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Evaluation of and Recommendations for Research on Fast-Growing Tree Species for Wood Energy Production in the Dendro-Thermal, Charcoal Production and Gassification for Irrigation Projects.

Technical Report by Michael D. Benge, Bureau for Science and Technology, Office of Forestry and Natural Resources, A.I.D., Washington, D.C., an outcome of a consultancy from Nov. 27 thru Dec. 4, 1982, on Request of USAID/Manila.

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Evaluation of and Recommendations for Research on Fast-Growing Tree Species for Wood Energy Production in the Dendro-Thermal, Charcoal Production and Gassification for Irrigation Projects*

SECTION 1 -- Technical Appraisal of the Dendro-thermal, Charcoal Production and Gassification for Irrigation Projects

A. Introduction

Trees as a short-term rotational crop are a new approach to an old practice -- wood for energy. The Philippines has taken the lead through three projects: Dendro-thermal, Charcoal Production and Gassification for Irrigation. Under all three projects, large plantations of fast-growing trees are being established on underutilized lands that are generally low in soil fertility and dominated by cogan grass, *Imperata cylindrica*.

These projects have caught world-wide attention and the development agencies in many developing countries are waiting to see if the Philippine experience succeeds or fails. Success of these three projects will not only generate many new projects in the Philippines, but similar projects will be undertaken in other developing countries.

B. Objectives

Tree production for wood energy should have five objectives:

1. Successful establishment and immediate fast growth of trees on underproductive lands in order to convince decision makers and farmers that trees can be successfully grown as a short term rotational cash crop.

2. Production yields in established plantations that will meet the demands of the end users (e.g., Dendro-thermal plants, Charcoal Production and Gassification for Irrigation) in 3 to 4 years.

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3. A second rotational crop yield (coppice crop) within 6-8 years that will equal or surpass the first 3-4 year harvest yield.

4. Sustained yields over the life span of the end user (estimated 40 years for the Dendro-thermal plants).

5. An expanded program that gradually shifts tree plantations from a single purpose of wood for energy to larger plantations of multipurpose forest production. Such production units would not only supply wood for energy, but would also produce high value roundwood and food. Woodfuel energy (to supply the Dendro-thermal plants, the Charcoal Conversion Units and the Gassifiers) would become a by-product of the forest, from processing waste and understory removal for forest improvement.

C. Technical Assistance

The present technical assistance package has adequate funding and an adequate number of technical experts and scientists to carry out short-term research and the technical assistance as outlined in the scope of work. Realistically, it is doubtful if the present TA package can logistically support more than 7 or possibly 8 sites. It will be virtually impossible to provide adequate technical assistance and generate research data on 16 to 18 sites with the present TA package. With only 14 to 20 man-months of TA by each of the consultants, it will not be possible to provide continuity to the project or the discipline needed to conduct long-term agronomic research or to develop the management practices that will be necessary to protect the very large investment being made in the three projects.

D. Research

Research should not interfere with or slow down initial plantation establishment but should complement activities in a problem solving mode.

Both short-term and long-term applied research is needed to provide the hard data that would optimize wood production, sustain yields and determine the cost-effectiveness of inputs needed. Research should be based on local socio-economic conditions under on-farm conditions. This research is necessary to protect the substantial investment in the three projects by the GOP and USAID. Some research will pay off in 2-3 years while other research will require a longer period.

Three major factors that will affect maximum production and sustained yields, and environmental quality are:

1. Seed quality improvement and the development of adequate quantities of seed and other propagating material of appropriate fast-growing and nitrogen-fixing trees with the genetic capability to produce high yields on a short rotation (Reference Appendices A, B and Section 2-B.4).

2. Soil nutrient availability.

3. Plantation establishment and management practices.

E. Management

The initial design of the plantations should be simple and silviacultural procedures such that farmers do not have to decide over which trees should be cut and which should be left standing. It will take several years for farmers and cooperative managers to gain silvacultural expertise and the experience (such as scheduling activities) necessary for adequate management of the plantations for maximum production. Therefore, a simplified block harvest design is recommended for the initial plantations (e.g., trees are evenly spaced within rows and within blocks and every tree harvested in a row). This simplified management system should evolve to a multi-purpose system over the years (as mentioned above, A.5.).

It is imperative that applied research on appropriate management practices be carried out to maximize and provide sustained yields (reference Section 2).

F. Recommendations

It is recommended that:

1. Additional ESF funding be requested (and allocated) to pay for the in-depth and long-term research to create the hard data needed and to learn how to optimize and sustain wood yields.

2. The three projects jointly hire three technical people to design and jointly direct and implement the long-term research program. Their fields of expertise should be:

   a. Wood energy research and design (Appendix D);

   b. Agronomy and tree plantation crops (Appendix E);

c. Genetics and tree improvement (Appendix F).

3. The GOP agencies involved in the three projects obtain an agreement with the Ministry of Agriculture, Bureau of Soils, that the Bureau provide the necessary cooperation, personnel, and facilities to conduct soil tests and profiles on the 18 sites and that the processing of these will be expedited.

4. Leucaena not be considered a panacea, for it will not grow well on all sites and may grow better on one portion of a site than on another. If emperical data on site conditions indicate that other exotics (such as Albizia, Gliricidia and Pithecolobium) or local species (such as Agho--Casuarina) would have better growth, then these species should comprise the majority of the plantings on that site for initial plantation establishment. (Reference Section 2-B.3.).

5. An intensive effort be made to improve the quality of the present seed supply (Leucaena and others), and an intensive germ-plasm improvement and seed multiplication program be launched in the Philippines (Reference Section 2-B.4.). This program should include cooperation with other Asian countries and cooperation between the government and the private sector.. The Science and Technology Bureau, A.I.D./Washington could be requested to provide assistance in this effort (Appendix G).

SECTION 2 -- RESEARCH RECOMMENDATIONS

A. Introduction

Twenty-four man-months of technical assistance (provided under the present technical assistance package with Hodum, Inc.) is inadequate to conduct the in-depth research needed to generate reliable and accurate data. Without reliable and accurate data, the economic returns for inputs needed to optimize production yields and to ensure sustained yield cannot be determined. Furthermore, this information is needed for expansion of plantings to supply the amount of wood needed for the facilities (such as the Dendro-thermal plants) to operate at full capacity and continue operations. Also, this research data is needed in order to accurately calculate what portion of the Philippine energy needs can be met with wood.

Research should not be a prerequisite to plantation establishment if basic data (such as soil pH) is known about the site so that preliminary decisions can be made on which species to be planted (e.g., Leucaena will not grow well on more acidic sites). However, research should be a prerequisite to making future decisions on which tree species and varieties are best adapted and will give optimum yield on specific sites; what soil amelioration is required to maximize and sustain yield; what management practices are required and what the response curves are for the various inputs of capital, land and labor (cost of these inputs in order to determine the points of diminishing returns). This information is needed before expanded plantation size can be determined to meet the needs of the various wood energy projects.

Some research (such as soil ameloration, establishment techniques and weed control) can provide good data in a year or two. Other research (such as coppicing and sustained yield data) will take a much longer time before accurate data can be generated and assessed.

A well implemented and thorough research program can provide reliable and accurate data to economically increase and sustain yields of the tree plantations over the life of the projects (e.g., for the Dendro-thermal plants -- 40 years). For example, initial plantings of Leucaena (or other trees) on certain sites may show poor performance. However, research on soil amelioration may prove that by applying a few pesos worth of Molybdenum (a micro nutrient whose absence inhibits the performance of Rhizobium for nitrogen production), excellent yields of Leucaena can be obtained on that site, exceeding yield performance of other trees.

Research should be an applied mode, carried out on all plantation sites and conducted under actual field (farmer) conditions. Research plots should be on sub-sites representative of conditions found throughout the plantation sites. For example, most sites will have deeper soils at the bottom of hills on level ground, shallower soils on the steeper hillsides and still different soils on the tops of hills. Research should be conducted on plots on all of these different site conditions and not just on the deeper soils found on the flatter ground.

Only a portion of the research data generated on one site will be transferrable to another site (such as response to nutrients and weed control). Each site is unique, thus research is needed on all sites. Research will provide the data needed so that rational decisions can be made about future plantings and the future production capabilities of each site, and the economics of optimizing yields can be determined. It is imperative, therefore, that research scientists work closely with project economists so that data can be evaluated in cost/benefit terms.

It is recommended that research on all sites, by all three projects (Dendro-thermal, Charcoal Production, Gassification for Irrigation) be placed under one qualified research director who would provide necessary discipline and continuity to the program (see Appendix E for the biodata of one such qualified scientist).

B. Research design

It is recommended that the three projects jointly hire one qualified scientist who has in-depth experience in the design and implementation of research on maximizing the growth of trees for wood energy. One such person is Dave Dawson, who was in charge of the design and implementation of the U.S. Forest Services research program on Energy and Wood from Intensively Cultured Plantations (see Appendix D for biodata).

Also, it is recommended that a standardized research design and methodology be used in the program, one that is now being jointly proposed by USAID and IDRC as part of the Asia research networking program. Training on research methodology should be available through these agencies.

The research should include, but not be limited to, the following:

1. Base-line data gathering.

2. Soil amelioration (due to its importance in optimizing tree yields on nutrient-poor soils, it is treated as a separate section instead of being included under Plantation Establishment and Management).

3. Species and variety trials.

4. Tree improvement and seed orchard establishment and management.

5. Plantation establishment and management.

   a. Nursery and establishment procedures.

   b. Site preparation and weed control.

   c. Coppice management.

   d. Soil engineering and water management.

   e. Spacing trials.

   f. Agroforestry (intercropping).

   g. Ground covers.

   h. Fire control.

   i. Rat, ant and termite control.

1. <u>Base-line data</u>

It is imperative that base-line data be generated for all sites so research results can be adapted to site conditions. Such base-line data should include rainfall, altitude, temperature and soil tests.

Soil profiles and analyses should be made on all sites. The profiles should average no less than 1 profile per hectare with samples collected down to the C horizon (parent material, approximately 90 to 120 cm). The profiles should be taken at depths of surface to 20 cm; 20 cm to 50 cm; and 50 cm to 120 cm. The profiles should average 1 per hectare where there isn't any apparent change in the topography or surface soil type. Where changes are noted the number of profiles

per hectare should be adjusted to identify the changes. Soil analysis should include pH, for both macro and micro nutrients and moisture-holding capacity (ref. no. 2 below and Section 2-B.3.c.).*

2. Soil amelioration

Regardless of the genetic potential of the plant materials, optimum yields will not be obtained unless adequate levels of soil nutrients are available. Continued harvest of trees will mine nutrients from the soil. Most of the sites have nutrient poor soils, not capable of sustaining yields in perpetuity. If these sites are marginal for agricultural production, they are also marginal for sustained tree production. A great share of the abandoned cogan lands were once farmed by Kaingeros. They were abandoned because crop yields could not be sustained. Approximately 70 kg. of phosphorus (p), 330 kg. of potassium (k), and 57 kg. of sulfur (s) are removed from the soil when 12 cubic meters of dry biomass is harvested from one hectare of land (10). Other nutrients important for maximum tree growth are removed also. Most of these nutrients can be returned to the soil in the Dendro-thermal project if the ashes from the furnaces are pelletized (for ease of handling and shipment) and returned and applied to the tree plantations.

Soil analysis is very important if maximum wood production is to be obtained from Leucaena and other fast growing trees. Phosphorus is an essential nutrient for plant growth.

Most tropical soils are low in phosphorus. Phosphorus is important for root development and research has shown a direct relationship between phosphorus availability and nitrogen fixation. The application of small amounts of Boron (on boron-deficient soils) has proven to dramatically increase the growth rate of some trees. The micro nutrient molybdenum is necessary to activate Rhizobium and nitrogen production in nitrogen-fixing trees.

* Based on recommendations of Dr. Mark Hutton, expert Leucaena agronomist and soil scientist and has over 20 years experience with adapting Leucaena to adverse soild conditions. Formerly at Commonwealth Scientific and Industrial Research Organization of Australia, Dr. Hutton has recently completed five years research on the adaptation of Leucaena to acid soils at CIAT in Cali, Colombia. He will continue his work at IMBRAPA in Brazil.

Low levels of calcium in the surface soil material (20 cm to 1 m) can be a major limiting factor in root development and deep root penetration which will result in poor performance of Leucaena on acid sites. Adequate amounts of nutrients are important not only for the maximum growth of Leucaena, but are equally important for the growth of all trees.

Foliar analysis is an excellent and easy field method for determining nutrient deficiency in a tree or plant. By analyzing the nutrients in the leaves one can determine if the tree is taking up adequate amounts of specific nutrients. However, it is important to choose leaves that are relatively new and fully expanded and not older leaves. The plant will rob older leaves of nutrients and shift them to the newer leaves.

Foliar analysis is valuable only if information is available on which nutrients are essential for the maximum growth of a specific species of trees (such as Ca for Leucaena). However, it will not tell you if you have adequate amounts of these nutrients to sustain yield production. Also, some nutrients may be available in the sub-soil but not in the upper strata. If the roots do not reach the nutrients available at a lower level, the growth of the tree can be retarded. Such is often the case with Leucaena and Ca in acid soils (3). Also, foliar analysis may not give an accurate indication of micronutrients, such as Mg, Fe and Mo. Molybdenum (Mo) deficiency will show up as a nitrogen deficiency, indicated by yellow leaves.

Is soil amelioration economically feasible? Can one afford to fertilize trees under Philippine conditions? Perhaps the question should be asked, "Can one afford not to fertilize?" In the case of some necessary nutrients (such as Mo), soil amelioration is very inexpensive. Only by experimenting and by comparing fertilized plots of trees to unfertilized plots and by costing out inputs vs returns can this question be answered.

Many tree species require the same levels of nutrients. There are some exceptions such as in the case of Mo which acts as a catalyst to maximize nitrogen production of Rhizobia in nitrogen-fixing trees. The Rhizobia can produce adequate levels of nitrogen to satisfy the trees' requirements. Nitrogen is an essential nutrient. However, nitrogen-fixing trees do not need another source of nitrogen. Much of the research information concerning nutrient requirements can be transferred from one species to another. However, nutrient availability will differ from site to site and some tree species will give a greater response to a specific nutrient than others.

Soil taxonomy is being used as a tool by some researchers to determine soil similarities between sites to predict performance of tree species (Tab R). This can be a useful tool, however, soil nutrient levels will vary between sites (even with similar soils) thus growth rates of trees will still vary.

The importance of fertilization on impoverished tropical soils has been demonstrated by research in Colombia, where NPK contributed substantially to sustained improvement in the rate of growth and general vigor of Eucalyptus grandis. Plots receiving boron as well as NPK produced 7 times greater yields of straight poles than plots receiving no boron (18). Applications of 50 gm. of NPK (10-30-10) and 5 gm. of boron to Eucalyptus grandis and Pinus oocarpa seedlings at transplanting time significantly increased initial growth and helped the young trees get ahead of the weeds and grass. By this means, the number of post-planting cleanings necessary to establish a plantation was reduced. The difference of magnitude was such with E. grandis that the researcher concluded this species should not be planted without the combination of NPK and boron. The plantation of E. grandis on the research site without any fertilizer was a complete failure. Other results recorded in the experiment were that without boron there were three times as many forked trees as in the plots where 5 gm. boron was applied, and the incidence of terminal dieback was reduced with the boron application (19).

The greatest growth variability within a species will be effected by establishment practices, plantation management (such as coppicing), and seed quality.

3. Species, Provenance and Variatial Trials

Species trials are necessary to determine which types of tree will perform best on specific sites. Management practices (such as the ability of a tree to produce a high yield coppice crop) will be another determining factor in species choice. Species trials research must incorporate soil information so that trial results are valid. Therefore, baseline soil data and analysis is necessary before conducting species trials.

Ideally, one should conduct provenance (sub-species) trials of tree species. The Oxford Model is one of the most frequently used designs for provenance trials. However due to the genetic diversity of most tropical forests and widespread deforestation in many areas, it will be difficult to follow the Oxford model, which is based on the collection of seeds from 100 trees in one contiguous area. For many of the fast-growing tree species, it may be difficult or impossible to find 100 trees in one location, or be confident that the seed source will still exist

when the trials are completed (due to the rapid rate of deforestation).

However initial species and provenance trials can be launched by using seed collected from superior mother trees that have shown desirable characteristics. A standardized species trial design should be adopted, so that research results can be compared with results obtained from other sites and with results obtained by other researchers elsewhere in the Philippines and Asia. USAID and other organizations are now attempting to facilitate a research network in Southeast Asia. Standardized research design and methodologies must be a basis for this networking if the exchange of research data is to be of value.

A number of fast-growing trees (some are nitrogen-fixers), give a high cubic meter yield on a short rotation and are excellent sources of wood/charcoal energy. Leucaena leucocephala is well known; but it should not be considered as a panacea. It will not give sufficient yields on some sites (especially the more acidic ones) to meet the wood/energy requirements of the various projects. Other fast-growing species, such as Albizia, Gliricidia, Pithecolobium and Casuarina, may do as well or better than Leucaena on certain sites or on some portions of the same site. This can only be determined through species trials that incorporate soil conditions into the research design.

On some sites preliminary observations may indicate that one species outperforms another. However, research could prove that the species that yielded poorly on the unameliorated plots will outyield the other species with moderate soil amelioration at an affordable cost.

Whenever possible, nitrogen-fixing trees should be planted, for nitrogen is an essential plant and tree nutrient (Appendix H). Most tropical soils lack adequate amounts of nitrogen, which is essential for maximum production and sustained yield of short-term tree crops.

Leucaena

Research has proven that Leucaena is not the "Miracle Tree", as it has so often been touted, but like any other agricultural crop (such as corn), it requires specific agronomic inputs to maximize production and sustain yields (2)(3)(4). These inputs include:

a. Pure seed of known pedigree with the genetic capability for maximum wood production.

b. Well-drained soils with a pH above 6.

c. Adequate levels of macro and micronutrients available in both the upper and sub-soil strata, (such as P, Ca, Mo, Mg, K, S, Zn, Cu, and Fe).

d. Adequate nursery (or field) and establishment practices and plantation management (1)(3).

Each of the above can be considered a sub-system, the whole of which comprises the system within which Leucaena thrives. Maximum wood production and yield will not be obtained if a subsystem is not functioning properly.

On some sites, Leucaena may grow well at the lower portion of the hills, on deeper soils with less slope or on secondary forest areas with a higher organic matter content. Leucaena may not grow well on steeper slopes, which have poorer and shallower soils, while other species will (9).

Leucaena should be planted only on those sites where it grows well for maximum wood production. However on some sites, it may not be economically feasible or cost-effective to plant Leucaena. On these sites other species may produce higher yields.

It is possible to grow Leucaena on more acid soils, with a pH of 5.5 to 6 (even as low as pH5). However these soils often lack the necessary levels of nutrients and will require soil amelioration with fertilizers such as superphosphate and dolomite (1)(3). These inputs may be impractical or prohibitive in some areas of the Philippines.

This does not mean that Leucaena should not be tried on the sites that need soil amelioration. Some Leucaena varieties may perform surprisingly well. But in order to obtain yields projected to meet requirements and demands of the Dendro-thermal, Charcoal Production and Gassifiers for Irrigation Project, sufficient quantities of other tree species that show promise on these sites should be planted first.

4. Tree Improvement and Seed Orchard Establishment

Adequate quantities of quality seed of a known pedigree are necessary and must be the basis for any sound tree/crop improvement program. Additionally, base-line data for each site must be gathered (soil profiles, pH and nutrient analysis) and incorporated in species trials design or valid and useful research data will not result.

It is recommended that the three projects jointly employ a plant geneticist (plant or tree) who would be in charge of a tree improvement program, and would work under the overall research director (ref. Section 2 Research Recommendations, A. Introduction).

Genetic improvement can give gains of 10 to 30 percent in yield in the first few generations, and generations can be as short as 2 to 3 years for some tropical trees (20). A tree seed improvement program can produce immediate results within the first year by simply using quality seeds or other plant material from select trees that have shown desirable characteristics, such as fast growth and straight trunks. This is not only seed (and plant material) from Leucaena, but from all tree species. This means that project implementation and planting schedules will not have to be delayed.

It is imperative that sufficient quantities of quality seeds of all fast growing species, that are appropriate for planting in the Philippines and have the genetic capability of fast growth and high yield, be developed. Sufficient quantities of this seed must be readily available on the local level for the yield demands of the Dendro-thermal, Charcoal Production and Gassification for Irrigation project to be met.

An intensive effort should be launched to enlarge and improve the germ-plasm base of fast growing and nitrogen-fixing trees for future plantings in the Philippines. This collection should not only be made in the Philippines but it should be on regional and on an international basis as well. This effort should include the collection, testing, evaluation, selection, improvement and reproduction of the most promising germ-plasm.

Fuelwood research has been identified as one of four major research priorities of A.I.D at a recent A.I.D. conference to identify fuelwood research needs. The improvement of the germ-plasm base for fuelwood species was a high priority.

A great number of the fast growing and nitrogen-producing trees out-cross, therefore they express genetic inheritance from both parents. Thus all trees grown from seeds from one outstanding mother tree may not express similar characteristics. Some tree species such as Leucaena leucocephala are largely self-pollenating (Leucaena is estimated at 95%) and are easy to breed and while others are more difficult and take a longer time to set seed. Seeds from trees that are out-crossers will have only 50% of the genetic charactistics of the mother tree, therefore several years may be required to produce seeds with genetic uniformity.

5. Plantation Establishment and Management

a. Nursery and Establishment Practices

(1) Direct seeding, bare-rooting, containerization, and vegetative propagation are four methods used for tree establishment.

(a) Direct seeding may be an effective means of plantation establishment for some tree species, such as Leucaena. It is cost-effective and the roots are not damaged when transplanted (which can affect tree growth at a later stage). Ground preparation becomes most important in direct seeding.

One method that has proved effective in some places in the Philippines is to plow a double furrow with a buffalo-drawn plow and direct seed into the furrow, as one does with corn. It is most important to break up the top soil to enhance root establishment and reduce weed/grass competition.

Post hole or auger hole planting combines advantages of nursery propagation and direct seeding. A post hole digger or an auger is used to make a hole in the ground 5 or 6 inches deep. The soil is mixed with organic matter and appropriate nutrients are added. In the case of nitrogen-fixing trees, molybdenum is added to the mixture, phosphorus is added to those soils deficient in the nutrient (almost all soils), calcium is added for trees like Leucaena for establishment on acidic soils, and nitrogen is added for non-nitrogen-fixing trees. The soil is placed back in the hole and a scarified seed inoculated with the appropriate strain of Rhizobium (if necessary) is placed in the hole at the onset of the rainy season. A modified corn planter can make direct seeding easy. A corn planter can easily be fabricated in the Philippines (reference Appendix I).

This method is very advantageous, for root development is enhanced by the added phosphorus (and calcium in the case of Leucaena on acidic soils). Research has shown that tree establishment and growth can be enhanced by the

hole size and other site preparation (15)(17). This method will also enhance initial growth of seedlings, giving them a faster start, thus an edge over competing weeds.

(b) The bare-root method of planting trees has been used for some species of trees. Seedlings are very light and large numbers can be carried by one person to the planting site. However, the roots dry out easily, the root hairs and some roots may die, and the seedling will suffer from transplant shock, making it a slow starter and a poor competitor with weeds and grass.

(c) Root trainers have many advantages over plastic bags and bare-rooting, such as reduced weight (compared with plastic bags), little or no root damage, a higher rate of survival, and seedlings start faster and compete better (a more detailed comparison is given in Appendix J).

(d) Vegetative propagation (detailed in Appendix C).

(2) The presence of the appropriate strains of Rhizobium and Mycorrhizae will enhance tree growth and reduce nutrient and fertilizer requirements to sustain high volume wood yield.

(a) Rhizobium have the ability to fix nitrogen and are usually associated with legumes as well as with <u>some</u> non-legumenous trees (such as Casaurina). It is important that nitrogen-fixing trees are inoculated with the appropriate strains of Rhizobium which will make it unnecessary to fertilize with nitrogen. Most tropical soils are deficient in nitrogen, and trees will not grow well without it. Inoculation with Rhizobium can be done either in the nursery or in the field and it is a cheap insurance to inoculate in order to protect the investment in tree planting.

(b) <u>Mycorrhizae</u>

The research program should include research on <u>Mycorrhizae</u>. Mycorrhizal fungi facilitate the uptake of phosphorus and have the ability to transform unavailable forms of phosphorus

into forms available for plant uptake. Most tropical soils are phosphorus-poor, and adequate levels of phosphorus are necessary for maximum tree growth. Mycorrhizal fungi facilitate the uptake of other nutrients as well (Appendix K).

In the absence of Mycorrhizae, tree growth is limited. It has been hypothesized that appropriate strains of Mycorrhizae usually associated with trees are absent from cogan lands (Imperata cylindrica) that have been without trees for a prolonged period of time. The presence of appropriate strains of Mycorrhizae will help sustain yields without fertilizer. Also, Mycorrhizae will facilitate the more efficient use of fertilizer applied to trees, thus reducing fertilizer costs.

b. Site Preparation and Weed Control

Site preparation and weed control are important elements in plantation establishment, seedling survival and growth rate of trees. On lands dominated by Imperatar cylindrica, it is important to burn off the grass and break up the grassroot mass to allow good root establishment of the seedlings, to reduce competition for space, water, nutrients and light and to increase water infiltration and soil aeration (11)(12)(13). Research has proven that the elimination of the sod of grasses and the loosening of the soil favors the establishment and growth of trees.

Inadequate weeding causes trees planted on grasslands (15) to quickly show signs of ill health and poor growth (14). Where the herbicide (Roundup) was used to control grass in a three year old tree plantation, there was a significant growth improvement the following year (16). Trees planted on grasslands previously dominated by tenacious grasses but eliminated by intensive site preparation had 574% more volume after three years than trees planted in the same area with minimum site preparation (17). This research shows that site preparation is important and cost effective.

c. Coppice Management

The yield of some trees, such as Eucalyptus, decreases after the second or third coppice generation (18). When Eucalyptus is cut during the dry season, coppice regeneration results in up to 25% stump mortality (14).

It has been reported that some species of Agoho (Casuarina) coppice poorly and the coppicing ability of many other excellent fuelwood species, such as Acacia mangium, is unknown. Therefore, long-term research data is necessary to provide reliable data to choose species which will produce yields to meet projected wood demands for the various projects.

Initial observations in the Philippines indicate that Agoho (Casuarina) grows better on some sites than Leucaena and could provide adequate yeilds from the first harvest to meet projected needs at some Dendrothermal Plant sites. However, if Casuarina does not produce a good coppice yield, future harvests will not be sufficient.

Pat Dugan, Forestry Advisor, has observed that Casuarina regenerates better after cutting if a longer stump is left. This management practice is termed pollarding (lopping of branches in contrast to cutting the trunk closer to the ground, leaving a much shorter stump), which may provide an adequate volume of coppice yield but may be an uneconomical method of harvesting on steep slopes because of the size of the log. One the other hand with soil amelioration, other trees such as Leucaena may give equal or higher yields than Casaurina and produce a log that is more economical to harvest and haul. However, research to prove or disprove this will require a 6 to 8 year continuing and well disciplined research program. This is not indicated in the present TA package.

d. Soil Engineering and Water Management

Although most targeted plantation sites receive adequate rainfall, the rainfall pattern is uneven; the soil is compacted and water infiltration into the soil is poor. Therefore, maximum yields will not be sustained as sheet erosion will occur, resulting in soil and nutrient loss. Tree yields on many sites can be increased by increasing water infiltration through simple soil engineering techniques such as contoured hillside ditching (see Appendix L). Erosion problems will be reduced and the contoured ditches can be formed into catchments, which could provide water for fish ponds or food crops.

e. Spacing Trials

Optimum spacing of trees for maximum fuelwood yield has already been determined for some species. Spacing

trials for species such as Leucaena are well on their way at the University of Hawaii. However, these trials are being conducted on deep soils on relatively level ground and the results may not be appropriate for steep hillsides with shallow soils, as will be found on some plantation sites in the Philippines. Additionally, the spacing may vary for the production of stems (logs) that will be economical to remove from the plantations by the proposed cable systems and trucked to the conversion plants.

Optimum spacing for Leucaena for wood production will probably not be the same as for Casaurina, Albizia, Gliricidia, Pithecolobium, etc. Spacing trials data for some of these species may be available through organizations such as the UN/FAO or the International Development Research Center (IDRC, Canada). However, spacing will have to be adjusted for Philippine site conditions and for end user. Spacing may be different if different stem size is required for each of the end user, dendro-thermal power plants, charcoal conversion units and the gassification units. It also will be influenced by the harvesting systems designed for the various sites.

f. Agroforestry (intercropping)

Farmers who are growing the trees for the various projects will also be growing food crops for subsistence. These food crops could be grown between the trees in the plantations (sometimes referred as the taungya system) which may benefit the trees because the farmers would keep the weeds and grasses out of the plantations.

