation capability of most materials is reduced when they are wet. Also, heat absorption, and thus insulation needs, can, in many situations, be considerably reduced by painting the external building surfaces white. An example of the effectiveness of white paint in reducing heat absorption by simple wooden rustic stores at Huancayo, Peru is shown is Table 1. A fuller understanding of psychrometrics and the optimal ways of removing heat from potatoes by efficient air distribution can commonly lead to simple improvements in ventilating systems and is essential for their effective design for purposely built larger scale stores.

In the storage of seed potatoes similar engineering factors should be considered but additionally diffused light may be used. Where either the external environment is not suitable or capital is not for any reason available for controlled temperature storage of seed tubers, storage in natural diffused light in simple low-cost structures offers many advantages over conventional simple storage in the dark. The scale to which natural diffused light seed stores can be economically applied will depend on local costs, production, distribution, and marketing systems. In general, it is a technology particularly will suited to the smaller farmer.

TABLE 1

EFFECT OF WHITE PAINT ON THE TEMPERATURE OF SIMPLE WOODEN STORES

(HUANCAYO, PERU)

Temperature * (° C)

Time (hrs)	External surface		Internal surface	
	Natural	White	Natural	White
0800	2	2	2	2
0900	23	15	8	4
1000	32	22	15	8
1100	37	24	17	10
1200	42	25	22	14
1300	44	28	24	15
1400	46	32	25	15
1500	20	17	19	15
1600	20	17	19	14
Ave	29.6	20.2	16.8	10.8

* Average over 5 days.

The major advantage in the use of diffused light as opposed to storage in the dark at uncontrolled storage temperatures, is the effect of light in controlling sprout growth and consequentially reducing losses associated with excessive sprouting. Additional advantages are an increased sprout number or a reduction in apical dominance in most varieties, and an increased resistance to pests and diseases. All this commonly leads to earlier and more uniform field emergence which may result in increased yields. This seed storage system is currently being evaluated in many developing countries and an example of the type of results being obtained from demonstration stores in the Philippines are given in Table 2.

Where natural diffused light is used this influences considerably the design, construction materials, and details of the storage building. In purposelybuilt natural diffused light stores it is considered better to allow diffused light access through transparent walls for reasons of better light distribution and because heat gain per unit area into buildings is greater through roofs than walls. Where broad-span existing buildings are modified for use as natural diffused light seed stores, sky-lights will be necessary if full adavantage of space is to be taken but this will be at the expense of greater heat gain into the store. Within the stores the seed tubers should be placed in not more than double layers on purpose built slatted shelves or in stacked seed trays to allow light access to all tubers. Spacing between shelves is determined by their width and the width of the building. A shelf width of not more than 1.5 metres with a minimum spacing of 25cm between shelves is suggested. Generally the construction costs of diffuse light stores are very low, but the cost of shelving or seed trays can be a major factor in determining the scale to which this simple storage method can economically be utilized. For optimum light penetration purpose built stores should be long and narrow. Construction materials will depend on local availability, costs, and climate. In general, a simple frame of round timber, bamboo or equivalent is suggested. The transparent walls can be of either wire, nylon, or plastic open mesh; polythene or rigid corrugated plastic sheets or even timber, cane or bamboo spaced poles. Polythene or rigid plastic sheets should only be used in cool areas and when used care must be taken to allow for adequate

TABLE 2

COMPARISON OF NATURAL DIFFUSED LIGHT AND FARMERS SEED STORES*

(BAGUIO, PHILIPPINES)

Variety: Cosima. Date Harvested: 26/2/79. Date Stored: 5/5/79. Date Planted: 27/9/79.

A. STORAGE PHASE

	Ave. sprout length (cm)	Ave. sprout N° /tuber	% Rots by weight	% weight loss	Total % storage loss
Diffused Light Seed Store	3.14	5	2.9	19.7	22.6
Farmers Seed Store	4.72 **	4	44.1	27.9	72.0

** White sprouts with tip die-back.

B. FIELD PHASE

	Days to 75% emergence	% Final emergence	Days to maturity	Total Yield (t/ha)	Marketable Yield (t/ha)
Diffuse Light Seed Store	8	98	88	20	15.3
Farmers Seed Store	18	87	96	12.3	8.2

** Data provided by F. Rutab, BPI, Baguio.

ventilation. The roof should be well insulated and with large overhangs so as to provide shading to the walls and avoid direct sunlight from falling on the stored tubers for prolonged periods. Thatch roofs are ideal for this purpose. In hotter areas where potato tuber moth is known to be a storage problem, stored seed tubers should be well selected, treated with insecticide prior to storage, and the store walls ideally constructed of moth proof screen.

For the successful storage of either consumer or seed tubers in low-cost stores, in which the control over the storage environment is less exact than in more sophisticated stores, the pre-storage selection of tubers coupled with good store management is vital. The effect of different levels of prestorage selection is illustrated in Table 3. These results clearly illustrate that as the percentage of defective tubers placed into stores was increased an increasing percentage of the sound tubers placed into the stores became defective during the storage period. The quality of tubers placed into a store is the most important single factor affecting the technical outcome of any storage system.

TABLE 3

EFFECT OF PRE - STORAGE SELECTION AND STORE TYPE ON STORAGE OUT - TURNS

% Total Storage loss after 140 days

	Pre-storage selection level		
	0% defective tubers	25% defective tubers	50% defective tubers
Store type			
Wood store	14.7	41.9	61.8
Adobe store	15.6	43.6	64.3
Light/plastic	16.6	42.0	62.7
Light/screen	15.7	39.7	64.5
Open stable (light)	13.7	40.9	63.2
Adobe room (dark)	19.8	41.4	65.0
Losses			
Average/Gross loss	16.0	41.6	63.6
Initial defective	0	25	50
Net Storage loss	16.0	16.6	13.6
Net storage loss as % of initially sound tubers	16.0	22.1	27.2