However, food crops would compete with trees for essential plant nutrients, such as phosphorus. This could be avoided by providing the farmers with subsidized fertilizer for application to their food crops. The trees would also benefit from this fertilizer, increasing the growth of trees on nutrient-poor soils. The food crops would serve as a cover crop and reduce erosion. Research would have to be conducted to see if the benefits in increased tree growth are cost-effective and culturally feasible. Food crops could only be grown for one year at which time the trees would shade out food crops.

g. Ground Covers

It is recommended that a research effort be launched to develop and determine appropriate shade-tolerant ground

covers for interplanting under various kinds of trees used in the wood energy plantations.

Trees, unless planted in engineeringly sound systems with adequate ground cover, do too little to prevent soil erosion. A good canopy will reduce raindrop impact and organic litter will help reduce sheet erosion. However, the fine leaves of Leucaena and many other trees are poor interceptors of raindrops. Some trees like Leucaena will fold their leaves periodically (always at night and generally during storms), further reducing the leaf area for interception of raindrops. Also, the fine leaf litter decomposes rapidly, resulting in inadequate mulch to reduce sheet erosion.

Some legumes, such as Desmodium ovalifolium and Aeschynomene indica (local) and some grasses, such as Stenotaphrum secundatum (St. Augustine grass) are shade-tolerant and may work well as ground covers in wood energy plantations.

h. Fire Control

Fires can cause extensive damage to newly established tree plantations. Firebreaks cleared by hand or machinery are expensive to maintain; therefore other alternatives should be tried. Prior to plantation establishment, the grass on the plantation site and surrounding area should be burnt off.

Leucaena (both common and giant types) and Calliandra densely planted in rows spaced 1 to 1 1/2 meters apart will serve as effective live firebreaks. (Four rows may be required.) The rows should be prepared by plowing (buffalo or cow) and the seed dibbled into the edge of the furrow. The paired rows will form a canopy and shade out the grass providing a living firebreak (see Appendix M).

i. Rat, Ant and Termite Control

Rat, ant and termite damage to seeds and newly planted seedlings (especially Leucaena) has been reported in newly reforested areas. The most heavy damage seems to be plantings in Imperata (cogan) lands. This damage can be prevented or greatly reduced by certain preventive measures.

Rat populations are directly proportional to available cover (in which they hide and reproduce) and food

supply. Cogan grass is excellent ground cover for rats and should be burnt prior to plantation establishment to reduce rat populations. Rats relish tree seeds and newly sprouted seedlings, which are often the only green plants in the area. Rat populations can be controlled by placing out bait traps as one does for rice, corn or other field crops (ref. Appendix M).

The chemicals thiram and aldrin applied to tree seeds have been found to be effective against rodents, and endrin has been used to repel both insects and rodents (7)(8). The fungicide thiram is applied as a seed coating to repel birds (8).

Endrin has been used to protect seeds against ants and dieldrin and aldrin have been effective against ants and termites. Dusts containing 5% chlordane, 2 1/2% aldrin, 2 1/2% heptachlor or 1 1/2% diedrin has been effective against termites when applied around the base of trees. Chlordane is effective against termites in mounds. However, chlordane has a residual effect and the Environmental Protection Agency has banned its use in the United States without a special waiver.

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Leucaena Seed Improvement

Dr. James Brewbaker has warned of seed contamination and adulteration, which may adversely affect the production of Leucaena for wood (5). Although Leucaena is essentially self-pollenating, (there is an estimated 5% chance of outcrossing), there is a very high probability that the varieties of Leucaena seed being used for wood production in the Philippines are not genetically pure, given the considerations that: the different varieties of Leucaena recommended for wood production (K8, K28, K29, K67, K132 and K636) were collected from wild stands; the varieties planted in the germ-plasm bank in Hawaii are not maintained in isolation; Leucaena seed reproduction in the Philippines generally has not been done in isolated varietal pure stands; seed adulteration on occasion has been known to occur; and the usual procedure of seed collection has been to collect seeds from trees to which the collectors have easy access (short and weedy trees rather than the tallest).

One evidence suggesting genetic impurity is the uneven growth of trees, which is being observed in most Leucaena plantings in the Philippines and elsewhere. Growth variation can also occur even with genetically pure seeds with differences in site conditions (such as nutrient availability and soil depth), other environmental factors (such as competition) and establishment and management procedures.

1. Immediate Seed Resources

   a. Trees in existing Leucaena plantings that have shown desired characteristics (such as fast growth and large, straight trunks) should be identified and marked. Desired characteristics should be identifiable at 2 years of age.

   b. Outstanding trees should be cut off (preferably sawn) at 1 meter in height at the beginning of the rainy season and allowed to coppice. A large number of new branches will develop from the cut stump, forming a bushy growth. It has been reported that coppiced stumps will bear more seeds than a full tree and the seeds are more readily accessable. Coppicing does not alter the genetic make-up of the selected tree.

c. Whenever feasible, other undesirable Leucaena trees in the immediate vicinity should be marked and cut and prevented from flowering and setting of seed. This can be done by frequent cutting of the coppice, which can be used for livestock forage or as a green manure mulch. The cutting of these trees will prevent cross pollenation of desired seed trees with undesirable ones (seed adulteration).

d. During seed production, Leucaena is vulnerable to insect damage at both the flowering stage and when seed pods are developed. Larva of a small moth can destroy the florets of Leucaena, reducing seed set, and seed weevils will destroy the mature seed in the pods. Therefore to maximize seed production, it is recommended that the seed trees be sprayed with a systemic pesticide, such as Cygon -- O, O-dimethly S - (N Methyl Carbanoylmethyl) Phosophorodithioate.

e. Seeds should be collected when pods are fully mature (the entire pod should be light brown in color), but the pods should not be left too long on the trees. The pods can easily be harvested with a tree pruner (Appendix O). The pods can be threshed by placing them in a rice bag, and the seeds threshed from the pods by stamping on the bag or beating on the bag with a stick. Immature seeds and other trash can be removed by winnowing the seed as one would rice.

f. Seeds should be thoroughly sun dried before storage, and treated with a pesticide such as Sevin and a fungicide such as Captan. The seeds can be stored in plastic carboys (Jerry cans), which should be sealed and stored under dry (30% relative humidity) and cool (10°C) conditions (1). A "rule of thumb" for seed storage is: relative humidity plus temperature in degrees Fahrenheit should be less than 100 (for example 50% humidity +40°F=90 or 40% humidity + 50°F is o.k.).

g. Seeds should be scarified before planting to ensure even germination. The simple hot water treatment is recommended.

2. Future Seed Resources

Even though some seed sources allegedly can trace the origin of the Leucaena seed, due to seed contamination and adulteration it is recommended that seed orchards be established from seed of known pedigree. Therefore, new seed of the K8, K28, K29, K67, K132 and K636 varieties should be obtained from Dr. Brewbaker at the University of Hawaii and segregated seed orchards of the different varieties should be established and maintained.

Original planting spacings should be 1 m x 1 m or 1 m x 2 m thinned to 2 m x 3 m or 3 m x 3 m after 1 1/2 to 2 years. The plantation and surrounding area should be kept free of all other Leucaena (1).

The same procedures for seed orchard maintenance as mentioned in a. thru g. above should be followed for the establishment and maintenance of seed orchards of most trees.

Seed Improvement

Larger tree seed will initially produce stronger, more viable seedlings, which have a better chance to compete and survive because the endosperm of larger seeds contains more food for the growth of the embryo. This is termed the maternal effect and lasts a month or more after seed germination (6).

It is recommended that all Leucaena seed, and whenever possible all other tree seed, be cleaned and sized by separating them through hardware screens or dockage sives (round holes) and by the use of a Zig Zag Air Separator or a vibrating table separator. The specifications for the Zig Zag Air Separators and an example of a vibrating table can be found in Appendix P. A vibrating table can be purchased through any seed machinery - supply company.

I recommend the Zig Zag Air Separator, for it can be constructed from materials found in the Philippines, and it is easily made and maintained and less expensive. Additionally, the Zig Zag Separator will separate seed covered with fungus and insect or otherwise damaged seeds that may not separate out on a vibrating table.

The screening will generally separate out the common varieties of Leucaena from the giant varieties, for the common seed is usually smaller. By both screening and separating, the immature and malformed, the broken and insect or otherwise damaged seed will be removed. Approxmiately 20% of the seed (by weight) will become discards. Recommended hole sizes for the hardware screens are 10/64, 12/64 and 14/64 (inches diameter). This will give you four seed size seperations.

If seeds are propagated in containers, this seed sorting process will virtually eliminate empty containers, thereby reducing nursery costs. If the seeds are directly sown, the average seedling will be stronger and more capable of competing with weeds and grass and have a higher rate of survival. The growth rate of all seedlings will be more even.

Appendix C

Vegetative Propagation (To include tissue culture)

Vegetative propagation is an excellent method of cloning trees that show superior and desired characteristics for the rapid establishment of seed orchards of self-pollenating "super trees."

Tissue culture is a biotechnology that is proving to be a valuable tool in tree improvement. Super trees (conifers) are being developed by private corporations, using tissue culture to clone superior trees that show fast growth, superior form, and wider tolerances. These cloned trees are used for the establishment of seed orchards. Much of this work is closely guarded corporate secrets.

I have received reports of single "super trees" evolving from the same lot of Leucaena seed on the same site (Haiti and Mauritius). All of the trees showed good growth, uniform and of phenotypic character; however, in both cases one tree was outstanding; it was taller than the others, grew more vigorously and developed more and larger leaves. I observed the same thing in the Philippines -- one tree that seemed to have substantially greater vigor, which had been planted at BFD in Quezon City (and since cut down). Are these specific hybrids, chance crosses, mutants, tetraploids or simply the result of ordinary genetic recombination? We don't know. They may be sterile or not breed true even if self pollinated. But these trees could be inexpensively cloned by cuttings or tissue culture and multiplied to create seed orchards or plantations of "really super trees." Think of the potential!

Tissue culture is an appropriate tool to short-cut the lengthy time it takes to reproduce seed from superior trees. In the case of Leucaena, a second generation crop of seed can usually be produced in one and a half years. Therefore, tissue culture may not be an appropriate technology to use, unless it is for the cloning of mutants or sterile hybrids. However, for many other fast growing trees it may take 6-8 years to produce a second generation of seed, and all of that seed will not perform the same as the mother tree. Some species of trees are poor seed producers (either producing small amounts of seed or the percentage of viable seeds is low). Therefore, tissue culture could be used to clone thousands of the superior trees for the first generation seed orchard. The second generation could be cloned by rooted cuttings in "clonal hedges."

Many of the tree species may be vegetatively reproduced (by cuttings, etc.), which would seem to be a more practical course to take than tissue culture. However, it may be possible to get only about 100-200 viable cuttings from one superior tree. The project would have to wait another year and a half before making a second generation reproduction from these trees, which would give about 40,000 cuttings (enough to plant 4 hectares, at a 1 m x 1 m spacing). By using tissue culture methods millions of clones can be produced from one superior tree. (One has to be careful not to plant large monoculture plantations from identical genetic material for such plantations could be highly susceptible to disease or insect infestation). If you chose to, a smaller number could be cultured for a plant material orchard and the next generation could be produced by rooted cuttings (This may be an economical method in countries where the private sector has developed tissue culture facilities).

Tissue culture does not need to be expensive. Leucaena is difficult to propagate with the older rooted cutting method, although a relatively successful method has been developed in Taiwan (Ref. Appendix O). Rooting of cuttings has been more successful when the cuttings are immediately submerged in water after severance from the mother tree to maintain the water columns so that transpiration can continue. Juvenile tissue is required for successful vegetative propagation of many tree species, such as Eucalyptus.

Regardless of the genetic potential of the seed/planting material, maximum yield will not be obtained unless adequate amounts of soil nutrients and other required environmental conditions are present.

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BS - Forest Management - 1948

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Command and General Staff School. 1947 (32 Graduate Credits in Public Administration).

University of Wyoming, 1963 -- (Extension-Statistical Methods)

University of Michigan, 1969 -- Written Communication for Engineers, Scientists and Technical Writers.

Colorado State University, 1971 -- Statistical Methods in Natural Resource Management, Regression Methods in Natural Resource Research, EXAD-USDA, 1976.

Creativity and Problem Solving, 1976 -- Kuby Associates.

Management by Objectives for Top Level Management - University of Wisconsin - 1977.

Congressional Operations Seminar -- Gov't. Affairs Training Institute - 1979.

EMPLOYMENT

1946-1948 - Michigan State University (Dormitory Counselor - part-time while a student).

1948-1954 - 1954-1957 Soil Conservation Service (Work Unit Leader in LaPeer, Caro, Rockford, Mt. Pleasant, Mich.).

1957-1961 - (Regional Plant Materials Specialist SCS-ARS), East Lansing, Michigan and St. Paul, Minn.

June 1962-
March 1963- March 1963-Sept. 1965; Sept. 1965-July 1967, Forest Service, Research Forester (Plant Geneticist) Shelterbelt Laboratory, Lake States and Rocky Mountain Forest Experiment Station, Bottineau, N.D.

May 1967-
Aug. 1970 - Plant Geneticist, Genetics of Northern Forest Trees, Rhinelander, Wisconsin.

Aug. 1970-
July 1977 - Project Leader of Maximum Yield and Intensive Culture of Planted Stands Work Unit (FS-NC-1152) and Program Coordinator of Multiproject Program II, Maximum Yield from Woody Species -- including methods technology, tree improvement, harvesting techniques and economics. (Director's Representative, Institute of Forest Genetics, January 1977.)

Aug. 1977-
Feb. 1982 - Program Manager, Ass't. Director, U.S. Forest Service, North Central Forest Experiment Station, Maximum Yield of Wood and Energy from Intensively Cultured Plantations. (Also Chief, Forestry Sciences Laboratory, Rhinelander, WI.) See attached publication.

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MILITARY EXPERIENCE

1941-1942 - Enlisted status, U.S. Army

1942-1946 - Commissioned Officer - 2nd Lieutenant to Major, 751st Tank Battalion and 1st Ranger Force. Most of period served as Captain; Company Commander, Specialized Infantry (Rangers). Served in England, Africa, Italy. Awarded Purple Heart, Bronze Star, Distinguished Service Cross. Left Military Service January 1946, rank of Major.

RESEARCH INTERESTS AND AREAS OF EXPERTISE

Research Administration

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Program Manager, (Assistant Director) U.S. Forest Service, North Central Forest Experiment Station, Institute of Genetics.

Intensive Culture of Woody Plants -- Maximum Yield Program Manager and personal research, North Central Forest Experiment Station.

Growing Wood for Energy -- U.S. Forest Service - Cooperator with U.S. Dept. of Energy; International Energy Agency; Man and Biosphere Program, U.S. State Department.

Tree Breeding and Selection -- Particularly *Populus*, Institute of Genetics, (now Forestry Sciences Laboratory) Rhinelander, Wisconsin. Also, provenance testing *Pinus*, *Picea*, *Fraxinus*, *Ulmus*, *Larix* for Northern Great Plains adaptation.

Environmental Forestry -- U.S. Forest Service, Northern Plains Laboratory, (Shelterbelts), Bottineau, N.D. Selection, introduction and breeding trees for shelterbelts and amenity plantings.

Afforestation, subhumid areas -- U.S. Forest Service, Northern Plains Laboratory, Bottineau, N.D.

Plant Introduction -- Plant Materials Specialist, U.S. Soil Conservation Service. Also, member USDA Committee on Plant Introduction.

Land Use Planning, Erosion Control -- U.S. Soil Conservation Service.

ASSIGNMENTS

1962-1973, Forest Service Representative on the NC-7 Regional New Plants for Agricultural and Industrial Usage-Technical Committee.

1971, Forest Service Representative on National Coordinating Committee on New Plants for Agricultural and Industrial Use. (ARS, ASES, CSES, Forest Service and Land Grant Colleges.)

November 30 - December 1, 1976, at request of MITRE Corporation and ERDA, served on a review panel to evaluate the results (3 months before publication) of the $500,000 ERDA Contract Research Study to MITRE on energy plantations.

April 14 and April 15, 1977; February 1978; March 1979: Participation on intenstive-culture forestry for energy production to International Energy Agency Working Party on Biomass.

1975-1981, Continuing consultant with Dept. of Energy on Biomass for Energy, proposal and contractor performance reviews, etc.

Sept. 1976 -- U.S. Delegate Expert Panel on possibilities of wood for energy source. Man and Biosphere Program, U.S. State Department.

October 1978 -- Information exchange trip sponsored by U.S. Department of Energy and U.S. Forest Service to Holland, Belgium, Italy to exchange information on Populus culture.

May 1979 -- Cooperation with National Academy of Sciences on "Revegetation of Denuded Lands."

PROFESSIONAL SOCIETY MEMBERSHIP

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USDA FOREST SERVICE
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ENERGY&WOOD from intensively cultured plantations: research and development program

North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture

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ENERGY&WOOD

from intensively cultured plantations: research and development program

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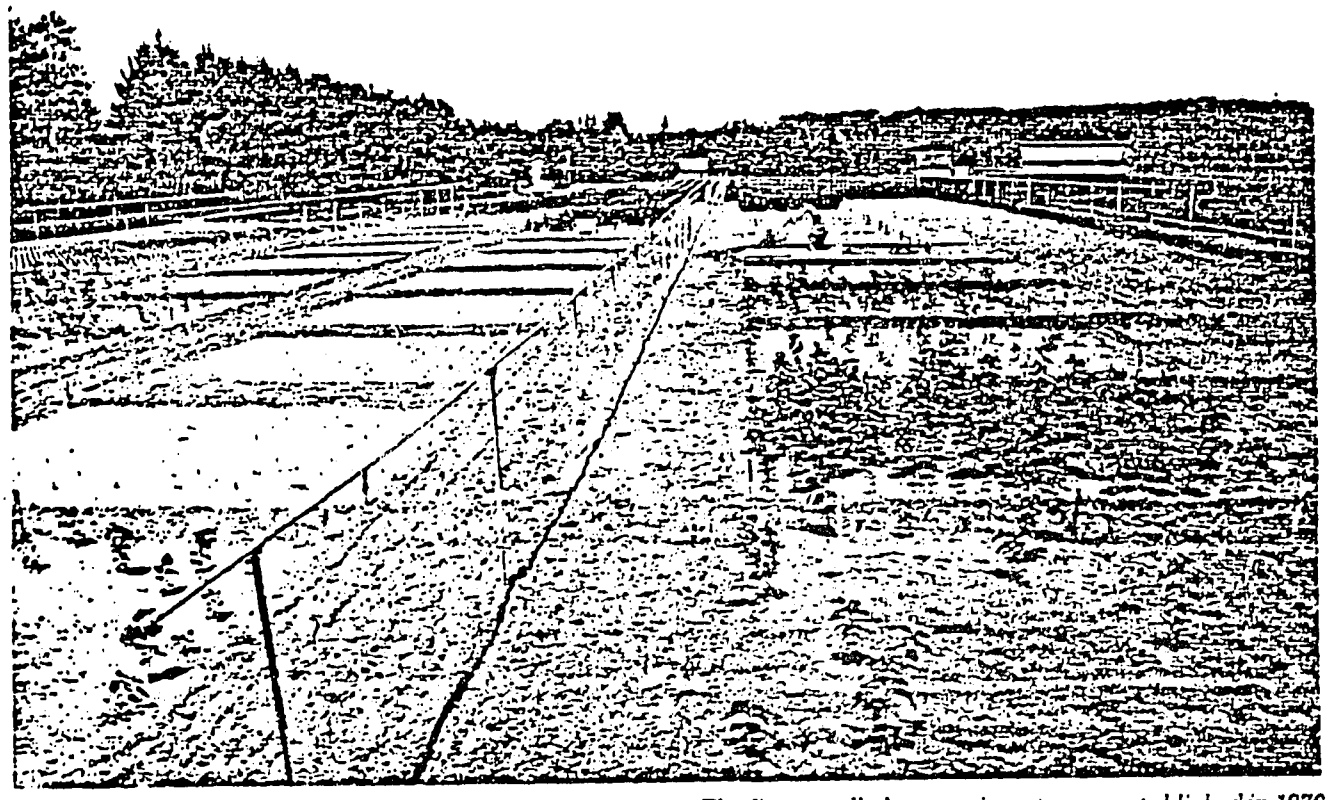

The first small plot experiments were established in 1970 to test the growth of various Populus *clones and the effect of spacing on yield.*

BACKGROUND

The Maximum Yield Work Unit was established in 1971, by the North Central Forest Experiment Station in response to concerns expressed by both industrial foresters and researchers. Industrial foresters realized that new systems for growing more fiber on less land must be explored because of escalating fiber demand, increasing demand for recreation and nonforest uses of forest land, rising land prices and tax rates, and increasing harvest and transportation costs.

Forestry researchers realized that much basic genetic, physiological, and cultural knowledge could be applied if environmental conditions for growing trees could be more closely controlled as in agriculture. Research was begun to select promising species, establish intensively cultured plots, explore new harvesting methods, evaluate pulping qualities of the fiber, and assess the economic viability of this system. This program used a systems approach, with researchers from many different disciplines working together.

In 1976, the program was expanded to incorporate both developmental and basic research, active cooperation with industries, and the collaboration of scientists from different disciplines in a systems approach. The research team now includes silviculturists, physiologists, an ecologist, geneticists, a soil scientist, hydrologist, a wood technologist, a pathologist, an entomologist, an engineer, and an economist.

Supplemental funding from the Department of Energy since 1977 has enabled researchers to accelerate progress in several problem areas, with emphasis placed on the development of methods to plant trees and ensure their early survival. Establishment is the most critical problem in the short-rotation-intensive-culture (SRIC) system because larger research studies or large-scale industrial plantations cannot be established until the technology to successfully plant hardwood stands has been developed. Although practices for planting softwoods were developed long ago, no system for consistently establishing plantations of hardwood forest trees in the upper Midwest has been developed (except for the shelterbelt plantings of the northern Plains). The problems in large-scale planting operations are often different from those normally encountered in small plot experiments, and the additional funds have enabled researchers to provide

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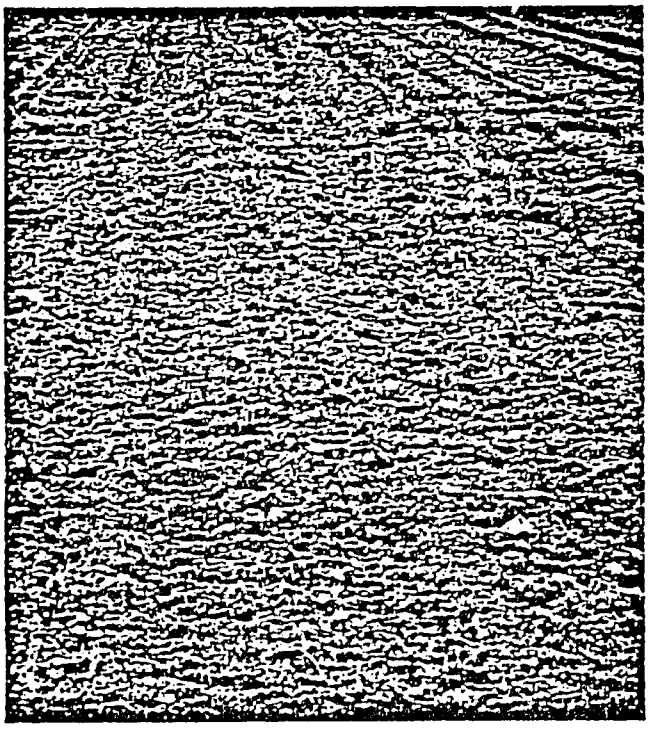
information to help industry establish larger pilot-sized plantations.

More than 10 acres a year of intensively cultured plantations are being established at the Harshaw Experimental Farm near Rhinelander, Wisconsin. Emphasis is on developing cultural practices and mechanized equipment suitable for operational plantation management.

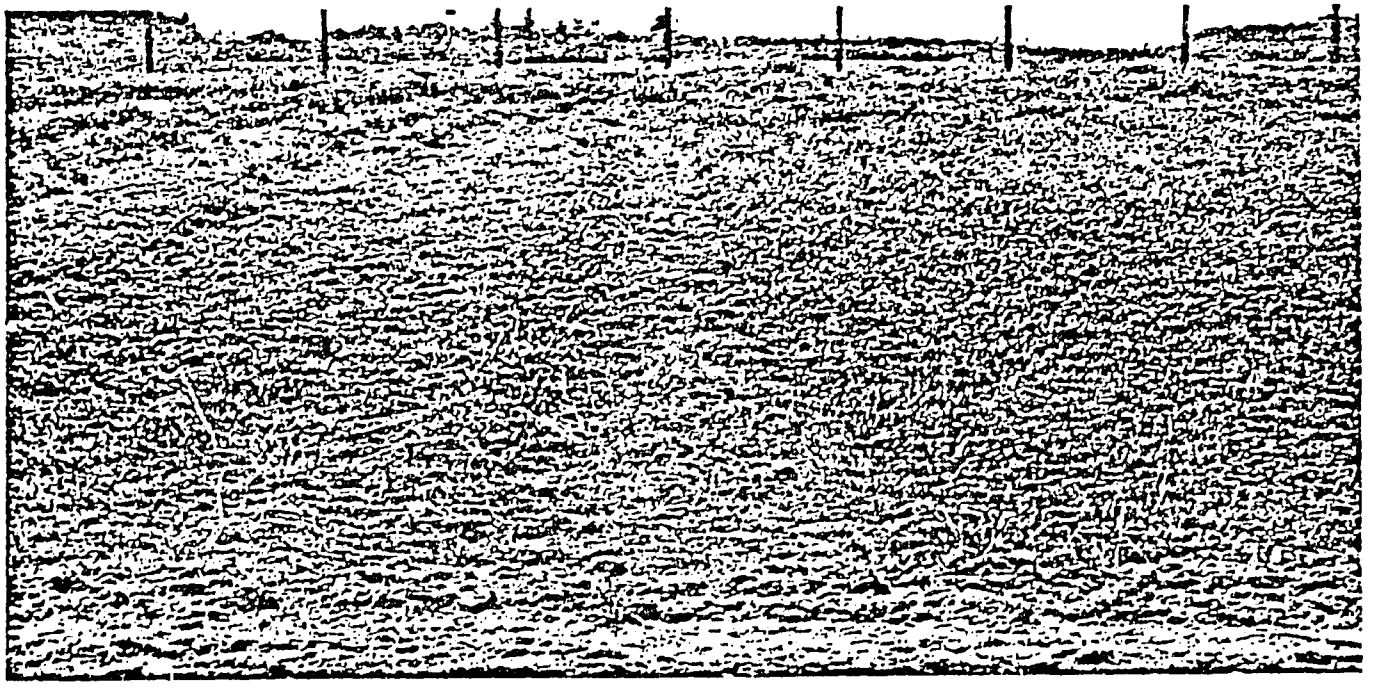


The USDA Forest Service's Maximum Yield of Wood and Energy from Intensively Cultured Plantations Research and Development Program includes two Research Work Units as well as scientists from other Research Work Units within the North Central Forest Experiment Station. Research problems, objectives, and results will be presented separately in this report for each problem area, although this does not accurately represent the overlap and interaction between problem areas due to the complex set of factors that determine biomass yield.

Briefly, the SRIC concept is that plantation biomass yields can be greatly increased by using genetically superior planting material and optimizing field environmental conditions. Generally, hardwoods have been tested more thoroughly for intensive culture systems because of their rapid juvenile growth and their ability to sprout from the stump after they are harvested, thus eliminating the need to replant the trees.

The establishment of intensive culture plantations with most species in any region of the United States will likely include essentially the same kinds of operations, although the precise nature of these operations will vary greatly by species and site. Many of these concepts are more typically termed "agricultural" rather than "silvicultural" in nature.

One of the most critical problems in establishing the short-rotation-intensive-culture system is weed control. Weeds are a serious competitor during the first 2 years, and research in weed control methods has recently been expanded.



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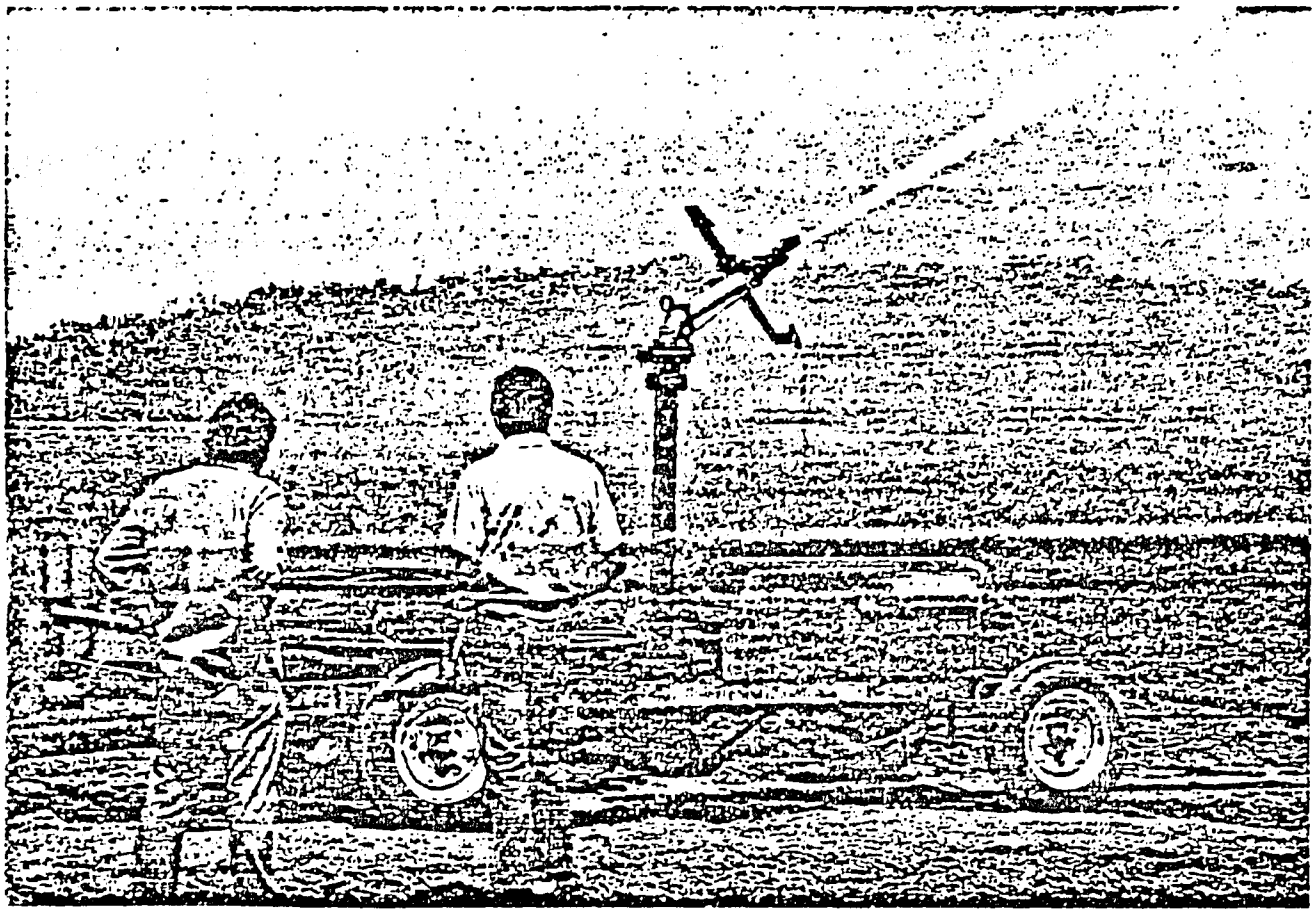
First, the land must be cleared and plowed to eliminate other plants and to make the site suitable for planting and cultural equipment (i.e., abandoned farm land is well suited). Seedlings or cuttings are planted with mechanical planting equipment at varied distances from a few centimeters to several meters within the rows that are from 1 to several meters apart. The first growing season is critical to the survival of the small trees, and plantations must be kept free of weeds either by cultivating, planting a cover crop between the rows, applying an herbicide, or other means. Each growing season the trees are provided optimal amounts of nutrients and water by fertilizing and irrigating. Diseases and insect pests are also controlled.

After 6 to 10 years, at a time when the trees reach near-optimal biological growth, the trees could be harvested using specially-designed harvesters. The wood will likely be chipped and used for energy, pulp, reconstituted wood products, feed, chemicals, or any combination of these products. In the spring following harvest, several new stems will sprout from each cut stump (coppice), and these will become the next crop of trees.

Irrigation is one of the cultural practices being studied in this research program. More precise information about the quantity and timing of irrigation is still needed.



SELECTION OF PROMISING SPECIES

These plots were established in 1974 to test the performance of different Populus *clones. Note the differences in growth rate of these clones after 3 years under similar intensive culture conditions.*

Research Problem

The characteristics of high-yielding trees for intensive culture are significantly different than those for conventional forestry. Selected species must be biologically efficient to take full advantage of the optimized conditions of intensive culture.

Research Objectives

Promising species and clones must be screened for a wide range of biological and physical properties. Initial tests include growth rate, response to different spacings, response to water and nutrient management, sprouting ability, insect and disease resistance, wood quality, and adaptation to regional climatic conditions. As results from physiological studies of crown architecture, photosynthesis, and translocation of photosynthetic products are obtained, they will be included in genetic selection and breeding programs.

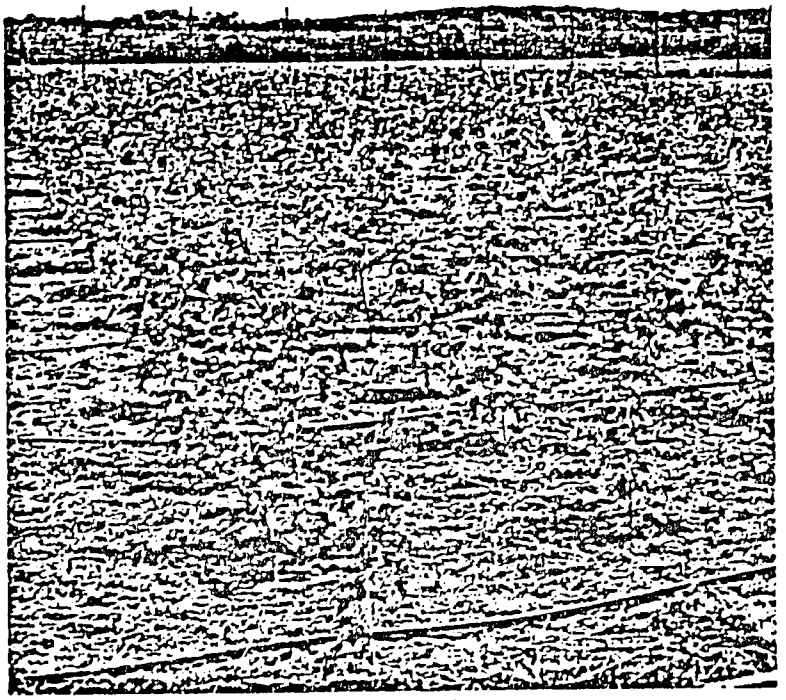
Research Results

The genus *Populus* (poplars and cottonwoods) was selected for the early experiments because of its rapid juvenile growth, ease of hybridization, vegetative propagation, and the vast amount of information already known about its growing requirements. In 1971, 30 *Populus* hybrid clones were tested in field plots at Rhinelander, Wisconsin, and Ames, Iowa. Fourteen of these have been selected for further testing under various intensive culture techniques. Other species tested included jack pine, (*Pinus banksiana*), larch (*Larix laricina*), alder (*Alnus*), and green ash (*Fraxinus pennsylvanica*).

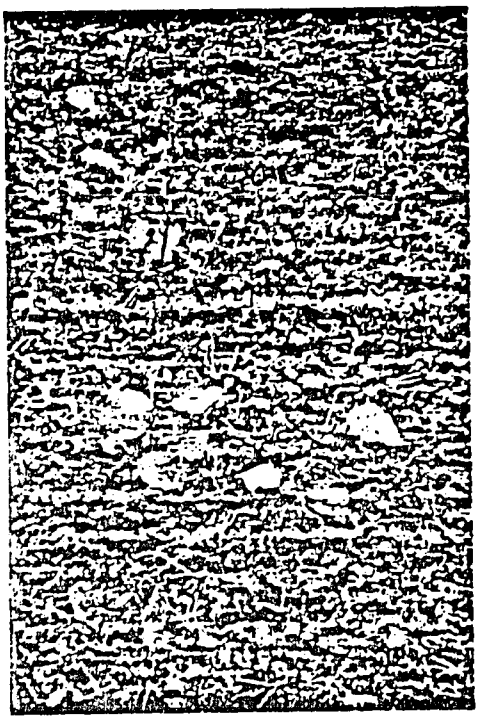
Rapid laboratory screening tests have been conducted using physiological and morphological characteristics, such as net photosynthesis rate, production of enzymes controlling nitrogen uptake and metabolism, branch angle, and leaf orientation on branches.

Controlled-environment chamber experiments were also completed for 25 Populus clones using 3 different combinations of growth period and temperature. After comparing total biomass, leaf weight, stem weight, height, and leaf number at 8 weeks, 14 clones were recommended for field testing.

STAND ESTABLISHMENT METHODS



Weed competition is one of the most serious problems in establishing hardwoods for intensive culture. In field experiments, the herbicide "Roundup" was found to keep stands almost free of weeds.



Planting low lying leguminous cover crops may be an effective way of simultaneously providing soil nitrogen and controlling weeds. White Dutch clover shown here prevents the growth of taller weeds that might otherwise shade and compete with the hybrid poplar cuttings, but is also competitive with the trees.

Research Problem

The survival of trees during the critical first 2 years is primarily determined by vigor of the planting stock; adequacy of site preparation, fertilization, and irrigation; and control of competing weeds. Because early site occupation is desired for intensive silviculture systems, high survival of planted trees is important. Stand establishment techniques have not been well developed for hardwood plantations, although application of agronomic and horticultural methods offer promise.

Research Objectives

It is expected that plantation establishment methods for *Populus* clones will be developed during the next 5 years to attain a survival rate of 90 percent. Methods for site preparation; mechanical, biological, and chemical weed control; and mechanization of cultural operations will be studied. In particular, conventional farming techniques will be tested. Alternative vegetative propagation systems will be studied, including methods for collecting and storing cuttings, methods for obtaining plants from greenhouse stock plants, methods for stimulating the rooting of clones that are difficult to root, and possibly systems for establishing cuttings in containers.

Research Results

Studies began in 1978 to test the effectiveness of 245 combinations of methods of weed control in both spring and summer plantings were evaluated after the first year. The best site preparation methods were chisel plowing or a combination of moldboard plowing to 9- to 10-inch depths followed by disking and spike-tooth harrowing. Crownvetch and birdsfoot

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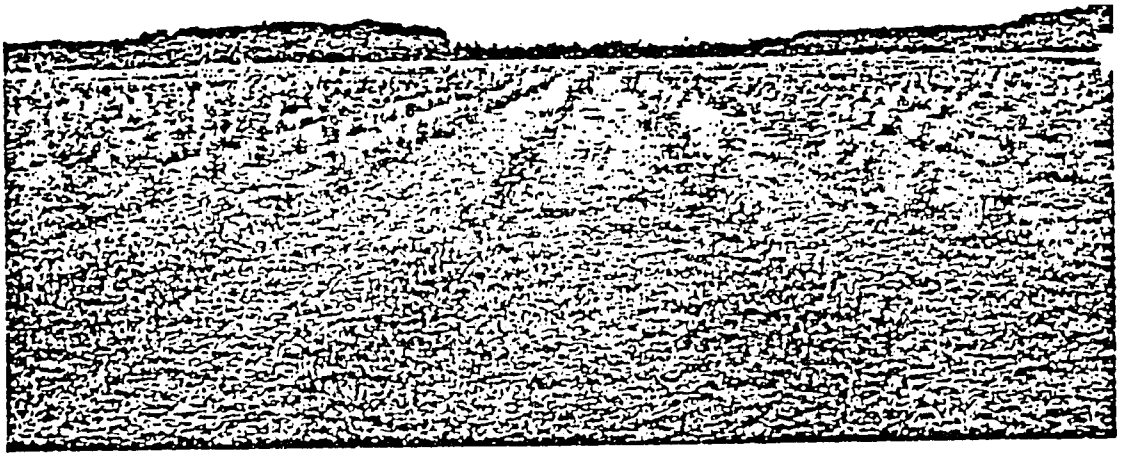


Weeds may be controlled by mowing, a method that is widely used in orchards.

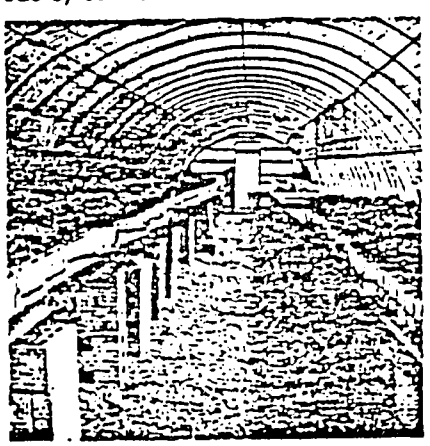
trefoil, both leguminous nitrogen-fixing plants, were the most effective cover crops for stimulating tree growth during the first year, but were not effective when evaluated the second year. "Linuron" and "Roundup" herbicides were the most effective herbicides when no other weed control method was used. A combination of a crownvetch cover crop together with herbicide "Treflan" was slightly better than any other weed control treatment.

One year of data is by no means conclusive, and the above-average rainfall during the growing season may have produced different results than a similar experiment in a drier year. However, this study provides preliminary information regarding promising site preparation and weed control methods that should be tested in larger plantings.

The optimal propagation method may vary with the time of planting. In this study, soaked and unsoaked hardwood cuttings had the best height growth and survival for all planting dates. Rooted hardwood cuttings in "Tubepak" containers provided no advantage in either survival or height growth. Bare rooted tip cuttings performed poorly for all planting dates.

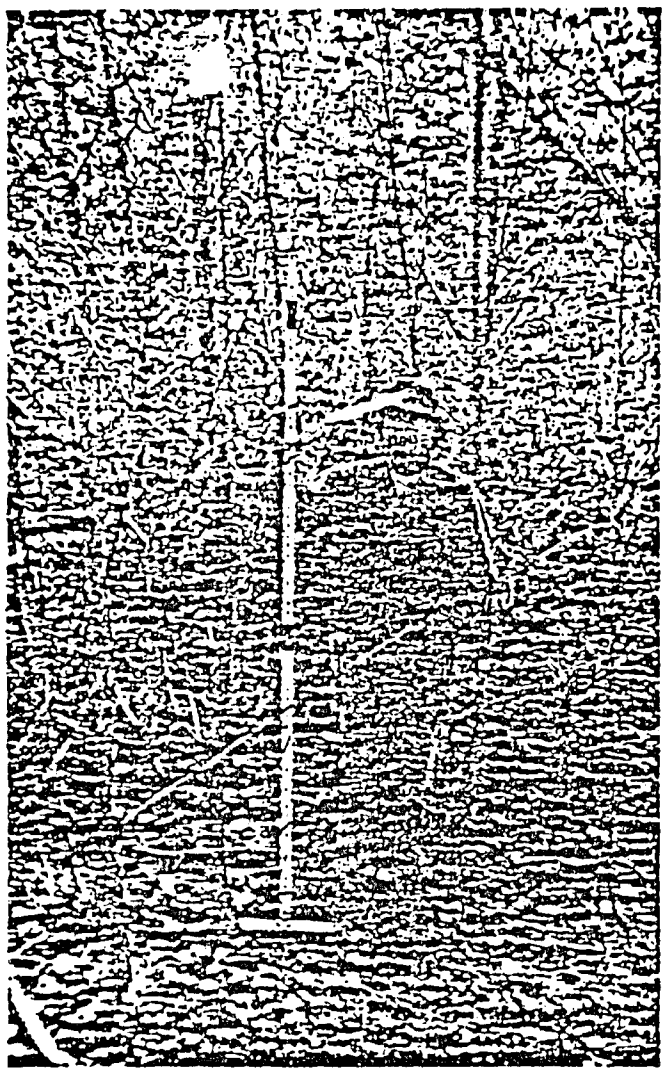
Some of the fastest-growing *Populus* clones, in particular, *P. alba L.* x *P. grandidentata* Michx. hybrid (Crandon), are difficult to establish vegetatively—less than 50 percent of the cuttings rooted using normal greenhouse practices. However, rooting greenwood tip cuttings in greenhouse flats at temperatures of 76° to 85°F provided 70 to 100 percent rooting success, faster rates of root elongation, and less mortality from fungal and bacterial infections. Hormone treatments increased rooting success and number of roots per cutting, but hormone concentration was less important than temperature.

Containerized Populus *cuttings are grown in the greenhouse in preparation for planting. The survival rate of these rooted cuttings will be compared to that of unrooted cuttings to determine the most effective methods of stand establishment.*



New greenhouse methods such as hydroponics are being tested for mass production of rooted greenwood cuttings. This method may be more economical for establishing cutting orchards because it uses less greenhouse space than containerized stock.

FIBER AND ENERGY YIELDS IN RESPONSE TO SPACING AND HARVEST CYCLES



Trees planted at close spacings will quickly occupy the entire site. After 6 years, essentially no sunlight will reach the ground in this stand, which was planted at 0.6 m x 0.6 m spacing.

Research Problem

One of the keys to maximizing fiber and energy production in forest stands is to optimize cultural practices— the spacing and rotation age for the selected species and clones. In particular, information is needed on the efficiency of capturing solar energy by plants and the energy relations in intensively cultured plantations.

It is known that closely spaced stands (1 × 1 m or less) fully occupy the site within a few years; therefore, essentially all the sunlight is intercepted by the leaves before it reached the ground. Closely spaced stands also attain maximum mean annual production early in the rotation, but the competition between trees begins to reduce the annual biomass production per tree. In addition, closely spaced stands are more expensive to establish and it is doubtful that these additional costs can be recouped through higher yields. Because the mean annual production is closely related to the stand's leaf area index (leaf surface area per unit land area), it appears that early optimization of leaf area may increase yields, much as cultural systems to optimize leaf area index in agriculture have been successful.

Research Objectives

Preliminary research on small plots to determine the effect of spacing and rotation age on yields has almost been completed, and researchers are currently evaluating the most promising spacings and rotation ages on yields of larger field plots. From the results of specific studies they will establish mathematical relations between total tree dry weight and easily measured variables such as diameter and height, determine effects of spacing on dry weight distribution among tree components, and determine leaf biomass and leaf area index with respect to various yields. The optimal combinations of spacing and rotation will be studied for the maximization of fiber and energy production in stands of *Populus*, alder (*Alnus glutinosa*), jack pine, and larch. The distribution of major nutrients within the stands will be studied and effects of frequent harvesting on nutrient budgets will be determined.

An integral part of biomass production studies is determining the efficiency of solar energy utilization by plants. This energy data is particularly needed for evaluating systems in which tree plantations would be utilized as an energy source. By comparing the heat of combustion of harvested biomass to the energy requirements for intensive culture, the net energy gains will be assessed.

Research Results

Early field tests of closely-spaced *Populus* 'Tristis' hybrids showed that total aboveground biomass yields could exceed 20 dry tons/ha/year for 4-year-old

trees grown under intensive culture. Tree growth and competition information from these plots was then used to model stand growth and project yields for 10- to 25-year rotations. The table below summarizes both the observed yields on small plots, and the projected yields of stems and branches (Ek and Dawson 1976):

Stem-Branch Biomass Yield

Item	Spacing			
	0.23 m	0.30 m	0.61 m	1.22 m
	t/ha/yr			
Actual yields:				
4 years	11.3	13.0	7.5	—
Projected yields:				
10 years	17.0	16.5	16.0	15.5
15 years	—	—	—	29.0
20 years	—	—	—	36.0

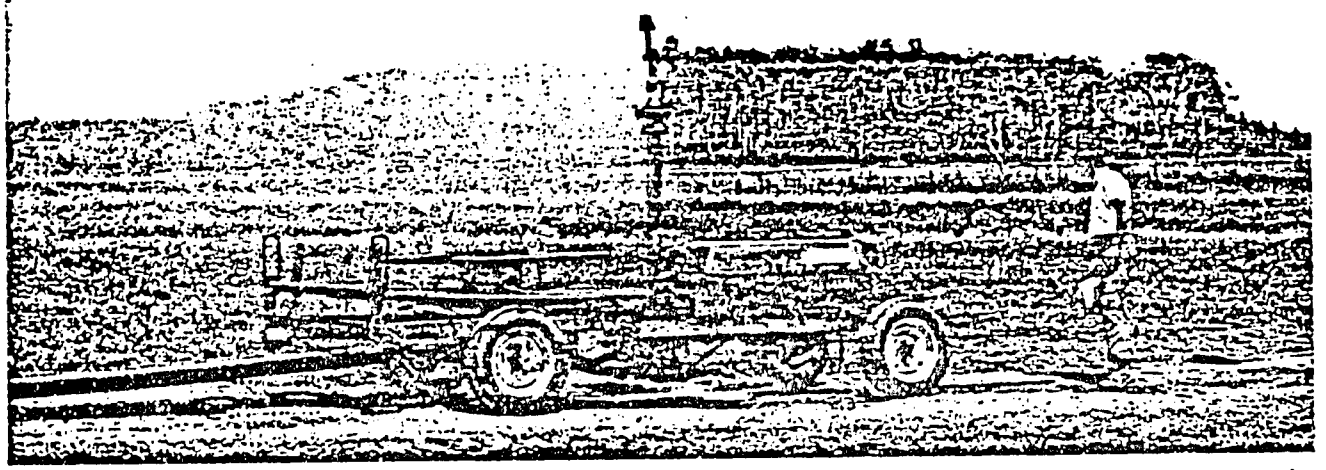
Field studies have shown that 1.0 m spacings will have the same annual yields as 0.23 m spacings after 4 to 6 years. Therefore, field tests of selected clones have now been established to test spacings up to 2.0 m and the effects of various cultural practices on those spacings.

Although hardwoods have been used most commonly in intensive culture studies, yields of softwoods may exceed those of hardwoods on certain sites. Hardwoods are site-demanding, and the establishment of hardwoods on poor sites may be uneconomical because of heavy fertilizer and weed control requirements. Intensively cultured plantations of 7-year-old tamarack (*Larix laricina*) were found to produce 4.3 to 5.2 tons/ha annually, when planted at close spacings, fertilized, and irrigated. Under similar conditions, 7-year-old jack pine produced higher yields, ranging from 6.8 to 8.1 tons/ha annually. Optional spacings will be determined by the expected rotation age; for example, the maximum mean annual increment for the 0.23 m × 0.23 m spacings occurred at age 6 for tamarack and age 5 for jack pine. As spacing increases, the corresponding rotation age increases also.

The use of such intensive culture methods as fertilization, irrigation, and cultivation appears to be an efficient use of energy. The ratio of net energy gain to total energy utilized was calculated to be 4.3 for *Populus* and 4.7 for jack pine, with a net energy content of 306 MBtu/ha for *Populus* and 236 MBtu/ha for jack pine. When comparing the net energy ratios for intensive culture systems and naturally regenerated forests, it appears that net energy returns are linearly and positively related with the energy invested in the system. Although net energy ratios of up to 157:1 have been reported for natural forests, the energy produced annually per acre by these stands is very low. To meet future fiber and energy demands from forests, more intensive systems will have to be used, and it appears that these systems will be efficient producers of energy.

Many hardwoods will coppice or sprout from the stump after cutting thus eliminating establishment costs for the next rotation. The vigor of coppice growth will differ greatly by species and clone and must be determined in field tests.

YIELD RESPONSE TO NUTRIENT AND MOISTURE REGIMES



A traveling irrigation system is used to provide water for the large field experiments. During operation, a water turbine powered winch advances the unit along a cable anchored at one end of the irrigation lane. The unit is drawn by tractor back to the starting point at the beginning of each day that irrigation is required.

Research Problem

Conventional silvicultural practices have historically provided less than optimum nutrient and water supplies to trees, and therefore tree growth has not approached the biological potential of the species. Traditional practices reduce the number of trees on a site to allocate the fixed supply of water and nutrients to fewer trees. With SRIC systems the number of trees (spacing) is fixed at the time of planting and the problem is to determine the quantity of water and fertilizer necessary for maximum yield. Related problems are to determine the timing of fertilizer and water application and the extent to which nitrogen-fixing plants may be introduced into intensive culture plantations to reduce costly nitrogen fertilization.

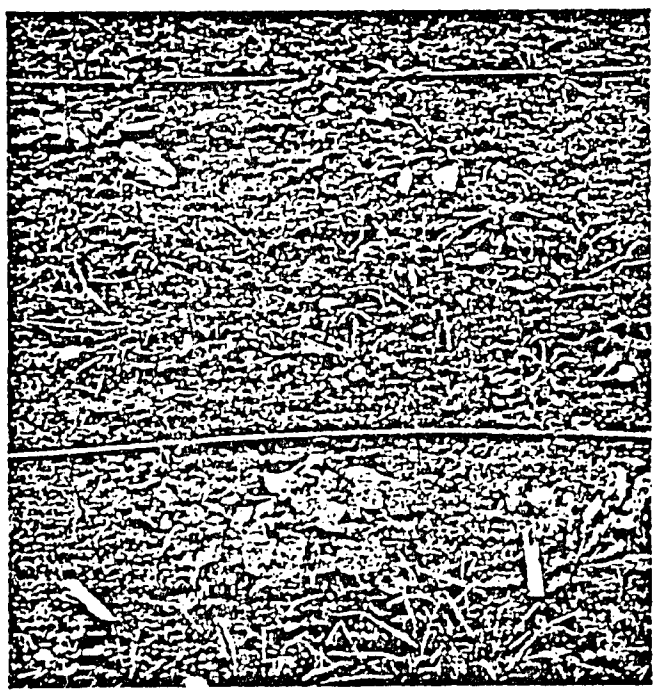
Research Objectives

Gross plant nutrient and moisture requirements are known for the genera under consideration for intensive culture, but the specific requirements for promising species and/or clones are not known. The growth responses with regard to fertilizer application rate, formulation, placement, and time all must be determined experimentally. Furthermore, the interaction of irrigation and fertilization in affecting plant growth will be studied. Research in growth-room, greenhouse, and field studies will be conducted to identify the soil-water potential and nutrient levels of the plant and soil for maximum plant growth for selected clones. Also, changes in physical and chemical soil properties and ground water quality will be identified.

Research Results

A Continuous Function Design was used in field experiments, with a moisture gradient superimposed

at right angles upon a fertilization gradient. The effects of the independent variables (water and nitrogen level) and all the combinations of these two variables on the growth of hybrid poplar were thus tested on ¼-acre plot. The water was provided by a trickle irrigation system and the fertilizer, ammonium nitrate, was applied by hand. Measurements after the second year show that up to 2 inches of irrigation per week considerably increased height growth, whereas additional amounts of irrigation (more than 3 inches per week) inhibited height growth. Fertilization with 100 lbs/acre/year nitrogen as ammonium nitrate increased height growth as much as 30 percent. Additional amounts of nitrogen decreased height growth. A smaller plot with an irrigation gradient and increasing percentages of nitrogen-fixing *Alnus glutinosa* planted among the *Populus* showed that *Populus* height growth increased about the same when mixed with a large proportion of *Alnus* as when fertilizer was applied. This has significant implications for reducing fertilization costs in intensive culture systems.



A trickle irrigation system is used for precise application of water in irrigation studies. Microtubes discharge water at 4-foot intervals along the ½-inch plastic pipe. The nutrient gradient was established by hand application of fertilizer.

EFFECT OF CROWN ARCHITECTURE AND CANOPY ON YIELD

Light interception is related to both the number of leaves per tree and the leaf area per tree. Leaves of selected Populus *clones grown under SRIC may exceed 30 cm in length, and provide a large surface area for light interception.*

Problem

The amount of sunlight that leaves intercept is greatly dependent on the arrangement of leaves on the branches (crown architecture) and the density of leaves within the stand canopy. This captured light, in turn, directly affects the amount of photosynthetic activity and total biomass production. When the most advantageous leaf arrangement on branches is known, trees with these characteristics can be selected for clonal testing under SRIC.

Total biomass production in both agricultural and silvicultural systems is closely related to total leaf area of the stand. Two of the major limitations to productivity of plants are the length of time required to obtain the optimum leaf area index and the ability to maintain that optimum leaf area. The low productivity of many forest stands is partly due to the lengthy period of time required to achieve optimum leaf area. A goal of SRIC forestry is to increase the

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effective leaf area earlier in the rotation and maintain it longer than more conventional forest systems.

The suitability of trees grown under SRIC for pulp production also depends partly on the distibution of biomass among tree components. Crown architecture will influence the percentage of biomass in branch and stem wood, and thus affect quality of yield for pulp and other wood products.

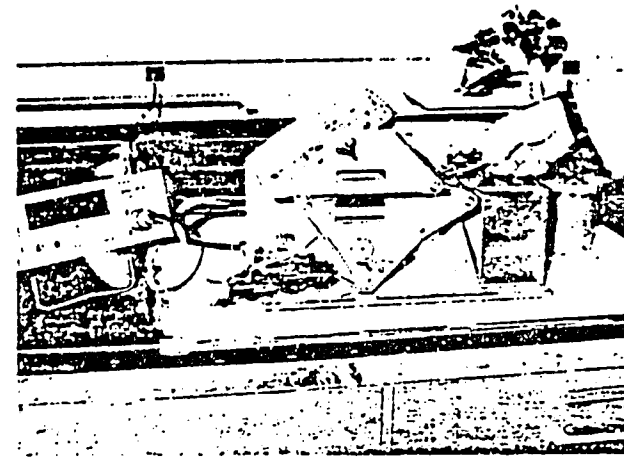
Research Objectives

The "ideal" tree for intensive culture will be further defined through studies that evaluate the effect of crown architecture and canopy density on yield. To identify these attributes, scientists will determine leaf development throughout the growing season, light interception by leaves within the stand, and affect of crown architecture on distribution of photosynthetic products within the tree. Studies will also address the affects of growth regulators on leaf production and the affect of spacing, cultural practices, and age on canopy characteristics.

Research Results

Distribution of the number of leaves per tree and the leaf area index was studied in a 5-year-old stand of *Populus* 'Tristis' grown under SRIC at 1.2 m spacing. Average leaf area index was 7.6, which is 1 to 5 times higher than reported natural stands of *Populus* in the same area. Trees contained an average of more than 6,600 leaves or 4,800 leaves per square meter. The percentage of leaf area on long shoots was 53 percent, compared to 10 to 20 percent on trees grown in native stands. Leaves on short shoots are produced early in the growing season and mature early. Long shoots produce leaves continually during the growing season, thus providing an advantage of continuous production of photosynthate throughout the summer.

During the first 3 years, leaf area per tree and number of leaves per tree for several *Populus* clones were not affected by planting densities from 0.2 to 1.4 meters. Thus, attainment of high leaf area indices and concomitant rapid growth depends greatly on the high density of trees in the early years of establishment. In SRIC forestry leaves are concentrated on a large number of individuals rather than a few as in more conventional forests.

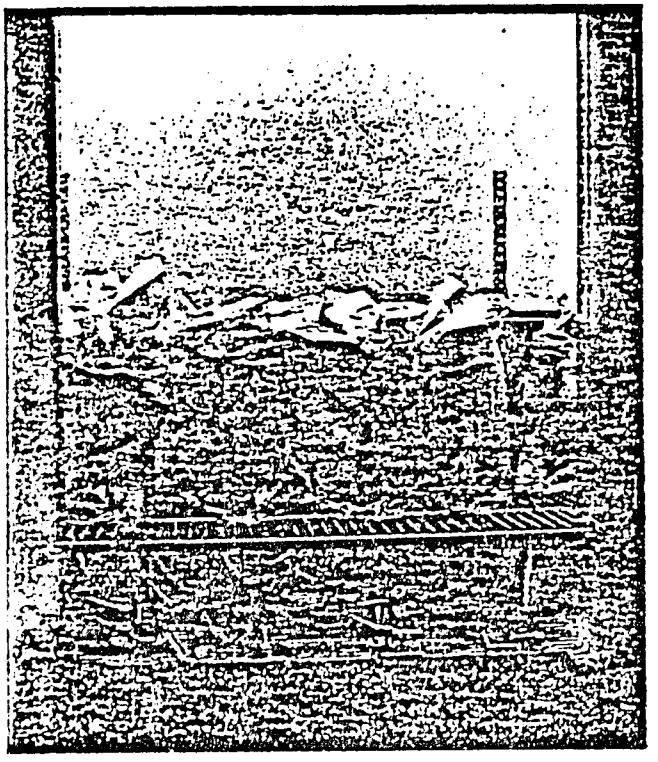


Leaf area index describes the surface area available for photosynthesis in forest stands and is one of the best indicators of photosynthetic capacity. Automatic measurement of the surface area of each leaf using this instrument has greatly accelerated research in this area.

Observation of the vertical distribution of leaves within the canopy showed that about 25 percent of the leaf area produced on 3-year-old *Populus* 'Tristis' was on the terminal shoot. Because photosynthates produced by the terminal shoot leaves are directly translocated to the stem, greater proportions of leaves on the terminal shoot will no doubt increase stem biomass production. The lower branches of intensively cultured trees retain their leaves longer than those of conventionally cultured trees, which results in an even greater leaf surface area for light interception. This retention can most likely be attributed to the optimum growing conditions of intensively cultured trees.

PHYSIOLOGICAL FACTORS INFLUENCING YIELD

Gross photosynthetic rates of Populus *are measured in the field using a $^{14}CO_2$ technique. Measurements of leaf conductance, leaf and air temperature, relative humidity, and photon flux density are made concomitantly to provide for the proper interpretation of photosynthetic rates.*



The CO_2 compensation point of excised Populus *leaves is measured in the laboratory. Such information about physiological responses may be used to preselect clones before expensive field screening is conducted.*

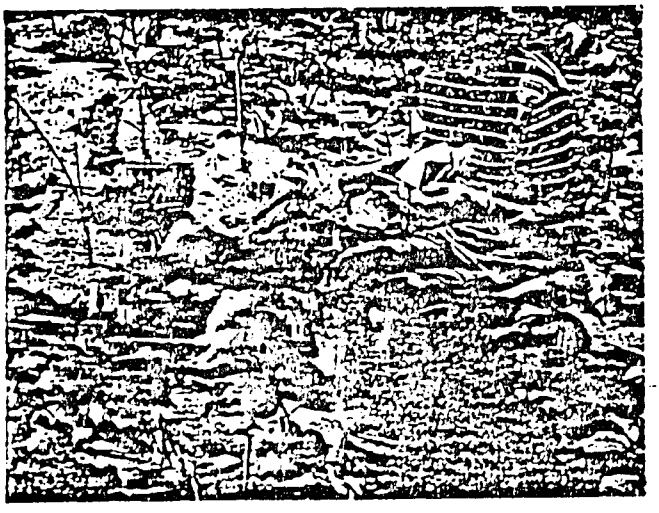
Problem

Photosynthates (mostly sugars) are produced in the leaves during photosynthesis and are then translocated to all other parts of the tree. These photosynthetic products may be used for maintaining plant processes (respiration) or for producing biomass. Therefore, the net biomass production is dependent on the rates of photosynthesis and respiration, as well as on the distribution of photosynthates among plant parts.

Numerous physiological variables have been identified through extensive agronomic research as important determinants of biomass production in crop plants, but the importance of most of these variables has not been determined for woody plants. When more information about the desirable characteristics of trees for SRIC systems is available, genetic tree improvement programs can incorporate these traits into selections.

Research Objectives

The relation between physiological variables and the quantity and quality of yield for selected trees



Populus *leaves are exposed to $^{14}CO_2$ in the field. Three days later, the whole tree will be harvested and the $^{14}CO_2$ activity will be measured in the leaves, branches, stem, and roots.*

grown under intensive culture will be studied. These variables will include rates of photosynthesis and respiration, photosynthetic efficiency, patterns of photosynthetic activity during the growing season, patterns of photosynthesis within the tree crown, and patterns of photosynthate distribution within the tree. Recommendations for selecting trees can then be based on the complex system of physiological variables know to affect yield.

The methodology for conducting physiological studies on trees in the field is not available, partly because of the size and complexity of trees. Therefore, considerable effort will be needed to develop field physiological research techniques for young intensively cultured trees.

Research Results

Field, greenhouse, growth chamber, and laboratory studies have been initiated to measure the rate of net photosynthesis, leaf conductance, and CO_2 compensation points of individual leaves at various positions within the canopy throughout the growing season. Concurrently, the translocation of photosynthates is measured by exposing groups of three fully-expanded contiguous leaves to $^{14}CO_2$. Trees are harvested after 72 hours and sampled for percentage of ^{14}C-activity in various tree components to determine the translocation of photosynthates produced during the exposure to $^{14}CO_2$. Laboratory experiments to confirm exposure and sampling methods have been completed, and as trees grow older and more complex it is expected that more sophisticated field sampling methods will be developed.

Field experiments with young *Populus* trees grown under SRIC have provided some preliminary results. The upper leaves translocate photosynthates upward for use in shoot development, the middle leaves translocate photosynthates both upward to the shoot and downward to the lower stem and roots, and the lower nonexpanding mature leaves translocate primarily downward to the lower stem and roots, where they are utilized for vascular and structural tissues. These results suggest that because mature leaves contribute mainly to stem wood production, it may be desirable to select for trees that retain mature leaves.

RAW MATERIAL QUALITY OF INTENSIVELY CULTURED TREES

Scanning electron micrograph of a tension wood fiber from short rotation intensively cultured Populus *tree. Surface dislocations (wrinkles) on the fiber affect subsequent paper strength properties (2000 X).*

Problem

The value of biomass produced under SRIC systems depends primarily on the type of specific products for which it can be used. Because wood is such a versatile raw material, an integrated research program must consider the value of wood produced under intensive culture for a wide range of current products as well as those that may be demanded in the future.

Intensive culture practices influence physiological processes which in turn affect the anatomy, chemical composition, and physical properties of the raw material and therefore the usefulness of the material.

Research Objectives

The effect of such variables as plant material, spacing, fertilization, moisture regimes, and age on the quality of raw material will be determined. Tests will be made to measure the suitability of raw material produced by SRIC (including bark) for pulp and paper, particleboard, fiberboard, chemical feedstocks,

energy, and animal feed. For the purposes of genetic selection and breeding programs, the most desirable raw material attributes for trees grown under intensive culture will be identified.

Research Results

The energy content of most woods is similar—hardwoods average 4,400 and softwoods average 5,000 kcal per kg of ovendry wood. The factors that contribute to differences in energy value of wood are the moisture content, density, and the ease of drying before conversion. Density will also affect transportation costs and may affect rates of conversion. Tests of juvenile *Populus* wood grown under SRIC have shown that moisture content and density are not significantly different from wood grown under conventional systems.

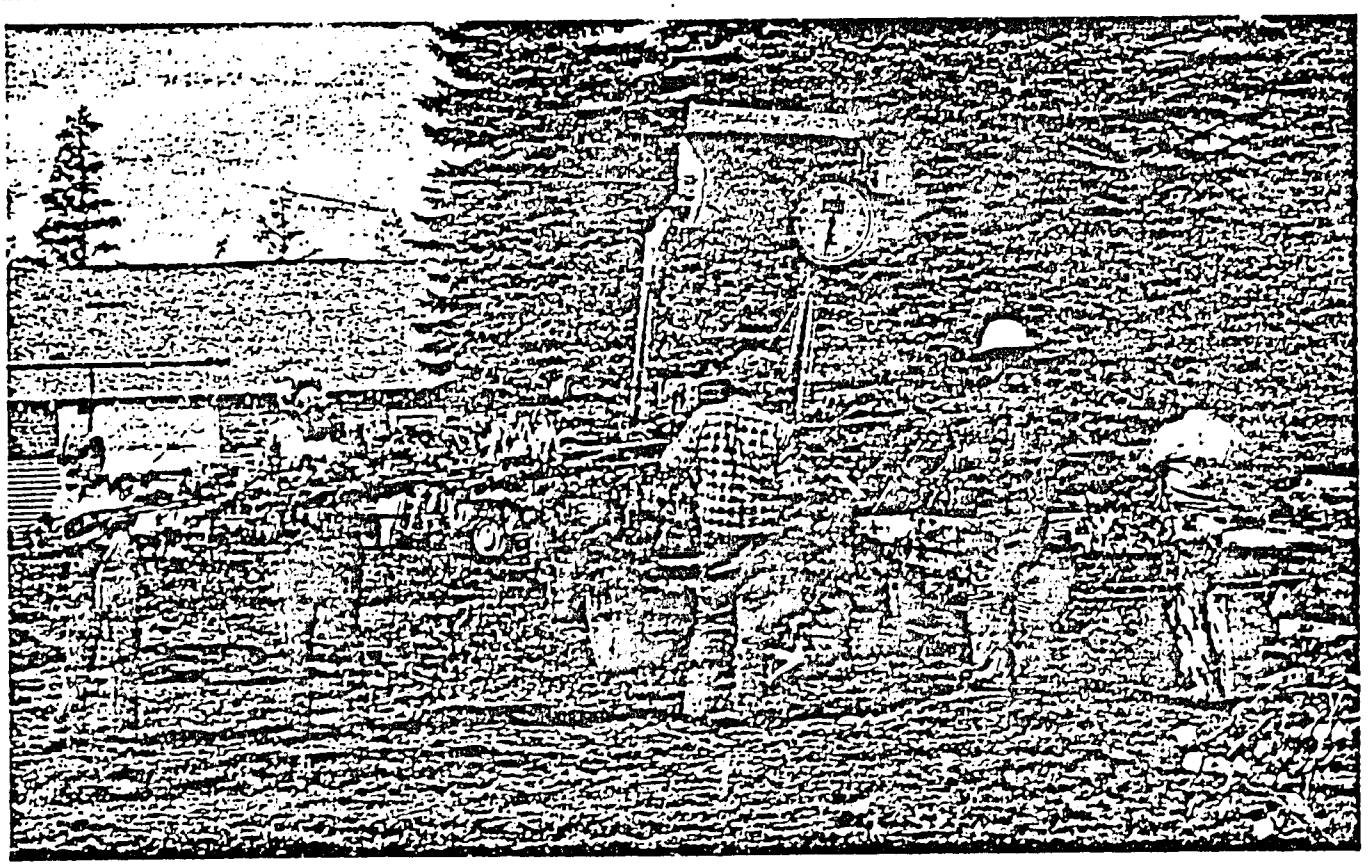
Wood quality may be important in indirect energy conversion processes and for the utilization of wood as liquid fuel and chemical feedstock. For example, lignin may hinder the conversion process, and appropriate plant selections could be made for genotypes with low lignin contents. When conversion processes and wood quality needs for these processes are better defined, research in this area will be more appropriate.

The primary concerns associated with the use of rapidly grown juvenile wood for pulp and paper are that high percentges of bark may be present in whole-tree chips and that juvenile wood has shorter fibers than mature wood, which can adversely affect pulp yields and paper strength.

Most anatomical characteristics vary greatly by species and clone and thus are important selection factors that affect utilization. Anatomical studies have generally shown higher percentages of spring wood and transition fibers in wood grown under SRIC; this fact is probably the reason for lower specific gravities for conifer wood grown under intensive culture. Intensive culture jack pine and larch fibers were only one-third as long as fibers from older mature wood, but improved pulping processes have made fiber length less important. However, more reaction wood is produced under intensive culture than under conventional silvicultural practices probably due to the accelerated growth rates.

In one study pulp yields of tension wood and normal wood were 60 and 53 percent, respectively. Al-

Trees from the first SRIC plots are used for a multiple of research purposes. After they are weighed to determine total above-ground biomass yield, the wood is used in utilization tests.



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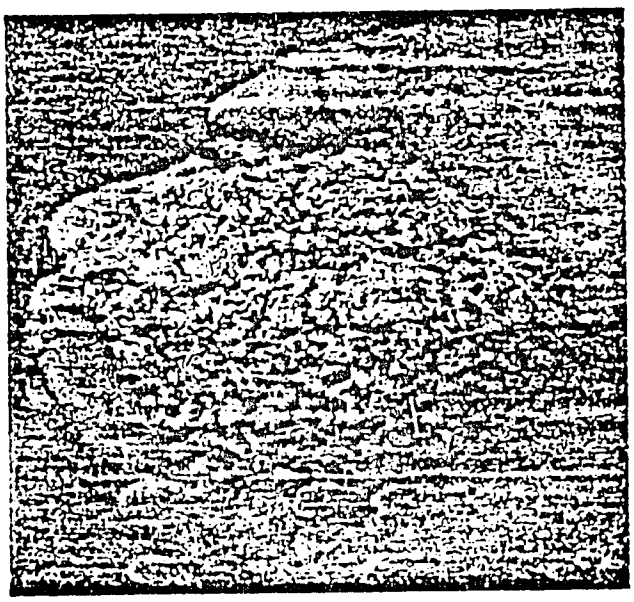
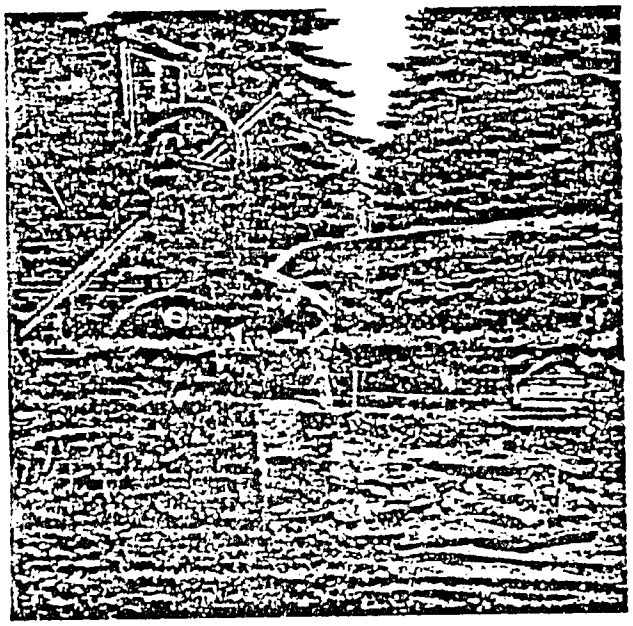
though paper from tension wood had inferior strength properties to that from normal wood, the properties of kraft paper produced from SRIC *Populus* are still within acceptable ranges. Tension wood fibers resisted collapse during beating and produced a thicker, more porous sheet, but the pulp was still clearly acceptable after refining.

Wood produced from 8-year-old jack pine and larch grown under SRIC was also found to be acceptable for kraft pulping, with 41 percent pulp yield for jack pine and 39 percent for larch. On the basis of handsheet strength tests including burst, tear, and tensile, larch was slightly superior to jack pine. The acceptability of *Populus* and the conifer raw material produced under a SRIC system differed little. Thus, it was concluded that biomass yield and clonal differences are the major factors for determining the most promising species and clones for SRIC.



Wood produced under intensive culture has been found to be acceptable for kraft pulping. The wood may also be suitable for thermomechanical pulping.

Wood grown under SRIC was also tested in thermomechanical pulping processes, which offers the advantages of higher yields and lower capital investments than kraft pulping. Tests showed this wood to be inferior to pulps obtained from mature wood because fiber lengths were shorter; fiber length is more critical for obtaining paper strength for thermomechanical pulps than for kraft pulps. However, optical properties were generally good, which suggests that blending of mechanical and kraft pulp may be possible. Bark content was a major factor in the lower performance of SRIC produced wood, which could be decreased by longer rotations and improved methods of whole tree chip segregation.

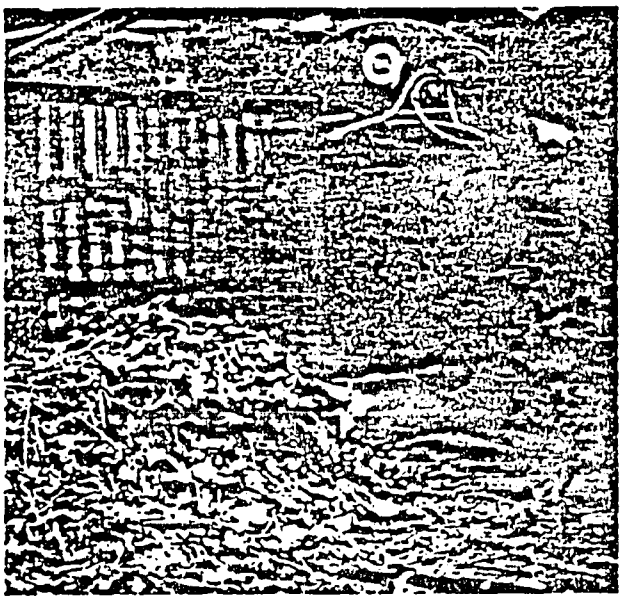


This whole-tree chipper automatically separates some of the foliage from the chips. The chips may be further separated by the Vacuum Airlift Segregation process.

Intensive cultured *Populus* may also be suitable as a raw material for producing flakeboard, a structural particleboard. Tests on five *Populus* clones showed clonal variation in board strength properties, with the better clones producing boards exceeding industrial guidelines for strength properties. Bark reduced board strengths much less than was expected.

Another alternative use for Populus foliage is animal feed supplement. Recently matured Populus leaves have been found to contain levels of nitrogen, carbohydrates, and pigments comparable to forage crops. Feeding tests with ruminants showed the foliage to be acceptable, although the palatability of clones differ.

To alleviate the problems resulting from high bark content in the manufacture of both reconstituted wood products and pulp and paper, a vacuum airlift segregation (VAS) process was developed to separate whole tree chips into components— wood chips, bark foliage, and fines. In the VAS process, chips are spread over a continuously moving wire mesh conveyor belt that passes under a series of vacuum hoods, which separates the components on the basis of differences in terminal settling velocities of the particles.

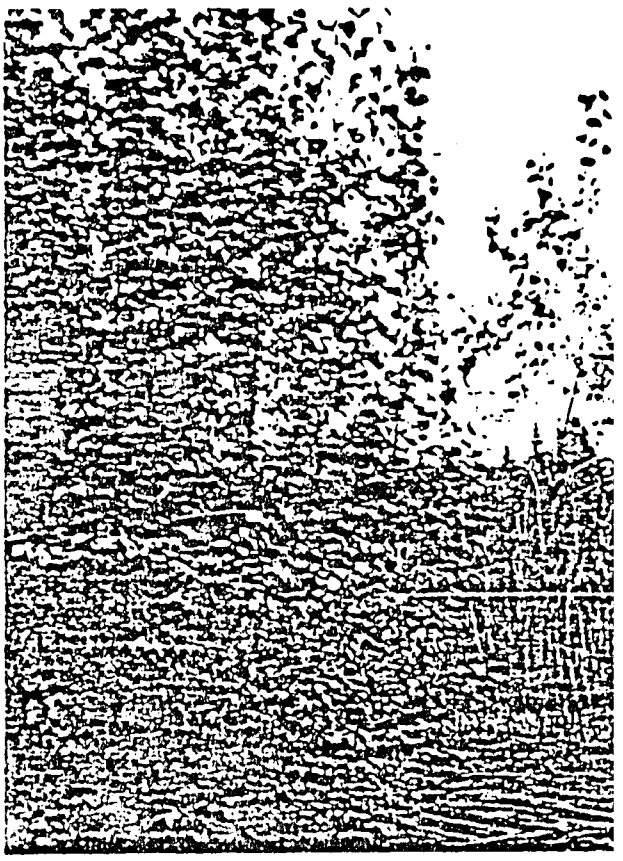


Populus *foliage has been found to be acceptable ruminant feed, although the palatability appears to vary by clone.*

Processing systems such as the VAS offer numerous alternatives for the utilization of the biomass, depending on the market demands and industry objectives. Four single- and multiple-use alternative systems are summarized below for 5-year-old *Populus* grown under SRIC at 1.2 m spacing.

System	Pulp yield *Metric ton/ hectare*	Energy *M kcal/ hectare*	Feed *Metric ton/ hectare*
Pulp only	42	—	—
Energy only	—	200	—
Pulp and energy	27	68	—
Pulp, energy, and animal feed	27	48	5

DISEASES OF INTENSIVELY CULTURED SPECIES



Leaf rust causes defoliation of Populus *before the end of the growing season. As shown, severity of damage varies between clones so selection will be made for those clones that are least susceptible to leaf rust.*

Research Problem

Intensive culture systems may be more vulnerable to disease than conventional mixed species stands because they contain only a few species or hybrids and they may facilitate transmittal of pests because they are closely spaced. At any rate, the susceptibility of a species to pests and the possible control methods must be determined before any species or clone is widely planted.

Research Objectives

It is well known that *Melampsora medusae* leaf rust, *Marssonina brunnea* leaf blight, and *Septoria*

musiva Peck leaf spot and canker are the most prevalent poplar diseases in the United States. The susceptibility of various *Populus* clones to these and other diseases will be determined through this research. Additionally, the incidence and severity of these diseases within the north-central region of the United States will be examined. Integrated control methods to reduce damage from these diseases will be recommended.

Research Results

The screening of clones for disease susceptibility throughout the intended establishment range is extremely important. *Populus* clones were planted at each of 13 sites throughout the Midwest in 1976 and 1977, with an intent to monitor the plots for 10 years. After one growing season, it was found that the most serious diseases were *Marssonina* leaf spot, *Melampsora* leaf rust, *Septoria* leaf spot, *Cytospora* canker, and *Septoria* canker. The severity of each of the diseases varied widely in the region.

Leaf rust injures trees by causing leaf damage and defoliation, and when severe, increases susceptibility to other diseases. Incidence was found to vary greatly between clones, and fungicide treatment delayed defoliation but did not prevent severe rust damage for one hybrid, *P. deltoides* x *P. balsamifera* 'Northwest'. Infection is usually most severe on lower leaves, thus it generally affects basal diameter growth but not height growth.

INSECT PROBLEMS IN INTENSIVE CULTURE

Research Problem

Because intensive culture crops are expected to be fairly uniform in species, age, spacing, and genetic composition, the potential for insect outbreaks may be greater than in forests with a wide range of species and ages. However, the SRIC system affords the opportunity of using cultural tools to control insects before they become destructive.

Natural enemies of *Populus* include more than 150 insects. The most destructive of these are leaf aphids, which feed on leaves and ultimately defoliate the trees. Jack pine and larch also have numerous defoliating, sapsucking, and shoot-stem boring insect pests.

Research Objectives

Insect damage depends on the number of insects attacking the tree or stand, the part of the tree infested, the season of attack, and the age of the tree. After the potential insect pests are identified, clones resistant to these pests may be selected, although resistance includes extremely complex factors such as nutritional status and vigor of the tree.

Control methods for insects in intensive culture systems will be identified. These may include site preparation to eliminate insect habitats occupied in other stages of the life cycle, fertilization to improve nutritional status of the tree or alter tissue components essential for specific insect pests, irrigation to eliminate the water stress conditions that are often causes of insect outbreaks, and hybridization to alter plant density. Close planting may provide stress from competition or modify environmental conditions to limit some insects and favor others.

Research Results

Insect damage has been surveyed on established intensive culture plots of *Populus* throughout the North Central States. Aphids, *Chaitophorus populitoliae* (Oest.), were found to cause the greatest defoliation damage, although considerable differences in severity of attack were observed among clones.

Further tests on the impact of defoliation in relation to clone and spacing have begun. An experiment to test the effects of various degrees and timing of defoliation on yield is in progress— certain percentages of leaves are manually removed at various times during the growing season. The effects of girdling and boring damage will be determined in similar experiments by physically damaging the trees. When the season and severity of impact can be related to actual yields, cultural control methods will be prescribed.

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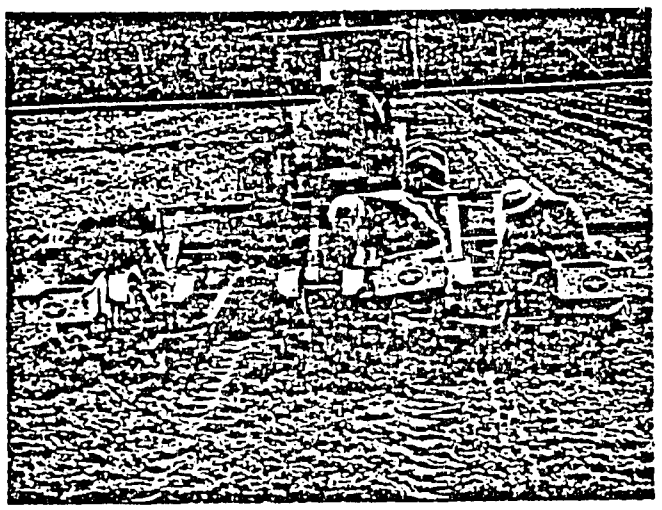
DESIGN OF MECHANIZED EQUIPMENT FOR INTENSIVE CULTURE SYSTEMS



This tree planter was modified for planting unrooted cuttings. The operators place the 8-inch cuttings vertically in a trench and the planter wheels pack the soil around them.

Research Problem

Labor costs are rising in all sectors of the economy, and forest and agricultural operations have become increasingly mechanized in order to lower production costs. Intensive culture systems must also be mechanized. Although they require many cultural operations widely practiced in agriculture, commercial agricultural equipment is generally not suitable for tree crops.

Researchers have improvised equipment for planting cuttings, cultivating, and irrigating. Small research plots have been harvested with chain saws. Yet these methods will be impractical for even the large-scale pilot plantings already established. Harvesters used for current silvicultural operations are not suitable for closely-spaced stands, which have small stems and multiple stems on each stump after the first rotation. An entire systems approach must be developed for harvest, collection, and delivery of wood to the pulp mill or energy conversion facility.

Research Objectives

Modifications of commercial agricultural and horticultural equipment will be investigated first, although substantially different equipment for intensive culture systems may eventually be developed if these modifications do not perform satisfactorily. In particular, equipment needs for planting, cultivation, fertilization, and irrigation will be assessed.

Probably the most critical need is for appropriate harvest equipment. Design criteria for a small-diameter short-rotation harvester are currently being developed, and preliminary designs for the cutting head are already underway.

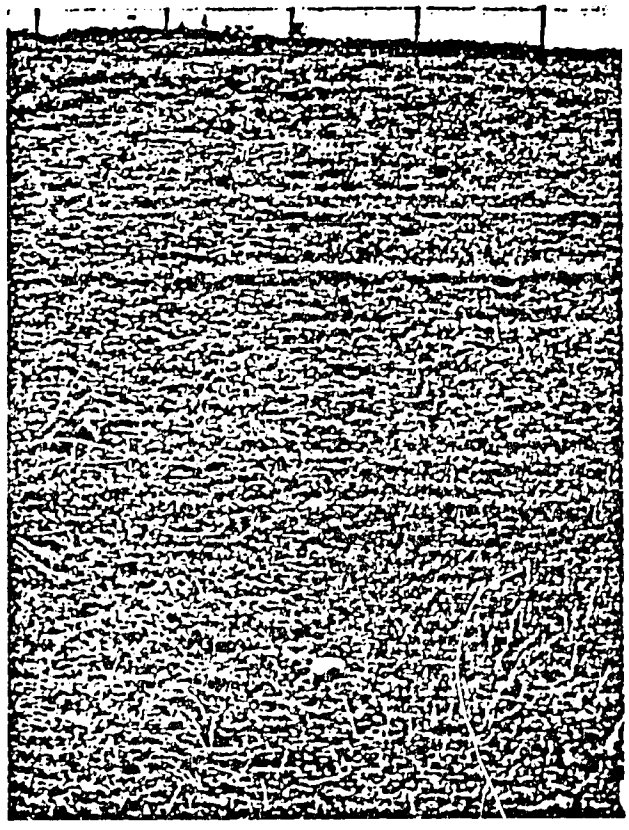
Research Results

Engineers working with this program have modified existing tree planting equipment to accommodate the large unrooted and rooted cuttings used in the large-scale field plantings. These modifications are currently being tested in the field and will be further improved as operational data are obtained. Similarly, a traveling irrigation system to deliver water over 3 to 9 m-high trees has been installed for the large field plantings. The irrigation system performance will be critical as the trees increase in height toward 9 m or taller, because the system must be able to deliver water uniformly over the land area.

Preliminary design criteria have been developed for the mechanized harvest equipment. In general, it must be capable of harvesting one or more rows of the plantation at one time, severing each tree sequentially in the row, and forwarding the material to the landing site. The lack of information about optimal spacings and rotation age (and thus stem diameter and height) make the design efforts and equipment development a continuous process. Consequently, it is highly unlikely that the first generation of small-diameter harvesters developed will be those which are ultimately commercially produced.

To ensure an acceptable level of regeneration by coppicing, the harvester must make a clean cut surface and provide minimal pressure against the stumps and root systems. It must be able to cut at low stump heights and handle the multi-stem tree that will develop in coppice rotations of hardwoods. The wood will probably be used as chips, so the harvester must simultaneously chip the wood or a whole-tree chipper must be present at the landsite. Existing chip trucks will be suitable for final transport of chips to the mill or conversion site.

COST OF PRODUCING WOOD FOR FUEL AND FIBER



The effectiveness of herbicides in reducing weed competition (left) compared to the control (right). When large field tests are conducted for such intensive culture practices as weed control, the costs and effectiveness of alternative treatments can be compared.

Research Problem

SRIC systems have been explored in response to rising land prices and taxes, increasing demands for recreation and nonforest uses of forest land, escalating future fiber demands, and rising costs of conventional energy. The system appears to offer resource managers the opportunity to supply the same quantity of fiber on much less acreage and the opportunity to grow energy feedstocks at competitive prices. An additional significant attraction of this system is the potential realization of an equivalent return on investment with 6 to 10 years after planting, rather than the 30 to 60 years necessary for conventional silvicultural systems.

Before intensive culture management will be widely accepted by land managers, however, detailed information on the production costs and anticipated revenues must be obtained. Estimates of the economic feasibility of intensive culture systems for fiber and fuel are needed to compare with conventional silvicultural systems for fiber and alternative energy supplies, such as coal. Although only preliminary economic analyses can be made with the information now available about yields under specific treatments, the sensitivities of the final production costs to various cultural treatments are needed by research scientists.

Until basic SRIC growth information under specific treatment regimes is readily available, economic evaluations will be partially made by using a break-even analysis technique. Break even analysis permits the physical yields (e.g., dry tons per acre) or financial yields required to cover all costs included in a specific production schedule to be estimated. In addition, the sensitivity of total production costs to individual costs such as land rent, stand establishment, fertilization, irrigation, and harvesting will be determined.

As better biological growth information and production management inputs are obtained from larger-scale plantings, more sophisticated economic analyses for calculating present net worth and internal rates of return will be incorporated into the evaluations. For example, cashflow analyses will be used to calculate costs and benefits of growing *Populus* 'Tristis #1' for two 10-year rotations and three spacings, with emphasis on impacts of different interest rates, inflation and price trends, and Lake States land use alternatives.

The cashflows will be contrasted with energy flows to determine cost-energy tradeoffs. In addition, the minimum operational size will be identified. The costs and energy balances will be assessed for biomass on the stump, delivery of whole-tree chips at 100 percent moisture content, and delivery of kiln-dried whole-tree chips.

Research Results

Break-even analyses were prepared for each of eight management alternatives ranging from 2-year rotations with numerous coppice harvests to 15-year rotations without coppicing. Low, medium, and high cost estimates were used for each production activity within each of the eight management programs. All management costs were compounded to the time of harvest or the end of the rotation. These are the minimum values that must be recovered when selling the wood before any profit is returned.

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Using recent simulation biological growth results and assuming that energy from wood is worth $1.00 per million Btu's and dry fiber is worth $30.00 per ton, the eight management alternatives were evaluated for potential profitability. Alternatives with rotation ages of 10 to 15 years, one coppice rotation, and average yields of 8.4 to 10.0 dry tons/acre (18.8 to 22.4 mt/ha)/year total biomass, appeared potentially profitable for both energy and fiber. The cost of wood produced under 4- to 5-year rotations approached $1.00/mmBtu and $30.00 dry ton only where low management costs were assumed. In general, the analysis suggests that the longer rotations will be more profitable than extremely short ones.

Because production costs are different between the first harvesting period and the following coppicings, the time required to recover the investment, i.e., when compounded yields exceed compounded expenditures, is also an important consideration. The farther into the future the payback occurs from initial point, the greater the risk of the investment and the more important the success of scheduled coppicings.

Evaluating the sensitivity of total production costs to changes in various cost factors provides considerable information for setting research priorities. Emphasis should be placed on cultural practices that will most decrease the total production costs if their costs were decreased. For example, a $10/acre decrease in fertilizer cost would decrease the cost of energy by $0.20/mmBtu; a $10/acre decrease in harvest costs would decrease the cost of energy by $0.15/mmBtu; and a $10/acre decrease in first-year establishment costs would decrease energy costs by $0.08/mmBtu. This result suggests that costs could be significantly reduced if fertilizer requirements were decreased by planting nitrogen-fixing cover crops, alder, or other nitrogen-fixing tree species.

More detailed economic evaluations using cash-flow analyses are in progress. Operational information on machine production rates, man-hours, and fuel consumption rates have been collected from the large-scale plantings at the Harshaw farm near Rhinelander, Wisconsin. Data will also be available from the pilot-sized intensive culture system now established in the Lake States. Costs and energy requirements have been compiled for the purchase and maintenance of equipment, and the cost curves and energy inputs for alternative equipment combinations are being developed.

INDUSTRIAL COOPERATORS

Populus *grows well on sandy sites irrigated with secondary pulp mill effluent.*

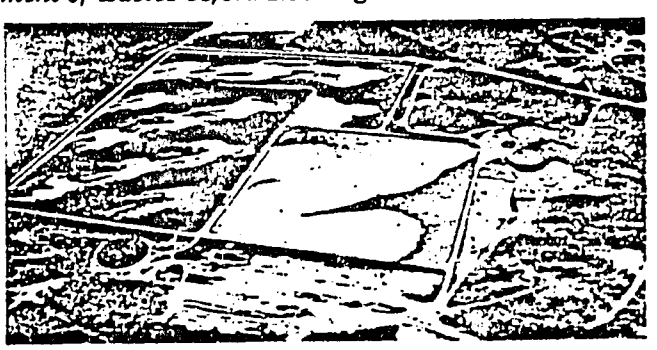
Research Problem

Industry will ultimately determine the commercial success of intensive culture concepts. Some of the intensive culture techniques developed under research conditions may not be feasible in large industrial woodlands programs. Therefore, it is extremely important to cooperate with industrial foresters throughout the research and development effort.

Research Objectives

The technical and economic feasibility of intensive culture cannot be determined by small field experiments such as those conducted at Rhinelander. Large plantations must be established to learn whether research results can be applied in industrial forest operations and to obtain information about the cost of operational intensive culture systems.

More than 30 million gallons of effluent are produced daily by a large modern paper mill in the Lake States. Currently, holding ponds are used for biological treatment of wastes before discharge into a river.



Research Results

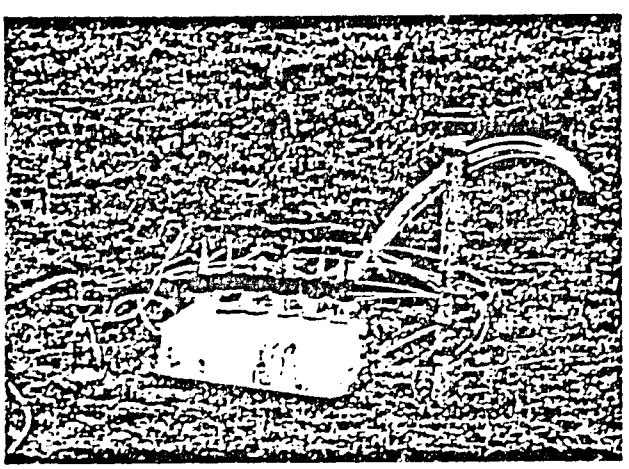
One of the pulp mills in the Lake States has been exploring the possibility of using mill effluent from a secondary treatment plant as an irrigating medium on trees growing on land adjacent to the mill. The company is interested in obtaining uniform high quality wood and in reducing transportation costs, harvesting costs, and taxes on vast acreages of forest land.

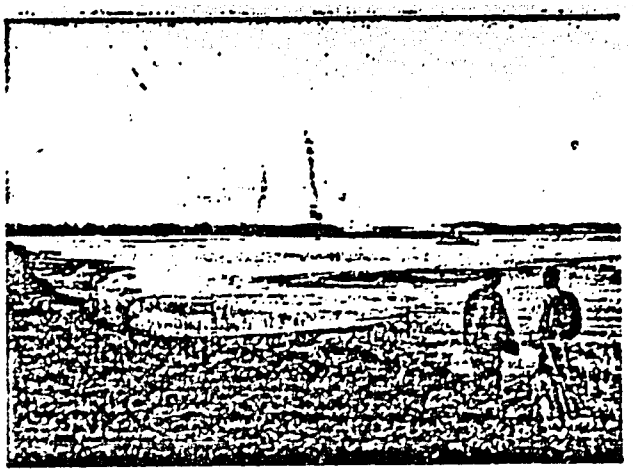
Moreover, the company is concerned about developing a means of disposing of some 30 million gallons of effluent a day, which is presently treated and then discharged into a river. One possible use for this effluent is irrigation of intensive culture trees. In areas of the United States where water is limited and industrial plants have to find a way to dispose of effluent, irrigation with treated effluent may be a solution to both problems.

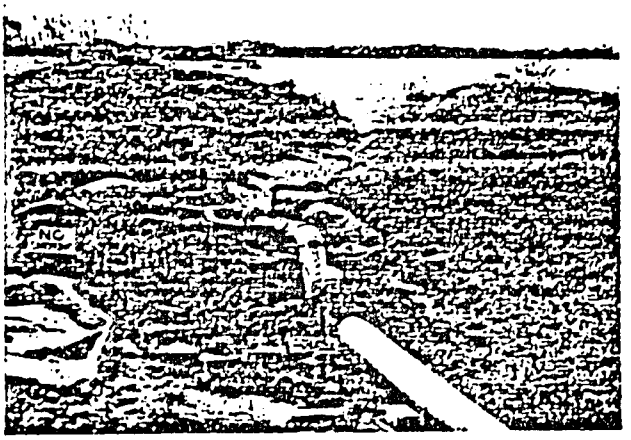
A large-scale pilot study is in progress to test the most intensive methods for growing fiber. A 40-acre site has been cleared, and tilled, and *Populus* cuttings will be planted at two spacings. An irrigation system to distribute the effluent will be installed to maintain an optimum moisture regime for the trees. In addition, a 1-acre test plot of willow (*Salix*) and several *Populus* clones has been established to determine the tolerance of these species to high applications of effluent and the effect of the effluent on groundwater quality.

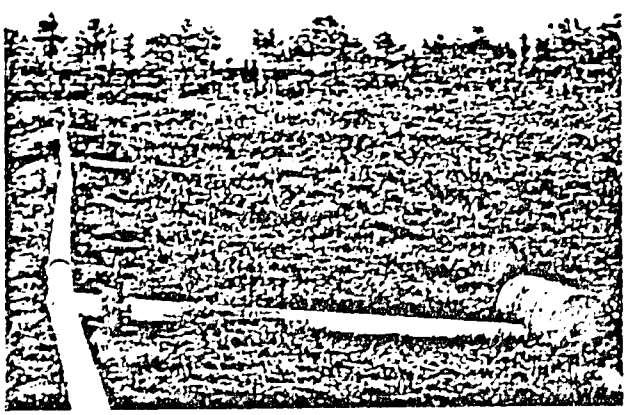
The groundwater at the site has been thoroughly mapped to identify depth, direction of flow, and chemical nature. Throughout the study it will be monitored to detect changes due to irrigation with the effluent.

Water sampling probes are used to monitor the groundwater quality under and near the site where effluent is being applied.









Wastewater effluent from the pulp mill holding ponds (top) is pumped (middle) to the experimental fields. There, it is applied onto the intensive culture Populus *with a flood irrigation system (bottom). Flood irrigation is used to avoid the possible odor problems of overhead spraying.*

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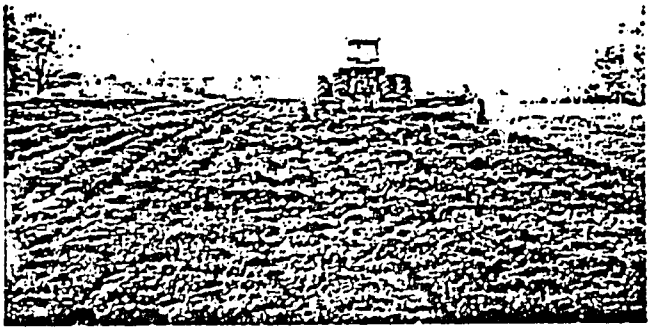
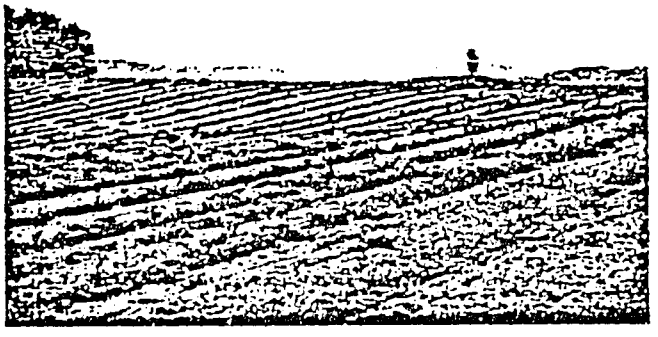
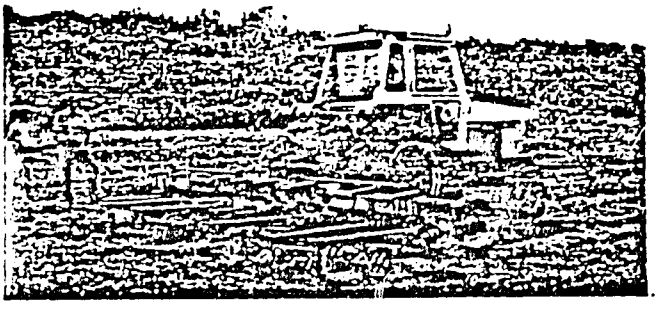
As a separate effort, more than 1,200 acres of *Populus* and *Alnus* were planted in 1978 by the Packaging Corporation of America near Manistee, Michigan, in cooperation with the Maximum Yield Program. Nurseries of superior clonal material were established and hardwood cuttings were planted in 3.3 x 3.3 m spacings. Agricultural techniques and equipment were used to mechanically prepare the site, fertilize, and cultivate. Smaller acreages were established during the previous 3 years, with considerable failure due to stand establishment problems and weed competition. Successful cultural practices for many of these problems have gradually been worked out and survival of trees for 1978 was more than 80 percent. It is expected that an additional 1,200 acres will be established in 1979.



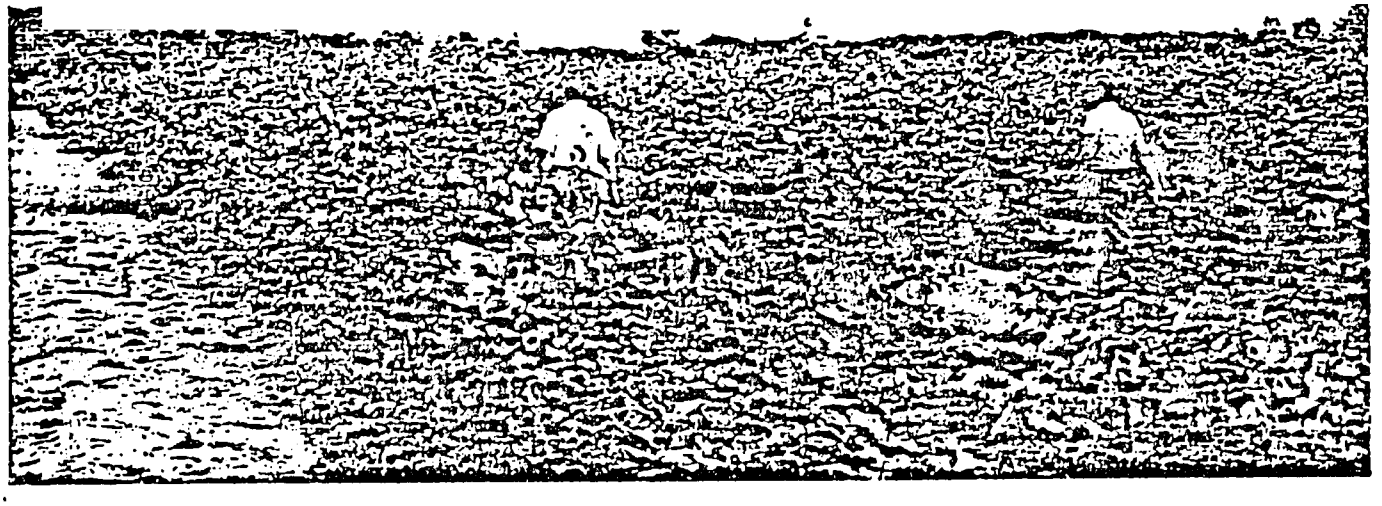
Commercial agricultural equipment is used for site preparation. In some fields, the mills' sewage sludge was applied to provide soil amendments.



Large plantings have been established by Packaging Corporation of America to obtain operational and economic information about meeting their mill needs with intensively cultured Populus.



At the Packaging Corporation of America plantations, a 20-foot cultivator is used to clean three rows of Populus *at one time. About 100 acres can be cultivated daily during the first growing season.*



Some of the older plantings are growing well, particularly this stand of 2-year-old Populus. *Wide spacings were used because the trees will be grown for 10-to 15-year rotations.*

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U.S. Department of Agriculture, Forest Service.
1980. Energy and wood from intensively cultured plantations: research and development program. U.S. Department of Agriculture Forest Service, General Technical Report NC-57, 28 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Since 1971 there has been significant progress in greatly increasing yields of wood and energy (biomass) from intensively cultured plantations compared with natural stands. This publication reports the results of studies and summarizes the "maximum-yield" research in progress at the North Central Forest Experiment Station.

KEY WORDS: biomass, maximum-yield, short rotation-forestry, physiology, tree-planting.

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KEY WORDS: biomass, maximum-yield, short rotation-forestry, physiology, tree-planting.

CAPSULE BIODATA

(As of May 12, 1982)

1. Name: RAFAEL P. CREENCIA

2. Position: Consultant and Management Partner - CAPE
CAFE (Canlaon Farming Enterprises) INC.,
Villa Isabel, Canlaon City, Negros Oriental

Program Leader - Cacao Under Coconut Research Program, Philippine Council for Agriculture and Resources Research (PCARR)

3. Address: Office - Villa Isabel, CAFE, INC., Canlaon City
Home - Kanlaon Lodge # 64, Cor. Rodriguez-Corazon Sts., Bacolod City; Tel. 2-04-81

4. Date and Place of Birth: October 24, 1937
Indang, Cavite

5. Dependents:

Name	Relationship
Carmelita Creencia	Wife
Arlene Creencia	Daughter
Arnel Creencia	Son

6. Educational Attainment/Training:

a. Degree/Diploma

Degree/Diploma	Institution	Year Graduated	Specialization
BSA	UPCA	1959	Agronomy
M. S.	Univ. of Mass., USA	1969	Plt. Science
Ph. D.	Univ. of Mass., USA	1973	Plt. Science

b. Non-degree

High School - Indang Rural High - 1953
Secretarial Course - Philippine College of Commerce - 1955
Supervisory Training Course - UPCA - 1962
Highway Beautification - Univ. of Mass., USA - 1969-1973
PERT/CPM - La Salle Graduate School, Manila - Dec., 1973

7. Civil Service Eligibility: Sugar Technologist - August, 1960

8. Employment Record:

	AGENCY	DATES
Asst. Professor	UPLB-CA	July 1973 to May, 1981
Instructor (On leave)	UPLB-CA	June 1967 to July, 1973
Instructor	UPLB-CA	July 1963 to June, 1967
Research Instructor	UPLB-CA	January 1962 to July, 1963
Research Assistant	UPLB-CA	April 1959 to Dec., 1961
Student Assistant	UPLB-CA	1956 to April, 1959

9. Other Appointments/Positions held:

Government

Head - Plantation Crops Division, Dept. of Horticulture, UPLB June, 1974 to May, 1980

Professorial Chair Holder - Philippine Coconut Research and Development Foundation - Aug., 1977 to May, 1980

Member - Graduate Faculty, UPLB - July, 1973 to May, 1980

Member - Plant Board (Inter-Agency) - June, 1977 to May, 1980

Member - Coffee and Cacao Sub-Committee, Philippine Export Countil - June, 1977 to May, 1980

Member - Sub-committee on Coffee and Cacao, Bureau of Standard June, 1977 to May, 1980

Secretary - Horticultural Section, Agriculture and Forestry Division, National Research Council of the Philippines- June, 1978 to May, 1980.

Member - Executive Committee, Dept. of Horticulture, UPLB - June, 1974 to May, 1980

Chairman, -Personnel Committee, Dept. of Horticulture, UPLB - June, 1974 to May, 1980

Co-Researcher - Pilot Project for Agroforestation Development with Musae - Jan., 1978 to May 31, 1980

Project Leader - Integrated Research on Medicinal Plants - Jan., 1978 to May 31, 1980

Program Leader - Cacao Under Coconut Research Program - (National) - July, 1978 to May 31, 1980

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Consultant - Hilly Land Dev. Proj., Silliman University - 1977 to 19.

National Team Member - Plantation Crops Commodity Research Team, Philippine Council for Agriculture & Resources Research - July, 1976 to May, 1980.

Consultant - GERD Foundation, Inc., UPLB - Palawan Integrated Area Development Program - June, 1980 to Augl, 1980

National Team Leader - Cacao, Coffee and Tea Commodity Research Team, Philippine Council for Agriculture & Resources Research - June, 1973 to June, 1976

Research Coordinator/Program Leader - Spencer Foundation, Inc./ UPLB Integrated Research Program - 1975 to 1977.

Chairman - Beverage Crops Research Committee, UPLB- 1973 to 1977

Project Leader - National Food and Agric. Council Integrated Multiple Cropping Project - 1975 to 1977

Project Leader - Abaca Development Program - 1975 to 1977

Member -International Documentation Center for Abaca- 1976-1978

Member - Presidential Committee on Agric. Credit (Sub-committee on Industrial Crops), Central Bank of the Philippines - July to November, 1976.

Consultant - Visayas State College of Agriculture (for research) 1975 to 1976

Consultant - Phil. Coconut Authority, National Multiple Cropping Program - 1976

Consultant - Ford Foundation Upland Development Program - Jan., 1976

Consultant - FAO Rubber Research Project, Rubber Research Center, Thailand - 1976 to 1977

Consultant - Southeast Asia Regional Colleges of Agriculture, Regional Planning for Panay and Negros Occidental - April, 1976

Consultant - World Bank/National Economic Development Authority project on Marginal Hilly Land Development - Nov., 1977

Consultant - USAID/Manila, Agroforestry Division - 1975 to 1976

Consultant - Iloilo National Agricultural College - Research and Curriculum development - 1979

Consultant - Central Philippine University - Research and Curriculum Development - 1979

Scientist II - National Science Development Board - Coffee and Cacao Development Projects - 1962 - 1965.

Private:

Consultant and Management Partner - Canlaon Farming Enterprises (CAFE) - Jan., 1980 to date

Member - Freemasonry - 1978 to date

Junior Warden - Indang Lodge 115, Grand Lodge of the Philippines- 1980

Vice-President - Diversified Agro-Industries Management Corp. June, 1978 to May, 1980

Board Chairman - DAIMCOR (Main) - June, 1978 to May, 1980

Director - DAIMCOR Supermarket - June, 1978 to date

Director - DAIMCOR Brokerage - June, 1978 to date

Director - DAIMCOR Real Estate - June, 1978 to date

Consultant - SATEC, France, Palawan Integrated Area Development Program - June to August, 1980

Director - Agro-Systems Research and Development Corporation- June, 1977 to 1979.

Management Partner - DAIMCOR Consultancy & Management Services- June, 1978 to date

Management Partner - Agrix Consultancy and Management Services- June, 1974 to July, 1978

Director - Agrix Supermarket, Inc., - June, 1974 - July, 1978

Director - Los Banos Children Choir - 1976- 1979

Member - Panel of Consultants, SYNERGISTICS, Inc. - 1978 to Sept., 1979

Consultant- Davao Fruits, Inc. - 1977 to 1979

Consultant - Matling Industrial & Commercial Corporation - 1975 to 1977

Consultant - Don Pedro Cojuanco Stable - 1977 to 1980

Consultant - MABACALERA - 1979 to 1980

Consultant - Construction & Development Corporation of the Philippines, Agricultural project in Sabah - Sept., 1978

Consultant - World Bank/National Eco. Dev. Authority/Presidential Program Development Office - Samar Integrated Rural Dev. Project - 1977 to 1978

Consultant - Maharlika Development Corporation - Agricultural Feasibility Study for the Naval Reservation at Ternate, Cavite - March, 1976

Consultant - Banco Filipino - Agricultural Feasibility Study for the bank's estate at Silang, Cavite - 1976.

10. Membership in Honor/Learned Societies:

Freemasonry of the Most Worshipful Grand Lodge of the Philippines

Clericultural Society of the Philippines

Citrus Growers Association of the Philippines

Circulo Hispanista

American Horticultural Society, Northeastern Region

The Britinica Society

Philippine Association of Nutrition, Inc.

Crop Science Society of the Philippines

Gamma Sigma Delta Honor Society

National Research Council of the Philippines

Philippine Geographical Society

UPCA Alumni Association

11. Fellowship, Scholarships and Travel Grants:

Travel Grant to Far East cacao growing countries - Hershey Chocolate Company, U.S.A.-August, 1980

International Conference on Cacao and Coconut and post-conference visit to cacao plantations in Sabah - Travel grant from USAID/PCARR - June 20, 1978 to July 2, 1978.

Travel Grant to Thailand on FAO Rubber Research project-December, 1976 to January, 1977

Travel Grant to Thailand on FAO Rubber Research Project-May, 1976

Travel Grant to Nigeria to attend the "1975 International Cacao Research Conference"- Sept., 1975

PCARR/UPLB Training Grant to Study PERT/CPM at La Salle Graduate School - December, 1973

UPLB Special Detail Grant to pursue M.S. and Ph.D. degrees in U.S.A. - 1967 to 1973.

Several government and private travel grants to serve as resource person, speaker/trainor in various conferences, seminar, workshops, symposiums, conventions, meetings and training programs in different places in the Philippines.

Special detail grant from UPLB to serve as Consultant for the GIRD Foundation, Inc. project in Palawan.- June- Aug., 1980

Travel Grant to present a paper at the Annual Conference of the American Horticultural Society, NE Region at the University of New Hampshire, Durham, New Hampshire, USA March, 1968.

Travel Grant to present a paper at the Annual Conference of the American Horticultural Society, NE Region at Harvard University, Boston, Mass., USA - Nov., 1967

12. Teaching:

Taught 5 undergraduate and 3 graduate courses at UPLB, College, Laguna, Philippines

Graduated 43 undergraduates and 12 graduate students at UPLB, College, Laguna, Philippines

Served as member of Advisory Committee for 43 undergraduate and 25 graduate students at UPLB, College, Laguna, Phil.

13. Research:

Completed 52 researches

Presented 13 research papers

Published 11 research publications

14. Publications:

Popular - 14 papers

Semi-technical - 9 papers

Technical - 7 papers

APPENDIX F

PLANT GENETICIST AND TREE IMPROVEMENT SPECIALIST

General

- Supervise and advise GOP agencies in the design and implementation of a strategy to improve the growth, adaptability, form, and utility of tree species for large-scale wood production and reforestation projects.

Specific

- Review existing work on species/provenance/varietial trials.
- Install and monitor selection trials over the range of sites available for planting (e.g., dendro-thermal plants, charcoal production and gassification for irrigation project sites) with tested and untested promising genetic sources.
- Undertake a tree selection and breeding program for best species to supply bulk quantities of genetically improved seeds and plant materials.
- Design progeny trials of selected plant materials on the range of sites to be available for planting.
- Design systems for rapid, mass production of genetically improved seeds and rooted cuttings, or other clonal propagation methods.

It is recommended that a qualified Filipeno be found to fill this position. However if a qualified person is not available immediately, the S&T/FNR Forest Support Program can furnish the GOP with the Biodata of qualified persons, who could fill the position until a qualified Filipeno could assume it.

APPENDIX G

COOPERATION AMONG ASIAN INSTITUTIONS IN FORESTRY RESEARCH

Concept Paper presented by USAID for consideration of the participants of the "Regional Workshop For Forest Research Directors," East-West Center, Honolulu, Hawaii, August 24 - 28, 1982.

A. Purpose

The importance and urgency of increasing forestry development activity throughout tropical and subtropical Asia calls for an increase in international cooperation that combines and targets resources of the donor community to address forestry problems. The establishment of a network of research institutions concentrating on forestry research topics is proposed. Initially, the effort would be limited to research on reforestation and multipurpose production systems for lands marginal to intensive agriculture, but future integration of research activities in other areas would be possible.

B. Proposed Organization

There are a large number of forestry and agriculture research institutions in the region working on reforestation and multipurpose production systems. These existing institutions would be mobilized through a network to upgrade and increase the level of research being carried out at these centers, to strengthen the interaction between them, and to better unify the various research efforts. It is suggested that five to ten existing research institutions, already working on research in this area with financial support from national, bi-lateral, or international sources, be provided with the necessary funding to participate in the network. An Asian institution might be sought to act as a coordinative body to promote the institutional networking, monitor progress, and assure that research results and experiences are effectively disseminated among the participants.

Twinning relationships between Asian research institutions and research institutions in other developing countries and industrialized countries could

be established where appropriate (following the twinning concept proposed in the World Bank/FAO document "Forestry Research Needs in Developing Countries—Time for a Reappraisal?"). Donors would help support the research program and national institution strengthening by supporting the work of individual participating institutions or by other means of providing assistance.

A detailed examination of ongoing programs of Asian research institutions working on reforestation and multipurpose production systems for lands marginal to intensive agriculture would be necessary, but various preliminary surveys indicate that at least one research institute in each ASIAN country represented at this meeting has significant on-going research on this topic, and in many countries such as India, Philippines, and Thailand more than one institution is active in this area.

C. Research Focus

The research to be supported initially through the network (i.e., reforestation and multipurpose production systems for lands marginal to intensive agriculture) is put forward because it is thought to encompass most of the varied aspects of priority forestry research and project interests in the region, but is still sufficiently focused to bring order and discipline to cooperative research and information transfer activities.

While this suggested theme would include biological research activities including species trials, it would also be sufficiently broad to incorporate other technical, social, institutional, educational, financial, and economic dimensions of reforestation and multipurpose production systems for agriculturally marginal land. More specifically, the network could emphasize common reseach interests selected from: Silviculture, Production Systems, and Socio-economic Considerations.

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Silviculture:

- choice of species and provenance
- tree breeding and seed research
- seed storage and dissemination
- vegetative propagation methods
- site preparation and stand management
- pest, disease, and fire control
- effects of reforestation on soil

Production Systems:

- agro-forestry
- large-scale plantations
- natural regeneration
- on-farm, linear, and community plantings

Socio-economic considerations:

- local preferences for species and production systems
- local organization for stand establishment and care
- harvesting, transport and storage
- economic and financial yield
- product supply and demand

The major degraded and problem land areas in Asia could be the focus of the network's activities; for example:

- Imperata grasslands (16 million has. in Indonesia; 5-6 million has. in Philippines; 250,000 has. in northern highland region of Thailand; 100 has. in Malaysia, etc., possibly 50 million has. total in S.E. Asia).
- Highly eroded and/or sloping upland hillside and watershed areas (Himalayas, northeastern Thailand, Philippines, Sumatra, etc.)

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- Saline/alkaline arid areas (36 million has. in India and Pakistan)
- lowland humid tropics (natural forest regeneration in Malaysia, Philippines, Thailand, Indonesia).
- mangrove forests (Philippines, Indonesia, Bangladesh,)
- marginal croplands (unproductive sugar cane land in Pakistan, unproductive rice paddies in India)

D. Network Activities

Strengthening Asian research institutions and increasing the contribution of research to Asia's forestry development is the urgent task of this initiative. To accomplish this, a long-term commitment (at least ten years) and the following activities are needed:

- training of research personnel
- periodic field-oriented technical meetings of research personnel
- analysis, publication, and dissemination of research findings
- establishment of informal and/or formal twinning relationships between research centers of excellence and the institutions participating in this network.

E. Project Development

As part of the establishment of the network, the following steps need to be taken:

- review of ongoing reforestation research in Asia
- identification of donors and research institutions to participate in the network
- specific definition of common research topic(s) to be pursued as the basis for initial network activities.

to initiate cooperative activities at an early date, a limited number of topics should be selected at the outset. Additional topics could be added after gaining experience and establishing the desired working relationships and methodologies.

It is proposed that a project identification and development team be fielded possibly under the auspices of IUFRO and combining the technical expertise of interested bi-lateral donor institutions (USAID, IDRC, etc.) and international organizations (IBRD, FAO, etc.). This team would work with Asian forestry research institution personnel to develop the terms of reference for the network.

DJ/8/26/82

ECONOMICALLY IMPORTANT NITROGEN FIXING TREE SPECIES

(J. L. Brewbaker and Brian K. Styles, eds.
Prepared for Bellagio Workshop; Document #2A)

Format:
SPECIES AND FAMILY
1. ORIGIN; HEIGHT,SHAPE
2. USES AND CHARACTERISTICS
3. ADAPTATION (INCL.MIN RAINFALL)
4. COMMENTS, Chromosome No.

ACACIA ALBIDA DEL. (MIMOSOIDEAE; LEGUMINOSAE)
1. Africa and Israel, to 20 m; leafless in rainy season
2. Forage (pods, foliage), shade
3. Dry tropics, Sahel (to 300 mm min)
4. Slow growth 2n=26

ACACIA AURICULIFORMIS A. CUNN. EX BENTH. (MIMOSOIDEAE; LEGUMINOSAE)
1. Australia, New Guinea; to 30m, spreading
2. Fuelwood, pulpwood; sp.gr..68; 15 m3/ha/yr
3. Wide adapt., acid soils; humid tropics (750 mm. min)
4. Not too tolerant of drought? fire? winds? 2n=26

ACACIA CONFUSA MERR. (MIMOSOIDEAE; LEGUMINOSAE)
1. Philippines, Taiwan; to 14 m, spreading
2. Firewood (high sp. gr.), ornamental
3. Wet subtropics (to 750 mm min), acid soils
4. Slow growth 2n=26

ACACIA FARNESIANA (L.) WILLD. (MIMOSOIDEAE; LEGUMINOSAE)
1. Tropical America; to 10 m, often shrubby
2. Fuelwood; forage, tanning; perfume from flowers; ornamental; black dye used tomake ink
3. Dry tropics; wide variety of soils
4. Very thorny; can be weedy 2n=52

ACACIA MANGIUM WILLD. (MIMOSOIDEAE; LEGUMINOSAE)
1. Australia and Papua New Guinea, Indonesia; to 30 m, erect, stately
2. Timber (.65 sp gr), Firewood?, to 30m3/ha/yr
3. Moist tropics (to 1000 mm min), acid soils?
4. Insects on leaves, genetic variability

ACACIA MEARNSII WILLD. (MIMOSOIDEAE; LEGUMINOSAE)
1. Australia; to 25 m, spreading
2. Fuelwood, charcoal, tannins; dense wood (.75sp.gr.), to 25 m3/ha/yr
3. Moist sub-tropics, mid elevations; to 800mm min?
4. Can become weedy 2n=26

- Gujarat on Gandhi Nagar India
Outgrows everything else
Gujarat State forest Dept

ACACIA NILOTICA (L.) WILLD. EX DEL. (MIMOSOIDEAE; LEGUMINOSAE)
1. Africa and India; to 20m, usually less
2. Firewood, charcoal, fodder (pods, leaves), tannin and gum
3. Dry tropics (but thrives under irrigation)
4. Extremely thorny, variable 2n=52,104

ACACIA SALIGNA (LABILL.) H. WENDL. (MIMOSOIDEAE; LEGUMINOSAE)
1. W. Australia; shrub or small tree to 7 m
2. Fodder; fuel; sand-dune fixation; tannin; recolonization of mining areas; erosion control ornamental
3. Humid to subhumid tropics; 300-1000mm. rainfall; adapted to both sandy and swampy sites
4. Rapid growth outside native areas; tolerant to drought, salt, winds, and fire; may become weedy

ACACIA SENEGAL (L.) WILLD. (MIMOSOIDEAE; LEGUMINOSAE)
1. Africa, Pakistan, India; to 13 m,often shrubby
2. Firewood, charcoal; to 5m3/ha/yr, gum arabic, feed (pods, foliage)
3. Drytropics (to 200mm min), poor soil,hot
4. Extremely thorny, becomes weedy 2n=26

ACACIA TORTILIS (FORSK.) HAYNE (MIMOSOIDEAE; LEGUMINOSAE)
1. Africa, Sahel, Israel, Arabia; to 15 m, often shrubby;
2. Firewood, dense; fodder (pods, leaves)
3. Dry tropics (to 100 mm min), heat tolerant, alkaline soils
4. Thorny, lateral roots

ALBIZIA FALCATARIA (L.) FOSBERG (MIMOSOIDEAE; LEGUMINOSAE)
1. Indonesia, New Guinea; to 45 m
2. Pulpwood, soft sp. gr. .33, moldings, boxes, soil improvement
3. Moist tropics (to 1000 mm min), midlands?
4. Soft wood, poor fuel

ALBIZIA LEBBEK (L.) BENTH. (MIMOSOIDEAE; LEGUMINOSAE)
1. Tropical Asia and Africa; to 30 m
2. Fuelwood (high value, 5200 kcal/kg), foliage for feed, yields to 5 m3/ha/yr, furniture
3. Wide adapt., dryand moist tropics (to 600 mm min)
4. Slow growth 2n=26

ALNUS ACUMINATA O. KUNTZE (BETULACEAE)
1. C. America; to 25 m or more
2. Firewood, sp. gr. .5; timber,to 15m3/ha/yr; shoes
3. Cool tropic highlands to 3000m, moist (1250 mm min)
4. Not heat/drought tolerant

ALNUS GLUTINOSA (L.) GAERTN. (BETULACEAE)
1. Europe to W. Asia; Asia Minor to N. Africa; to 40 m
2. Energy production (fuel); soil stabilization, e.g. river banks, roadsides, mine wastes; shoes; sp.gr. .52
3. Widely adapted, temperate or subtropical, to 500m
4. Not drought 2n=28

ALNUS NEPALENSIS D. DON (BETULACEAE)
1. Himalayas; to 30 m
2. Firewood but sp.gr. .35; utility timber
3. Cool tropic highlands to 3000m, mesic (800 mm min?)
4. Some insects, soft wood 2n=28

CALLIANDRA CALOTHYRSUS MEISSN. (MIMOSOIDEAE; LEGUMINOSAE)
1. C. and S. America; to 10 m, shrubby
2. Firewood; forage (high tannin) and green manure; sp. gr. .65
3. Moist tropics (min. 1000mm), cooler (above 500m?); to 40 m3/ha/yr with annual harvest
4. Shrubby (=C. confusa Sprague & Riley) 2n=22

CASUARINA CUNNINGHAMIANA MIQ. (CASUARINACEAE)
1. Australia, to 35 m
2. Firewood, sp. gr. .7; shade tree; river bank stabilization
3. Cool tropics to warm temperate; 500 mm min.
4. Can be weedy (Florida) 2n=18

CASUARINA EQUISETIFOLIA L. (CASUARINACEAE)
1. Australia and Pacific Isl. to India; to 35 m
2. Firewood, charcoal; sp. gr. 1.0, "best in world"; windbreak; timber for postwood
3. Warm tropics, coastal areas; typhoon tolerant, very saline tolerant; very saline tolerant
4. Coppices poorly?

CASUARINA GLAUCA SIEB. EX SPRENG. (CASUARINACEAE)
1. Australia (N.S.Wales to Qld.); to 20 m
2. Firewood, charcoal, fencing, piles for seawater, windbreaks in coastal areas; sp.gr. .98
3. Warm temperate to subtropics, coastal areas; salt-tolerant; heavy clay soils
4. Produces root suckers and can be weedy (e.g. Florida)

CASUARINA JUNGHUNIANA MIQ. (CASUARINACEAE)
1. Indonesia; to 30 m
2. Firewood, charcoal, poles, piling; wood very fissile
3. Tropical lowlands and midlands, forming dense forests; wide pH tolerance, moderate drought tolerance
4. Little studied; male clone (or hybrid) widely used in Thailand

DALBERGIA SISSOO ROXB. (PAPILIONOIDEAE; LEGUMINOSAE)
1. Indian subcontinent; to 30 m
2. Lumber, fuelwood, sp gr. .68
3. Warm tropics, mesic or arid (to 500 mm min); yields fast for a Dalbergia, slow by other standards
4. Slow growth 2n=20

ERYTHRINA BERTOEROANA URBAN (PAPILIONOIDEAE; LEGUMINOSAE)

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1. Tropical America; to 10 m; small crown
2. Live fence posts; soft wood which accepts wires and nails well; forage; windbreaks; easily cloned
3. Lowland and submontane moist tropics to 2000m; usually in wetter areas but needs good drainage
4. Fast growth; resistant to wind 2n=42

ERYTHRINA FUSCA LOUR. (PAPILIONOIDEAE; LEGUMINOSAE)
1. C. & S. America, to 30 m; broad crown
2. Shade for coffee and cacao; live fenceposts; soft wood
3. Lowland moist tropics to 1500m; often in swamps or on poorly drained clayey soils
4. Fast growth; effective green manure; easily cloned 2n=42

ERYTHRINA POEPPIGIANA (WALPERS) O.F. COOK (PAPILIONOIDEAE; LEGUMINOSAE)
1. S. America to Panama; to 40m
2. Shade for coffee, ornamental; soft wood; paper pulp; forage, mulch
3. Dry to mesic tropics, to highlands
4. Fast growth; coppices and clones easily 2N=42

GLIRICIDIA SEPIUM (JACQ.) WALP. (PAPILIONOIDEAE; LEGUMINOSAE)
1. S. and C. America; small tree to 10 m
2. Firewood, timber, sp. gr. .75, fodder, shade, ornamental; easily propagated by cuttings, living fence, to 8 m3/ha/yr
3. Dry to humid tropics (1000 mm min), also saline areas
4. Toxic bark/seeds/roots; aphids on foliage 2n=20

INGA VERA (L.) BRITTON (PAPILIONOIDEAE; LEGUMINOSAE)
1. Caribbean, C. America; to 20 m
2. Shade for coffee, fuelwood (sp. gr. .75), timber, shade, honey relatively fast growth
3. Humid tropics (1000 mm min?), lowlands
4. Little studied

INTSIA BIJUGA (COLEBR.) O. KUNTZE (CAESALPIINIDIDEAE; LEGUMINOSAE)
1. Southeast Asia, E. Africa, India; to 40 m, buttressed
2. Handsome timber, decking, truck bodies ("ipil" in Philippines), highly resistant to rot; slow growth
3. Moist tropics, prob. 2000 mm min;
4. Genetic variability 2n=24

LEUCAENA DIVERSIFOLIA (SCHLECHT) BENTH. (MIMOSOIDEAE; LEGUMINOSAE)
1. C. America, to 18 m (with shrubby variants)
2. Fuelwood (est. .5 sp. gr.), shade, forage
3. Dry to mesic tropics, prob. 500 mm min, to midlands (1500 m)
4. Little studied, great genetic diversity 2n=52

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LEUCAENA LEUCOCEPHALA (LAM.) DE WIT (MIMOSOIDEAE: LEGUMINOSAE)
1. C. America and Mexico, to 18 m (with shrubby variants)
2. Fuelwood, nurse tree, forage, small timber and pulpwood; sp. gr. .55, some food use (pods, seeds, leaves), energy plantations, yields to 50 m3/ha/yr
3. Dry to mesic tropics, 500 mm min, lowland
4. Widely studied 2n=104

MIMOSA SCABRELLA BENTH. (MIMOSOIDEAE; LEGUMINOSAE)
1. S.E. Brazil & Argentina; to 12 m, thornless
2. Fuelwood, pulpwood, ornamental; shade for coffee; rapid growth?
3. Mid-elevation cool tropics and subtropics (flourishes at 2400m, Guatemala)
4. Little studied

PARKIA ROXBURGHII G. DON (MIMOSOIDEAE; LEGUMIONSAE)
1. Indo-Malaysia, Philippines; now widely pantropical; to 40 m, umbrella crown
2. Timber, ornamental, seeds used in local medicine
3. Humid tropics to 1000mm?; 500-700 m elevation
4. Pest-tolerant; protected in Indonesia

PARKIA SPECIOSA MASSK. (MIMOSOIDEAE; LEGUMINOSAE)
1. Thailand, Malaysia; to 15 m, thin crown
2. Food (seeds from large pods)
3. Humid tropics, to 1500 m elevation
4. Seeds often insect infested; slow growth; hybridizes with P. roxburghii

PARKINSONIA ACULEATA L. (CAESALPINIOIDEAE; LEGUMINOSAE)
1. Americas; to 20 m, spreading
2. Fuelwood; fodder; ornamental; fences; local medicine
3. Widely adapted, to moist tropical and dry areas, also sandy and saline soils
4. Very thorny; weedy in Argentina 2n=28

PITHECELLOBIUM DULCE (ROXB.) BENTH. (MIMOSOIDEAE; LEGUMINOSAE)
1. C. to S. America, to 20 m, irregular and untidy spreading tree
2. Fuelwood (to 5500 kcal/kg), smoky; forage, construction postwood, shade (thorny hedges), food (pods), some tannin and oil (seeds)
3. Dry to mesic tropics, to cooler elevations (So. Florida)
4. Thorny (segregating), poor form 2n=26

PONGAMIA PINNATA (L.) PIERRE (PAPILIONOIDEAE; LEGUMINOSAE)
1. Indian subcontinent, Malaysia, China, Tropical Asia; to 8 m
2. Firewood, fodder (leaves), oil (seeds), pest control (leaves), shade tree, medicine
3. Mesic tropics (min. 600mm), saline tolerant; to full height in 5 yrs.
4. Aggressive spreading roots; also known as <u>Derris indica</u> (Lam.) Bennet

Not a fast-growing Tree

PROSOPIS ALBA/CHILENSIS "Complex"
(Includes P. alba Griseb. and P. chilensis (Mol.) Stuntz; also P. flexuosa and P. nigra)
1. Argentina, Paraguay, Chile, S. Peru; to 15 m
2. Firewood, occasional use as timber; fodder (pods); to 12 m3/ha/yr
3. Cool dry subtropics (200 mm min); to 3000m in Peru
4. Thorny (segregating) 2n=28

PROSOPIS CINERARIA (L.) DRUCE (MIMOSACEAE; LEGUMINOSAE)
1. India, to 9 m, thorny, spreading
2. Firewood, excellent charcoal; fodder, some timber; green manure, yields to 3m3/ha/yr (under drought stress)
3. Dry hot tropics, to 100 mm min?
4. Thorny (segregating), weedy

PROSOPIS PALLIDA/JULIFLORA "Complex"
(Includes P. pallida (Humb & Bon ex Willd) and P. juliflora (Swartz) DC)
1. C. and No. S. America; to 15 m, aggressive
2. Firewood (.8 sp. gr.), exc. charcoal; fodder (pods), honey, wood, to 5 m3/ha/yr
3. Dry hot tropics, to 200 mm min; deep roots, some var. frost-tolerant
4. Thorny (segregating), often weedy (P. glandulosa and P. velutina are the mesquites of So. USA and elsewhere in tropics, often labelled juliflora in error) 2n=26,52,56

PROSOPIS TAMARUGO F. PHIL. (MIMOSOIDEAE; LEGUMINOSAE)
1. Chile, to 15 m,
2. Firewood, forage (pods, leaves), some use use (high sp. gr.)
3. Dry hot saline tropics, to 10 mm (uses fog drip?); remarkable saline tolerance
4. Slow growth, thorns?

PTEROCARPUS INDICUS WILLD. (MIMOSACEAE; LEGUMINOSAE)
1. S. E. Asia, Indo-China, Pacific IslandS; to 40 m, broad crown, lofty
2. Choice timber (narra), ornamental, furniture, flooring
3. Moist tropics; relatively fast growth
4. Needs deep soil; some diseases 2n=22

ROBINIA PSEUDOACACIA L. (PAPILIONOIDEAE; LEGUMINOSAE)
1. N.E. America, to 25 m
2. Fuelwood (dense), erosion control, nurse tree, posts, to 20m3/ha/yr; forage
3. Temperate
4. Restricted to highland tropics (little tested) and temperate regions 2n=20,22,24

SAMANEA SAMAN (JACQ.) MERRILL (MIMOSOIDEAE; LEGUMINOSAE)

1. C. & So. America, Mexico; to 40 m, wide spreading
2. Shade, timber and craftwood, food (pod), sp. gr. .52, ornamental
3. Mesic to wet tropics (to 600 mm min)
4. Not good fuelwood, rapid growth 2n=26

SESBANIA GRANDIFLORA (L.) POIR. (PAPILIONOIDEAE; LEGUMINOSAE)

1. India to SE Asia; to 10m, slender
2. Pulpwood, forage (leaves, pods), food (flower, leaves, young pods), ornamental; sp. gr. .42; to 22 m3/ha/yr, large nodules
3. Moist tropics (1000mm min), onto poor soils
4. Genetic variability, soft wood, borer susceptibility 2n=14,24

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NFTA 82-03

ECONOMICALLY IMPORTANT NITROGEN FIXING TREE SPECIES "B" LIST

(James L. Brewbaker and Brian K. Styles, Eds.
Prepared for Bellagio NFT Workshop, Sept. 1982)

The following species were considered important economically, but of less importance than the annotated "A" list. Many of these species (asterisked) are not known to fix nitrogen, which may account for their absence from the "A" list.

ACACIA ANEURA
ACACIA AULACOCARPA
ACACIA CAVEN
ACACIA HOLOSERICEA
ACACIA KARROO
ACACIA KOA
ACACIA MELANOXYLON
ACACIA PEUCE
ACACIA PENNATA
ACACIA SALICINA
ACACIA SEYAL
ACROCARPUS FRAXINIFOLIUS
ADENANTHERA PAVONINA
ALBIZIA PROCERA
ALNUS RUBRA
CAESALPINIA CORIARIA*
CASSIA FISTULA*
CASSIA GRANDIS*
CASSIA JAVANICA*
CASSIA SIAMEA*
CASUARINA CRISTATA
CASUARINA GRANDIS
CASUARINA OBESA
CASUARINA OLIGODON
CASUARINA SUMATRANA
CEDRELINGA CATENAEFORMIS*
CERATONIA SILIQUA*
CERCIDIUM FLORIDIUM*
COPAIFERA LANGSDORFII*
DALBERGIA LATIFOLIA
DIPHYSA ROBINIOIDES*
ENTEROLOBIUM CYCLOCARPUM
ERYTHRINA INDICA
ERYTHRINA ORIENTALIS
GEOFFROEA DECORTICANS*
INGA EDULIS
INGA PATERNA
KOOMPASSIA EXCELSA*
HAEMATOXYLON BRASILETTO
LYSILOMA BAHAMENSIS
MIMOSA TENUIFLORA
PELTOPHORUM PTEROCARPUM*
PERICOPSIS ELATA
PITHECELLOBIUM JIRINGA*
PROSOPIS GLANDULOSA complex
(P.glandulosa, P. velutina,
P. torreyana)
PROSOPIS PUBESCENS
SCHIZOLOBIUM PARAHYBA
SINDORA JAVANICA*
TAMARINDUS INDICA*

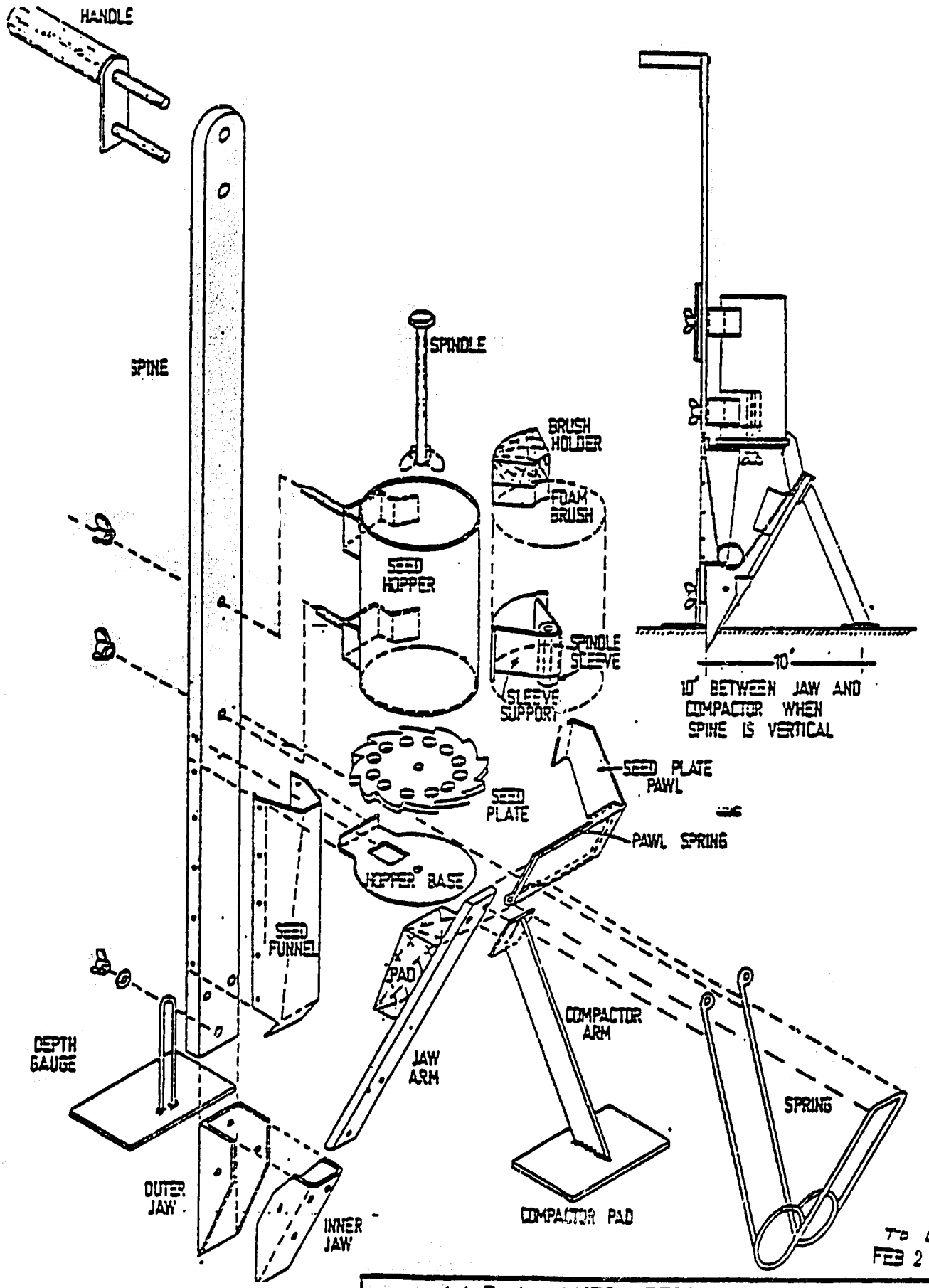
Best Available Document

PLANTERS

For planting maize, cowpeas, pigeonpea, desmodium triflorum (very similar to birdsfoot trefoil found in the U.S.) and certain species of trees directly into the ground two different styles of planters are needed. For farms less than 2½ hectares (95% of total land) a hand operated jab planter would be suitable. For farms of between 2.5 and 5 hectares, a walking machine like the Esmay planter would be best.

The jab planter should be designed so that the farmer can walk upright, jabbing the device into the earth with one hand. Automatic feed with the option of placing a pellet of fertilizer at the proper distance would be useful. Presently, the farmer uses only a machete to lift the soil and throw a seed under or a pointed stick to poke a hole in the ground into which seed is placed then covered with soil with a sweep of the foot. Above all, the cost must be low and fabrication must be possible in a simple metalforming or carpentry shop. Wood or sheet metal and springs are acceptable materials.

The walk-behind machine whould also have automatic feed of seed and fertilizer. Multiple row seeding is likewise an advantage. The Esmay seeder has worked well in tests but is a bit costly and complex for fabrication in some areas.



TO L/B.
FEB 28 1977

I.I.T.A. AUTO-FEED JAB PLANTER
SCHEMATIC ASSEMBLY DRAWING N° 1 OF 6
INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
IBADAN NIGERIA

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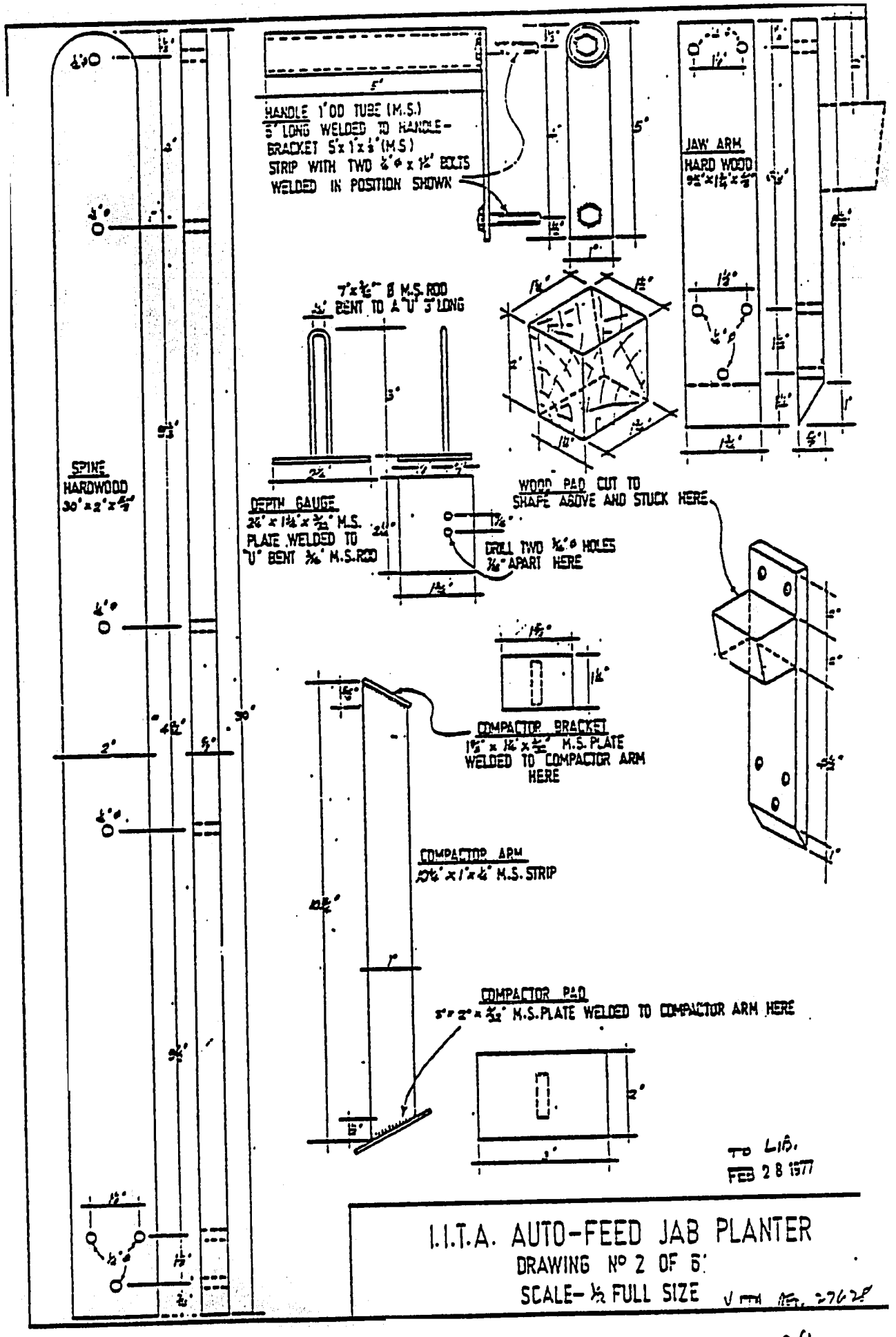
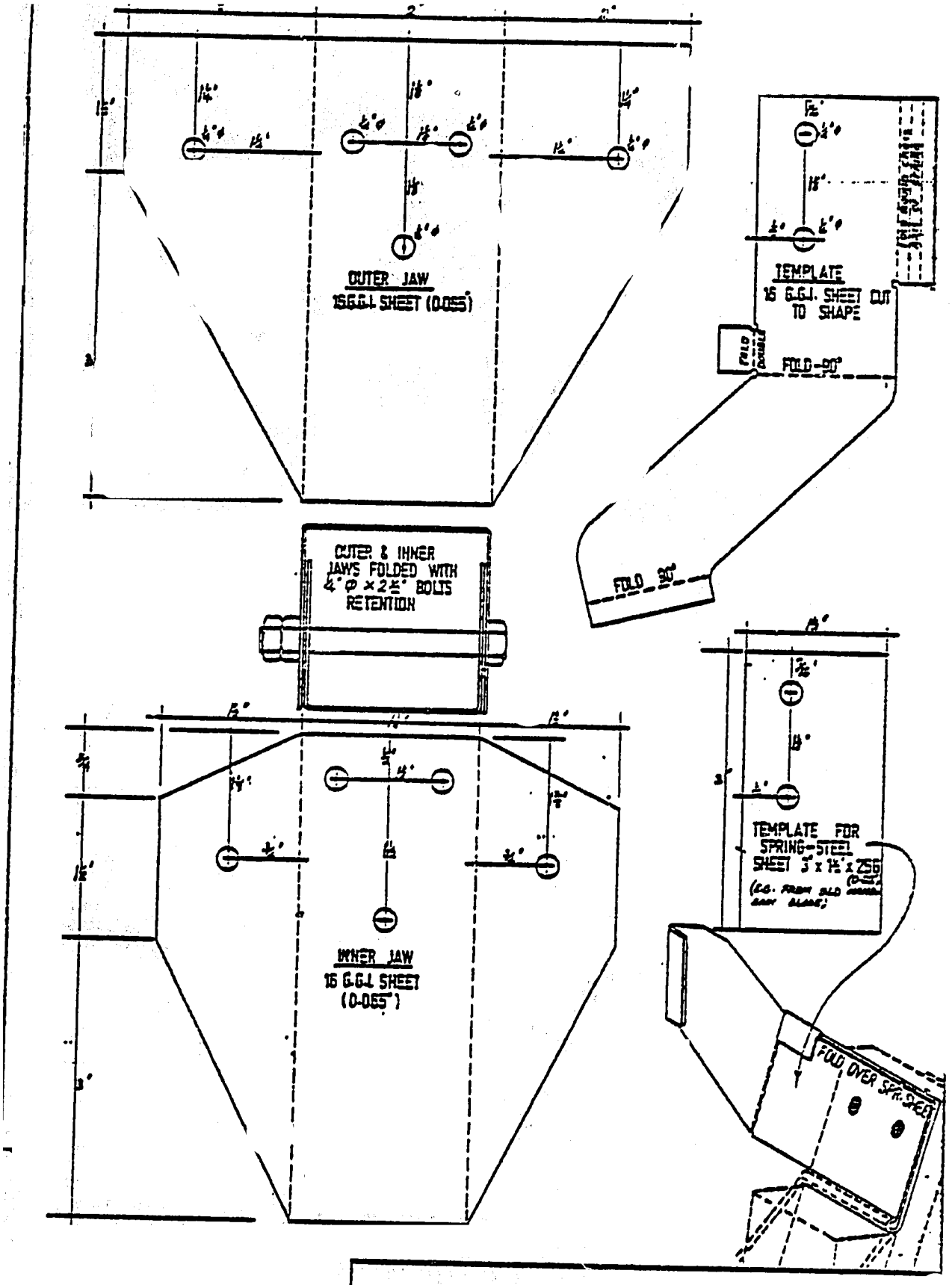
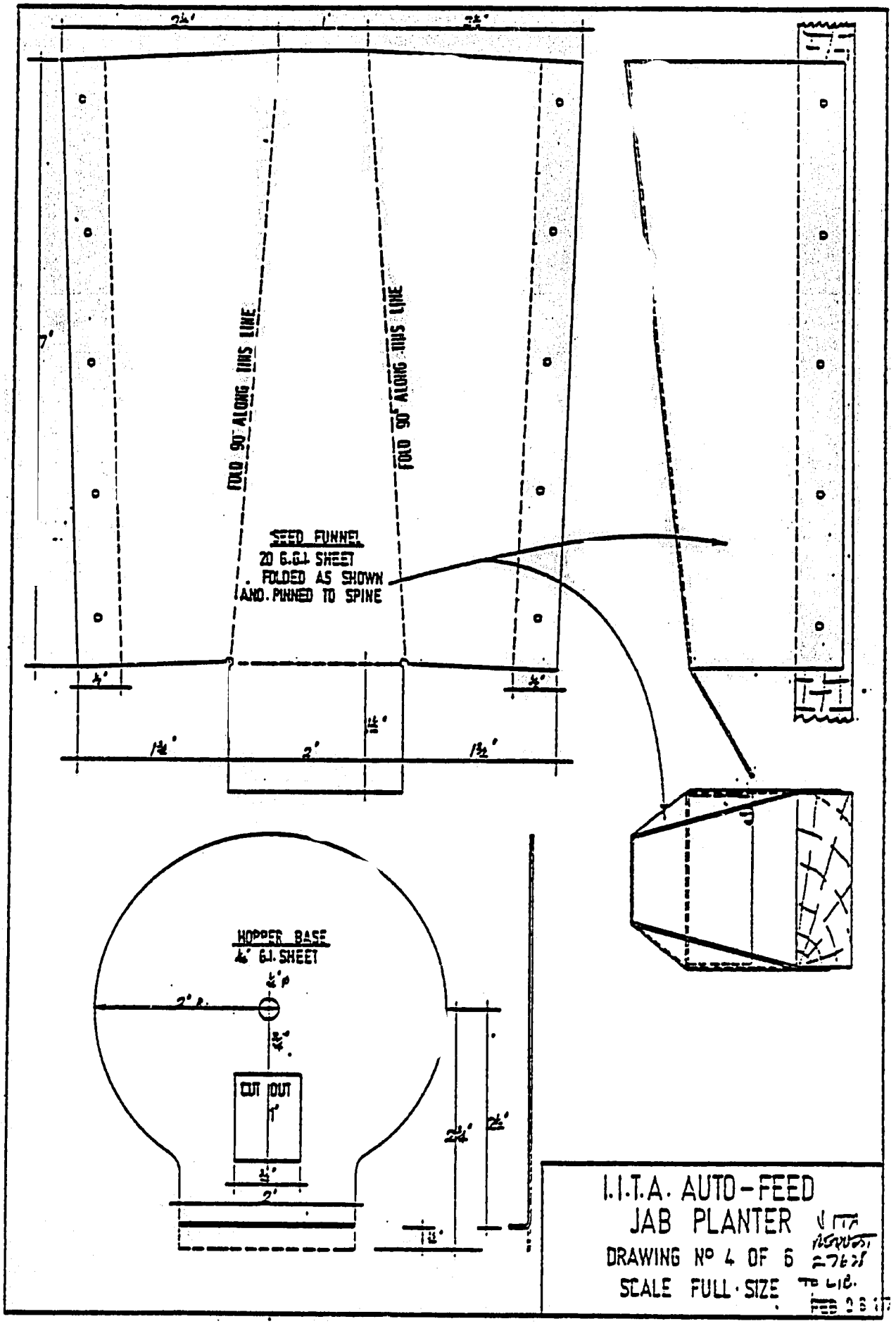

HANDLE 1" OD TUBE (M.S.)
5' LONG WELDED TO HANDLE-BRACKET 5"x1"x¼" (M.S.)
STRIP WITH TWO ½"Φ x 1½" BOLTS WELDED IN POSITION SHOWN
JAW ARM
HARD WOOD
7"x½" Ø M.S. ROD BENT TO A "U" 3" LONG
SPINE
HARDWOOD
30"x2"x
DEPTH GAUGE
2½"x1½"x 3/32" M.S. PLATE WELDED TO "U" BENT ⅜" M.S. ROD
DRILL TWO ½"Φ HOLES ⅜" APART HERE
WOOD PAD CUT TO SHAPE ABOVE AND STUCK HERE
COMPACTOR BRACKET
1½"x1½"x 3/32" M.S. PLATE WELDED TO COMPACTOR ARM HERE
COMPACTOR ARM
30½"x1"x¼" M.S. STRIP
COMPACTOR PAD
3"x2"x 3/32" M.S. PLATE WELDED TO COMPACTOR ARM HERE
TO LIB.
FEB 28 1977
I.I.T.A. AUTO-FEED JAB PLANTER
DRAWING Nº 2 OF 5
SCALE- ½ FULL SIZE

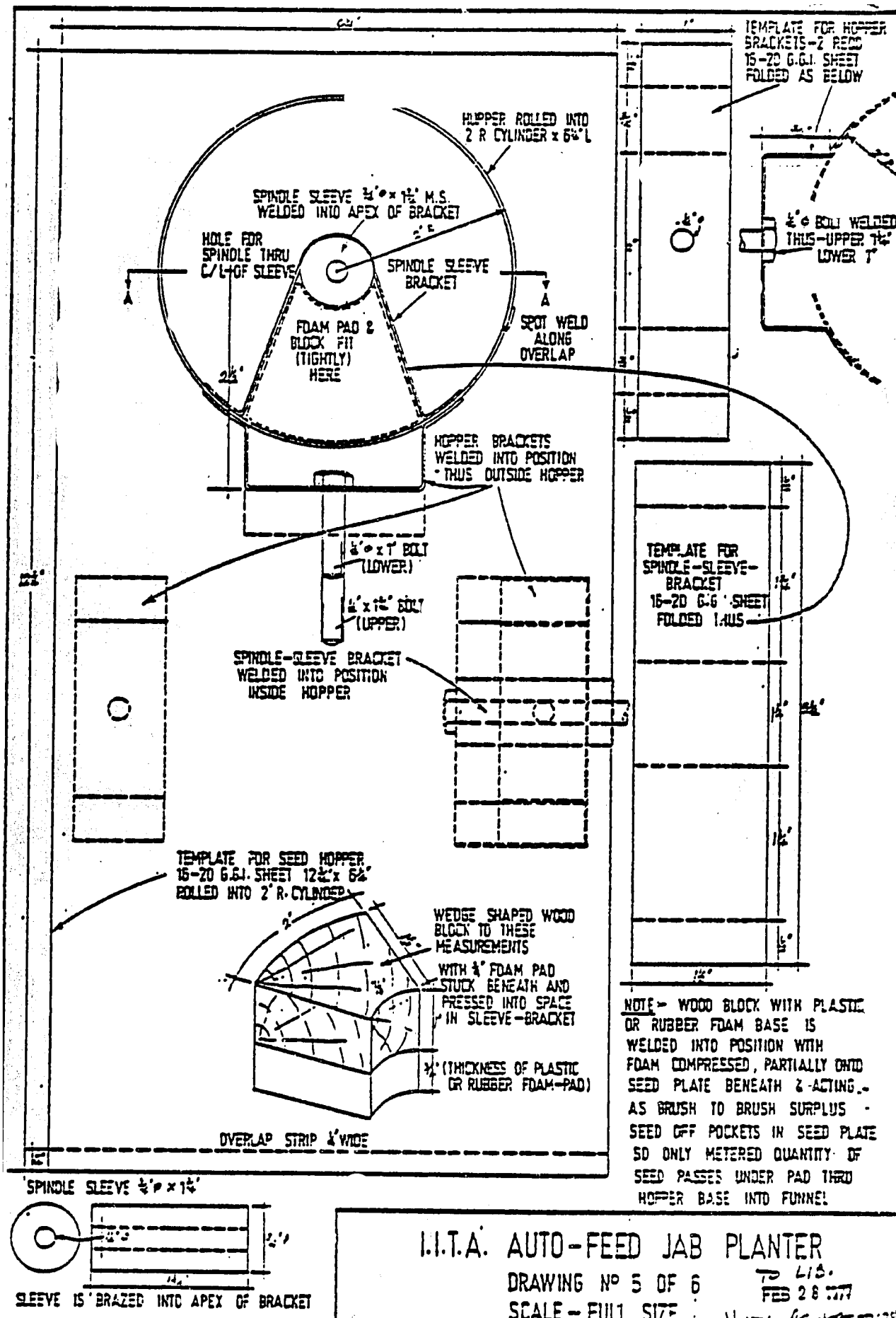


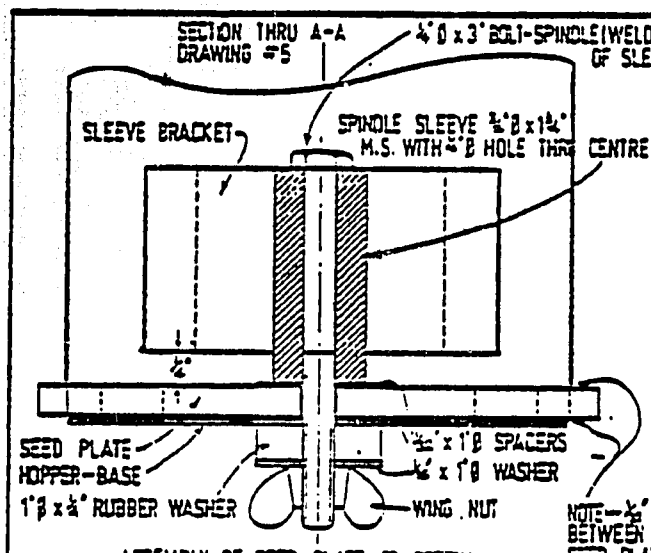
I.I.T.A. AUTO-FEED JAB PLANTER

DRAWING Nº 3 OF 6

SCALE – FULL SIZE

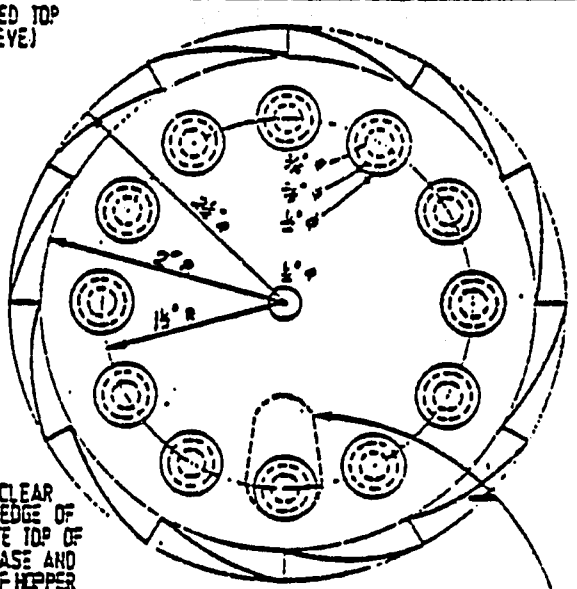

FOLD 90° ALONG THIS LINE
FOLD 90° ALONG THIS LINE
SEED FUNNEL
20 G.G.I. SHEET
FOLDED AS SHOWN
AND PINNED TO SPINE
HOPPER BASE
G.I. SHEET
CUT OUT
I.I.T.A. AUTO-FEED
JAB PLANTER
DRAWING Nº 4 OF 6
SCALE FULL SIZE


TEMPLATE FOR HOPPER BRACKETS-2 REQD 16-20 G.G.I. SHEET FOLDED AS BELOW
HOPPER ROLLED INTO 2 R CYLINDER x 6¼" L
SPINDLE SLEEVE ¾"ø x 1½" M.S. WELDED INTO APEX OF BRACKET
HOLE FOR SPINDLE THRU C/L OF SLEEVE
SPINDLE SLEEVE BRACKET
FOAM PAD & BLOCK FIT (TIGHTLY) HERE
SPOT WELD ALONG OVERLAP
¼"ø BOLT WELDED THUS-UPPER 1½" LOWER 1"
HOPPER BRACKETS WELDED INTO POSITION THUS OUTSIDE HOPPER
¼"ø x 1" BOLT (LOWER)
¼"ø x 1½" BOLT (UPPER)
TEMPLATE FOR SPINDLE-SLEEVE-BRACKET 16-20 G.G. SHEET FOLDED THUS
SPINDLE-SLEEVE BRACKET WELDED INTO POSITION INSIDE HOPPER
TEMPLATE FOR SEED HOPPER 16-20 G.G.I. SHEET 12¾" x 6¼" ROLLED INTO 2" R. CYLINDER
WEDGE SHAPED WOOD BLOCK TO THESE MEASUREMENTS
WITH ¼" FOAM PAD STUCK BENEATH AND PRESSED INTO SPACE IN SLEEVE-BRACKET
¼" (THICKNESS OF PLASTIC OR RUBBER FOAM-PAD)
OVERLAP STRIP ¼" WIDE
NOTE:- WOOD BLOCK WITH PLASTIC OR RUBBER FOAM BASE IS WELDED INTO POSITION WITH FOAM COMPRESSED, PARTIALLY ONTO SEED PLATE BENEATH & ACTING AS BRUSH TO BRUSH SURPLUS SEED OFF POCKETS IN SEED PLATE SO ONLY METERED QUANTITY OF SEED PASSES UNDER PAD THRU HOPPER BASE INTO FUNNEL
SPINDLE SLEEVE ¾"ø x 1½"
SLEEVE IS BRAZED INTO APEX OF BRACKET
I.I.T.A. AUTO-FEED JAB PLANTER
DRAWING Nº 5 OF 6
SCALE - FULL SIZE
FEB 28



ASSEMBLY OF SEED PLATE TO BOTTOM OF SEED HOPPER WITH ¼" SPACERS TO PERMIT ROTATION OF PLATE RESTRAINED ONLY BY FRICTION OF RUBBER WASHER COMPRESSED BY WING-NUT

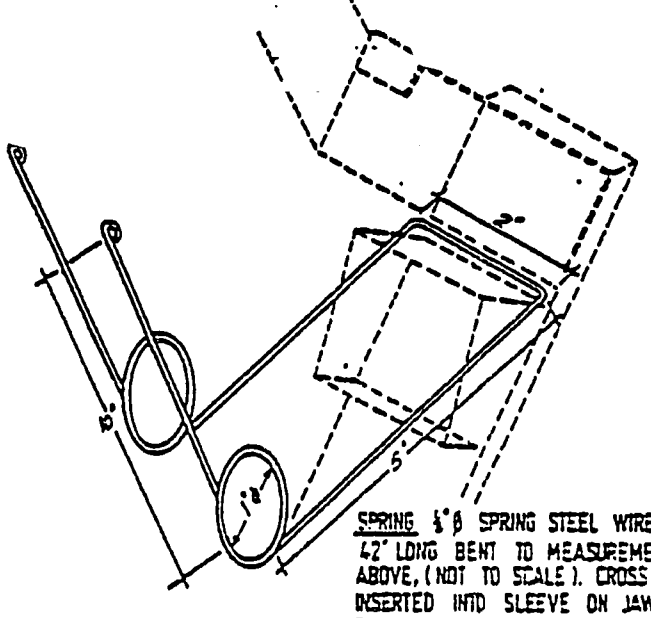
NOTE—¼" CLEAR BETWEEN EDGE OF SEED PLATE TOP OF HOPPER BASE AND BOTTOM OF HOPPER



3 SEED PLATE CUT FROM ¼" THICK ALUMINIUM PLATE

- #1 WITH 12 ½"Ø POCKETS FOR MAIZE
- #2 WITH 12 ⅜"Ø POCKETS FOR RICE, PEAS
- #3 WITH 12 ¾"Ø POCKETS FOR SORGHUM
- #4 FROM ⅜" THICK PLATE WITH 12 HOLES TO THIS SHAPE FOR FERTILIZER (≈ 4 GM. PER INJECTION)

MISCELLANEOUS HARDWARE	
¼"Ø x 3" BOLT-(SPINDLE)	1
¼"Ø x 2½" BOLT (JAWS)	1
¼"Ø x 1" BOLTS-(JAWS HANDLE ETC.)	11
¼"Ø x 1¾" BOLT UPPER HOPPER	1
¼"Ø WING NUTS	3
1/16" THICK, 1"Ø-⅜"Ø WASHERS	2
¼" THICK, 1"Ø-¼"Ø WASHER	2
⅛"Ø SPRING WIRE	42"
1"Ø x ¼" THICK x ¼" ID RUBBER WASHER	1
1/16" x ½" PANEL PINS	10
⅝"Ø x 1¾" M.S SLEEVE (¼"Ø HOLE THRU CENTRE)	1
4½"Ø x ¼" AL. PLATES (SEED)	3
4½"Ø x ⅜" AL. PLATE (FERTILISER)	1



SPRING ⅛"Ø SPRING STEEL WIRE 42" LONG BENT TO MEASUREMENTS ABOVE, (NOT TO SCALE). CROSS ARM (Z) INSERTED INTO SLEEVE ON JAW-ARM. FREE END SCREWED INTO EITHER SIDE OF SPINE JUST ABOVE POINT OF ATTACHMENT OF SEED FUNNEL. SPRING IS TENSIONED TO HOLD JAWS CLOSED.

I.I.T.A. AUTO-FEED JAB PLANTER

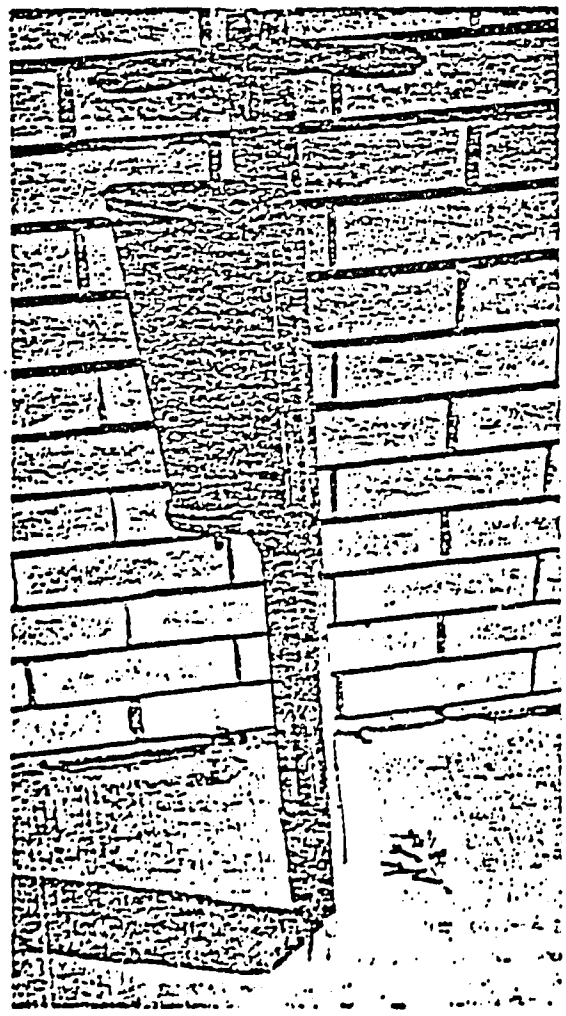
DRAWING Nº 6 OF 6
SCALE- FULL SIZE
(EXCEPT WHERE STATED)

U [illegible] REQUEST
[illegible]
FEB 28 1977
→ [illegible]

For the first row, we stretch a line between stakes and run the seeder along this line. The seeder has an adjustable row marker which marks the next row, so if we get the first row straight (easy when using a tight line), all the other rows in the planting will be straight too.

To make the furrows prior to hand sowing we use our Planet Junior garden plow, one of the high-wheel types that you find almost everywhere, which are made by numerous companies. I'm not sure about the other brands, but ours comes with three different-sized furrows. For large seed such as peas and potatoes, we use the moldboard plow attachment. After sowing the seed, the plow is run first down one side of the furrow, then back in the opposite direction down the other side, closing the furrow and covering the seed neatly and very quickly. It is certainly a whole lot faster than using a hand hoe. For small seeds such as carrots, we use the small cultivator tooth on the high-wheel plow and then cover the seed by hand during sowing.

HAND-OPERATED JAB PLANTERS



A hand-operated jab planter.

For at least a century, most of the corn in this country was planted with jab planters. Two variations on the same idea were built, but both of them are basically glorified dibble sticks. The lower steel blade of the planter was jabbed into the ground, and then, by moving the handles, three or four kernels of corn were dropped from the planting box through a planting tube into the ground opened up by the blades. When the point of the planter was pulled out of the ground, the dirt fell around the seed.

Even after these planters were more or less obsolete, farmers used them to replant hills of

Gene Logsdon demonstrating the use of the jab planter.

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corn skipped by the horse-drawn planter.

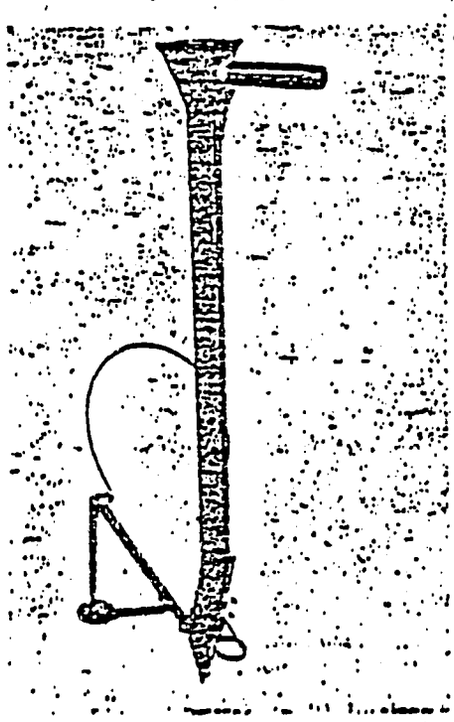
Today, a jab planter can come in handy for interplanting. For example, if you have a row of corn up and growing and want to plant pole beans beside the cornstalks, the hand planter is just what you need. You can walk along the row, plant the seeds where you will, and not disturb the soil around the already growing corn.

Fancy new models of the jab planter are still available and are used in research plot planting. They are available from manufacturers and suppliers of seed industry equipment. Old, used jab planters are often available at farm sales. You might pay $5 for one, or you might pay $35—you can never tell at an auction.

NORTH AMERICAN SOURCES OF HAND PLANTERS

Jab-Type Hand Planter

The Allan Machine Company has three models of jab planters which are hand fed, spring operated, have a metal barrel, and will adjust to different planting depths.



ALMACO Slim-Style Jab Planter model SHP-NBA
Allan Machine Co.

Model SHP-NBA

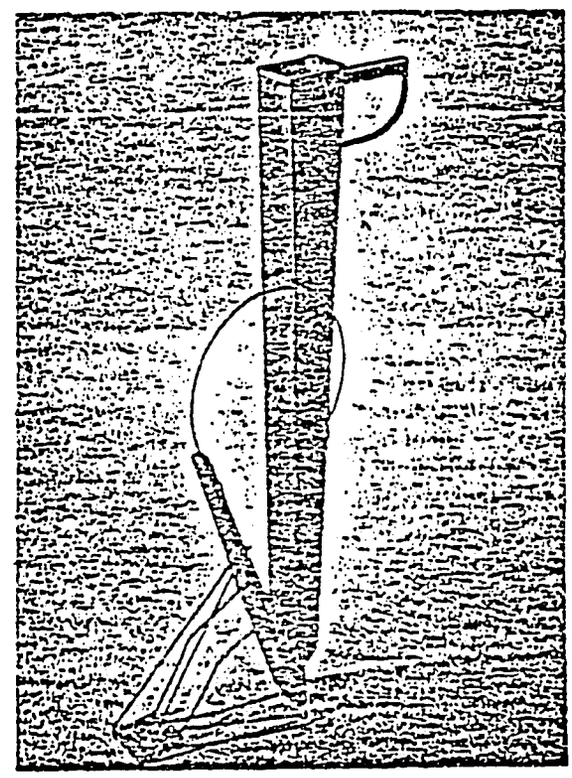
This is a slim-style unit and has a narrow, single barrel weighing 4½ pounds with a 1⅜-inch by ⅞-inch barrel opening.

Model HP-SBA

This is a single-barrel model which weighs 4 pounds and has a wooden back and a barrel opening of 2½ inches by 5 inches at the top.

Model HP-DBA

The third model has a double- or divided-barrel style and comes with a wood back.



ALMACO Single-Barrel Jab Planter model HP-SBA
Allan Machine Co.

Allan Machine Co.
P.O. Box 112
Ames, IA 50010

Potato Planter

Made of lightweight, corrosion-resistant ma-

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terials, this unit plants potatoes at adjustable depths. It has a one-year guarantee.

Hand Jab potato planter.
Esmay Products, Inc.

Esmay Products, Inc.
P.O. Box 547, Maple St.
Bristol, IN 46507

Jab-Type Hand Planter

Burrows offers two models, both made of sheet metal and hardwoods. A spring-operated, planting depth adjustment is provided. The 4-pound units are approximately 33 inches high and have an opening 2½ inches by 3 inches at the top of the barrel.

Burrows Equipment Co.
1316 Sherman Ave.
Evanston, IL 60204

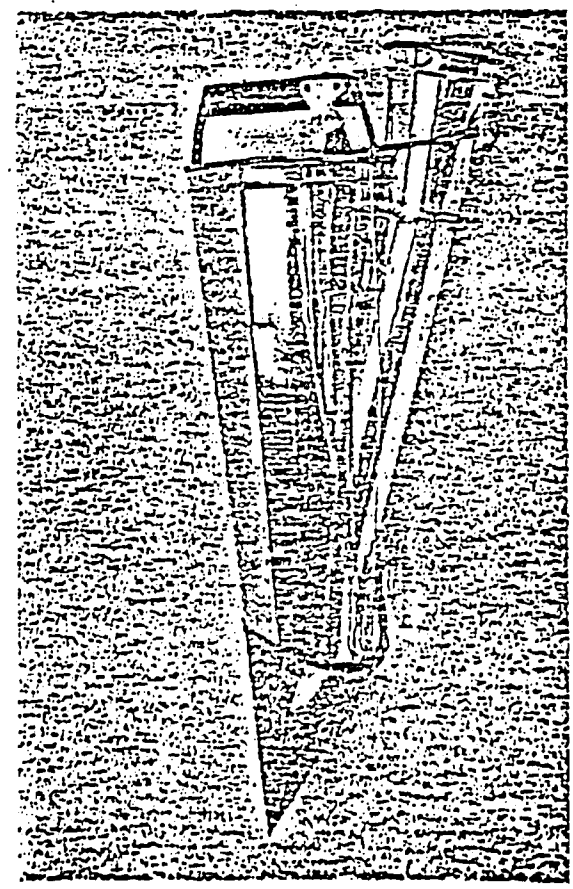
Maquinas Agricolas
Avenida Brazil No. 232
Marilia, Brazil

The Plantmaster

To operate the plantmaster, you select one of a range of seed-metering discs according to the seed size, adjust the foot, place the unit on the soil, and depress the handle. A seed is automatically inserted into the soil. Up to 2,500 seeds can be planted per hour at a depth between 6 and 66 millimeters.

Vandermolen Corp.
119 Dorsa Ave.
Livingston, NJ 07039

Richmond Gibson, Ltd.
Salisbury Rd., Downtown Salisbury
Wiltshire, U.K.



The Cumberland Plant Setter
Cumberland General Store

Cumberland Plant Setter

The Cumberland Plant Setter is a heavy

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in tank with a chute grooved and soldered to assure sturdy construction. High-carbon steel shovels with large, curved flanges rake the earth over the roots. It sets, waters, and covers tomato, tobacco, pepper, cabbage, sweet potato, strawberry, and other slip plants in one operation. Shipping weight is 12 pounds, height is 30 inches, and the diameter of the funnel chute is 4½ inches.

Cumberland General Store
Rt. 3, Box 479
Crossville, TN 38555

INTERNATIONAL SOURCES OF JAB PLANTERS

Hand Maize Planter

A single seed is placed in the soil automatically when the stick is inserted. It can be used with one hand and is suitable for small cultivation or experimental work. It weighs 0.5 pounds (0.2 kilograms).

Cossul & Co. Pvt., Ltd.
Industrial Area, Fazalgunj
Kanpur, India

Models PD, PCM, PC, PA

There are five variations of a basic two-handled, hand-powered, spring-operated jab planter.

Marila Industria E. Comercio Sasaki, Ltd.
Avenida Brazil, 232
Caixa Postal No. 196
Marila CEP 17.5000
Estado de Sao Paulo, Brazil

Hand-Operated Seed-Dressing Drum Plans

The object behind this drum was to build a seed-dressing device for village use, the design to be of fairly simple construction so that it could be made by local craftsmen.

The test drum used was an ordinary water tin of approximately 15 inches (330 millimeters) in diameter and 15 inches (382 millimeters) in height.

It was found that this drum had a capacity of 30 pounds (13.6 kilograms) of Chalimbana groundnuts, 35 pounds (15.9 kilograms) of soybeans or maize, and 38 pounds (17.2 kilograms) of fertilizer when filled correctly. In a durability test, a total of 1½ tons of fertilizer was mixed without signs of damage. The drum was also used for seed dressing of groundnuts and maize with satisfactory coverage performance and no apparent adverse effect on germination.

Intermediate Technology Publications, Ltd.*
9 King St.
London WC2E 8HN, England

THE HORN SEED SOWER

The simplest kind of broadcasting seeder, the Horn Seed Sower, consists of a reservoir which funnels seed into a long tube. The operator holds the tube, or horn, at the end closest to the reservoir, and with a skilled flex of the wrist, seed is flung out of the tube. It can be used to broadcast any seed to be grown in a solid stand and, in experienced hands, will result in a more even distribution of seed than would be achieved by hand alone.

SOURCES OF HORN SEED SOWERS

Horn Sower

This device sows primarily smooth grass or grain by swinging its horn back and forth. This sower spreads seed evenly from 30 to 40 feet at a rate determined by the adjustable feed gate in the base or tube joint and by rate of step. It comes with an 11-inch duck bag and an extension funnel attached to a tin distributing tube 22 inches long, 1¼ inches at the base and ¾ inch at the mouth. This sower has a capacity of ¼ bushel and a shipping weight of 1 pound, 8 ounces.

Cumberland General Store
Rt. 3, Box 479
Crossville, TN 38555

The Cyclone Seeder Co., Inc.
Box 68
Urbana, IN 46990

* Intermediate Technology publications can be ordered from International Scholarly Book Service, Inc., Box 555, Forest Grove, Oregon 97116.

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INFORMATION MEMORANDUM

SUBJECT: Comparative Advantages and Disadvantages of the Use of Root Trainers, Dibble Tubes, Plastic Bags, and Bare-Rooting of Seedlings*

Traditionally, nurseries in the lesser developed countries (LDCs) use either plastic bags for growing tree seedlings or bare-root seedlings grown in seed beds. Often, the nurseries are centrally located and seedlings have to be transported over long distances.

In the bare-root process, seedlings are often injured when they are removed from the seedbeds. Many of the roots are broken, root hairs (essential for nutrient uptake) are torn off and roots dry out easily. Such transplant shock results in a high incidence of mortality. Walters reported that Eucalyptus seedlings in Hawaii, when planted by the bare-root method, suffered as much as 85-95 percent die-back. Because of transplant shock, initial growth is slow, die-back may occur (it may take some more than 3 or more months to recover), and the seedlings are poor competitors with other vegetation.

With seedlings in plastic bags, the weight of the soil (as much as 1-2 kg.) limits the number of seedlings that can be transported (by vehicle and by hand). Frequently, adequate transport is difficult to obtain and planting sites are hard to get to, thus it is difficult and expensive to move large numbers of the seedlings in heavy and cumbersome plastic bags. This increases project costs and reduces the number of seedlings that can be planted during critical planting periods. Also, seedlings are commonly planted in the plastic bag after the bottom has been cut off, which can retard plant growth, cause die-back or increase mortality incidence because the seedlings are restricted from maximum access to available water and nutrients. This is most likely to be a constraint in semi-arid areas or during periods of minimal rainfall. Often, poorly supervised workers will even fail to remove the bottom of the bag which is usually disasterous.

Seedlings grown in plastic bags have poorly developed lateral roots, which are essential and needed to enhance initial establishment and to maximize nutrient uptake. However, excessive growth of lateral roots can cause strangulation of and injure the tap root. When seedlings are grown too long in bags, root-curl occurs, spiraling the root at the bottom of the bags.

When tubes are too small or seedlings are left too long in tubes, the roots at the bottom are deflected emerging from the tube. However, root deformation can occur in any container, especially if seedlings are held too long. Therefore good nursery management is of upmost importance regardless of what system or condition is used.

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*A portion of the information used in this memo was taken from the enclosed papers. (TECHNICAL SERIES #4, Compiled by: Mike Benge, S&T/FNR)

Once the root configuration is formed in the seedling stage, the root system continues to grow in the same pattern the rest of the life of the tree. Cannon reports that "The deleterious effects of abnormal root growth are seldom noticed in the first months or even after years of growth." "Rather, it is at more advanced ages and under adverse weather conditions when a deformed tree root system is most likely to fail to provide enough water or nutrients, or to anchor trees against strong winds." "Results indicate that although young seedlings suffer little from container-induced root deformities, several years after plantation establishment a significant proportion of these have grown poorly, fallen over, or died."

An alternative method to growing seedlings in plastic bags and in seed beds (bare-rooting) is a more modern method of containerization. Most of the widely used containers (i.e., root trainers and tubes) incorporate features such as vertical internal ribs designed to minimize root disturbance, to reduce root spiraling in the container and possible future strangulation problems, to maximize lateral root development and shape the roots into a form advantageous to the tree. Basically, the theory behind use of these types of containers is that, "If a tree seedling can be planted with a minimum of root exposure and disturbance, there will be less transplant shock, and survival and growth rates will be higher." [Kingham 1974 as cited by Tinus and McDonald].

Walters reports that for almost 20 years, little forestation was done with Koa (Acacia koa), Hawaii's most valuable native tree, because survival of bare root seeddlings was too poor to be worth the effort. However, several plantings of Koa seedlings (totalling about 75,000) grown in "Hawaii Dibble Tubes" (HDT) have survived at rates of about 85 percent. He goes on to say that survival of bare root Eucalyptus saligna plantings is unpredictable; one planting may result in 90 percent survival, the next in 10 percent. Survival of containerized (HDT) saligna plantings is predictably good; 91.2 percent with a standard deviation of 4.4.

Root trainers and tubes seem expensive when compared to the cost of plastic bags and seedbeds, however the use of them can result in considerable savings by reducing replanting and by increased growth. This often will more than off-set the cost of importing these containers. An additional cost is usually incurred because peat moss or a similar organic mix (which can be developed locally) is almost a necessity if maximum results are to be obtained from using these containers.

However, the costs of root trainers or tubes and buying or developing the planting medium are easily outweighed by the savings obtained by the (1) reduction of seedling mortality, (2) avoiding time lost in growing replacements, (3) avoiding the loss of growth time of replaced seedlings, (4) the advantages of reduced transportation requirements. Further savings are made from the increased

growth rates and stability of trees which have good established root systems. If the root trainers are carefully handled, a high proportion can be reused several times. Tubes last even longer. (If plastic bags cost one cent each, and each tube or cell of a root trainer costs eight cents but can be used eight times, the cost per unit is the same.) Some problems have been reported in the use of styrofoam block containers; such as poor durability and roots growing into the block, making the seedlings difficult to remove thus damaging the roots upon removal.

A seedling (along with the growing medium) grown in an average size root trainer will weigh much less than one-fourth the weight of one in a plastic bag and take up much less than one-fourth of the space. Therefore, there is a large savings in the transportation of these seedlings as well as a more efficient use of space and water in the nursery. The root trainers are more easily stacked in tiers when transported in trucks.

Also, it may be possible to increase seedling survivability and growth rates by impregnating the rootmass of the containerized seedlings with starch graft polymers (ref. Technical Series #2, The Potential of Starch Graft Polymers, "Super Slurpers" for Forestry and Agriculture). This could be a very valuable technology, especially for semi-arid and intermittent rainfall areas.

Some notes of caution--The medium used in root trainers and tubes will hold substantially less water than soil in plastic bags and similar containers. Therefore, these containers and seedlings may need more frequent watering in the nursery and especially during transportation over long distances. A way to deal with this problem is by removing seedlings from the containers and placing them in wax lined cardboard boxes which reduces water evaporation (see Walter's paper). This problem is much more critical with bare-rooting than with containerized seedlings.

Johnson and Menge state that "Most media components--such as pine bark, vermiculite, perlite, builder's sand and peat mosses--are devoid of mycorrhizal fungi." "In addition many nurserymen steam, pasturize or chemically treat media to eradicate harmful pathogens; this also eliminates beneficial organisms, such as mycorrhizal fungi." Also, composts and other locally developed organic mixes generally generate enough internal heat to kill off mycorrhizal fungi and other organisms.

Mycorrhizal fungi facilitate the uptake of nutrients, thus increasing plant growth, and "... have been reported to improve water transport." (Safin, Boyer and Gerdemann, 1971, as cited by Johnson and Menge) Mycorrhizae fungi are capable of transforming unavailable phosphorous into available forms for plant uptake. This is extremely important, especially in phosphorous deficient tropical soils.

Johnson and Menge report that in relation to chemical fertilizer applications required in commercial nursery operations, "phosphorous levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA (vesiclar-arbuscular) mycorrhizal fungi."

Ectomycorrhizae are associated with numerous conifers, such as pines, and with other trees, such as casuarina, eucalyptus, oak, beech, birch, willow and poplar. It is an established fact that in the absence of mycorrhizal fungi, the growth of Caribbean pine, casuarina, citrus and other trees will be retarded and in some cases, without inoculation, it may be impossible to establish these trees on some sites. Ectomycorrhizal fungi are associated with Basidiomycetes (mushrooms and puffballs) and Ascomycetes (cup fungi truffles). [Johnson and Menge, 1982].

I am enclosing selected papers relevant to the subject matter and have included some sketches that I have made showing various devices that can be constructed of locally available materials used in conjunction with root trainers. If further information or other Technical Series Papers are desired, please contact me. I would be interested to learn of your results if you do use root trainers or dibble tubes.

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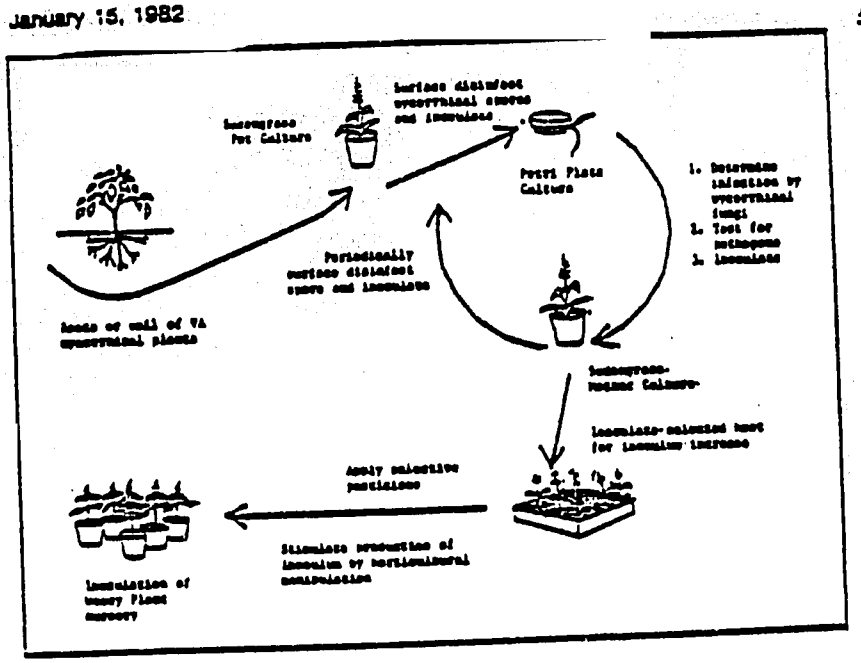

Fig. 1. Proposed scheme for commercial production of mycorrhizal inoculum.

Mycorrhizal inoculum costs

Item	Cost per pot
Cash Costs	
Management salary	7¢
Other wages & salaries	
Potting & inoculation	5
Moving pots	2
Pruning	1
Spraying	1
Watering (drip)	2
Harvesting	3
Grinding & packaging	2
Quality control	2
Maintenance mother culture	5
Plants & seeds	.2
Pots—4-inch	7
Media	2
Fertilizer	.3
Pesticides & other chemicals	1
Other production supplies	1
Repairs & maintenance	1
Insurance	2
Telephone	.5
Electricity & fuel	9
Taxes, licenses & bonds	1.1
Advertising	.3
Rent (land and/or buildings)	.8
Other cash expenses	13
Total Cash Costs	69.2¢
Noncash Costs	
Depreciation on machinery & equipment	2.2
Depreciation on buildings	.9
Interest on capital @ 12%	12
Total noncash costs	15.1¢
Total cost per 4-inch container	84.3¢

Fig. 2. Estimated costs for producing vesicular-arbuscular mycorrhizal inoculum on Sudan grass in four-inch pots.

Mycorrhizae may save fertilizer dollars

By Dr. Charles R. Johnson and Dr. John A. Menge

MYCORRHIZAL FUNGI are associated with the roots of nearly all plants. They form a symbiotic association termed mycorrhizae. Because of their importance to plant growth and their widespread distribution, mycorrhizae must be considered in all aspects of plant science and agriculture.

Mycorrhizal fungi are frequently categorized into four major groupings: ectomycorrhizae, vesicular-arbuscular (VA) mycorrhizae, ericaceous mycorrhizae and orchidaceous mycorrhizae. Ericaceous and orchidaceous mycorrhizae are associated with ericaceous and orchidaceous plants, respectively. Little information is available on these two types of mycorrhizae, and their economic importance is limited, so they

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Fertilizer cost comparison

Fertilizer: Material	Fertilizer: Rate[2]	Annual fertilization cost for 1,000 gallon containers[1]: Without VA mycorrhizae	With VA mycorrhizae	Potential savings
Micronutrients	2.5 lb/cubic yd	$22.14	$13.28	$ 8.86
Double superphosphate	5 lb/cubic yd	3.06	.91	2.15
Ammonium nitrate	Avg. 130 ppm N	37.81	26.47	11.34
Potassium chloride	Avg. 80 ppm K_2O	9.58	6.71	2.87
Other nutrients (Ca, Mg)		7.25	5.80	1.45
Totals		$79.84	$53.17	$26.67

[1]Based on January, 1981, price estimates.
[2]Fertilization rates based on commercial woody nursery operations using overhead fertigation system.
[3]Phosphorus levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA mycorrhizal fungi.

Fig. 3. Estimated fertilizer costs for woody landscape plants grown in gallon containers with and without VA mycorrhizae.

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will not be discussed further.

Ectomycorrhizae are associated with numerous conifers and other trees, such as oak, beech, birch, eucalyptus, willow and poplar. Ectomycorrhizal fungi are Basidiomycetes (mushrooms and puffballs) and Ascomycetes (cup fungi and truffles). They are characterized by a thick fungal layer, known as a fungal mantle, which covers the best feeder roots.

VA mycorrhizae are found on a majority of the angiosperms of the world. They do not visually alter the structure of roots and often cannot be detected without a microscope. VA mycorrhizal fungi are found in almost any field soil from arctic to tropical regions (17).

Both of these mycorrhizal types penetrate the outer regions of roots (cortical cells), but only VA mycorrhizae penetrate individual cells. Inside host plant cells, VA mycorrhizal fungi form branched structures known as arbuscules and ballon-like structures termed vesicles.

Arbuscules are thought to be the site of nutrient transfer between the symbiotic partners. Vesicles are likely storage organs that the fungus produces to store nutrient materials inside the plant host. Because a great majority of woody landscape species are infected by beneficial VA mycorrhizal fungi, this will be the only group of mycorrhizae discussed below.

What They Do

VA mycorrhizae are capable of improving growth of many woody landscape plants (10, 11, 12, 21). VA mycorrhizal fungi stimulate plant absorption of phosphorus and may be involved in uptake of other ions (4, 15, 16). Mycorrhizal fungi have been reported to improve water transport (19), although this may simply reflect improved nutritional status of mycorrhizal plants.

There is also evidence that mycorrhizae provide resistance to plant disease (20). Many scientists feel that VA mycorrhizal effects on disease are a result of improved phosphorus nutrition caused by the increased absorbing surface conferred by mycorrhizal hyphae.

Container production of ornamentals eliminates or significantly reduces populations of VA mycorrhizal fungi. Most media components—such as pine bark, vermiculite, perlite, builder's sand and peat mosses—are devoid of mycorrhizal fungi. In addition, many nurserymen steam, pasteurize or chemically treat media to eradicate harmful pathogens; this also eliminates beneficial organisms, such as mycorrhizal fungi.

Nurserymen have compensated for the absence of mycorrhizal fungi by applying luxury amounts of fertilizer and water to achieve desired growth. But high levels of nutrition and irrigation will not always be feasible, because of limited petroleum available for making inorganic fertilizer, high costs of fertilizer and rigid restrictions on water use. In addition, high nutrition and subsequent required pesticide applications are being more carefully monitored by environmental regulatory groups.

Inoculating container-grown plants with VA mycorrhizal fungi may reduce the need for current high levels of fertilizer, water and pesticides. This can be done, and it has some economic advantages.

Inoculum Production

Commercial production of VA mycorrhizal inoculum is being attempted at only a few places in the country. Currently, the only way to produce suitable quantities of inoculum is on roots of susceptible host plants. With the proper safeguards, mycorrhizal inoculum that is free of plant pathogens can be produced in commercial greenhouses.

Menge et al (13) proposed a scheme for producing inoculum as shown in Fig. 1. The inoculum is produced in pot cultures of selected hosts that have no root diseases in common with the host plant for which the inoculum is intended. For example, inoculum for citrus could be produced on Sudan grass but never on citrus.

Precautions must be taken to ensure the inoculum is free of nematodes, insects and harmful pathogens. Nemec (18) tested a number of fungicides that are compatible with producing mycorrhizal fungi.

Cost estimates of inoculum production can be generated using current greenhouse business analyses. A reasonably accurate cost estimate of mycorrhizal production, including technical labor and quality control, is approximately 84.3¢ for a four-inch container of VA mycorrhizal inoculum (Fig. 2). This would be enough to inoculate approximately 50 to 60 gallon containers.

A method similar to the one outlined above is being developed in England for large-scale commercial use (7). In this method, plants are grown in peat blocks that are standing in a shallow nutrient-flow culture. After VA mycorrhizal spores are produced in the peat blocks, the blocks are ground up for inoculation.

Inoculating Woody Landscape Plants

A number of methods have been used to inoculate plants with VA mycorrhizal fungi in greenhouse and nursery trials. Inoculation can be done when potting rooted cuttings into liner or gallon containers by placing five to eight grams of soil inoculum directly beneath roots of the cuttings. Phosphorus levels must be kept low (less than 34 parts per million for citrus) during all phases of plant growth, and other nutrients should be kept low for the first six to nine weeks of mycorrhizal infection.

Infection has also been accomplished by inoculating plants during propagation, shortly after root initiation, using mycorrhizal spores or soil inoculum. The greatest success with infection and subsequent growth response has been realized from early spring to summer.

Various methods have been used successfully to inoculate field-grown plants, including layering the inoculum under seed and banding the inoculum along plant rows (8). Commercial applications of mycorrhizal inoculum using fertilizer banding machinery were successfully carried out in a California citrus nursery (2). Some success has been achieved by pelleting seeds with inoculum (6) and by inoculating seed (3).

Growth and Economic Benefits

Because VA mycorrhizal fungi occur on a wide variety of woody plant species and improve growth of these plants, the potential of these fungi as commercial "biotic fertilizers" is enormous.

Researchers have shown that woody landscape plants in containers grow about as well with low to moderate nitrogen and potassium fertilization plus mycorrhizal inoculation as they do with luxury fertilization (10).

Benefits of these fungi on important tree fruits, such as citrus (13), avocado (14) and peaches (11), has prompted inquiries and demand for inoculum to improve plant growth.

Fertilization currently constitutes two to four percent of the cash nursery production expenses (5). This will continue to rapidly escalate.

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January 15, 1982

With inoculation, the expense of phosphorus fertilization could be reduced by approximately 70 percent. Current levels of nitrogen, potassium and micronutrients could be reduced by 30 to 40 percent.

This potentially could reduce fertilizer expenditures by 33.4 percent, for savings of approximately $26.67 per 1,000 gallon containers annually for woody plants under a typical fertilization program (Fig. 3).

Preliminary research has indicated that an additional benefit is improved establishment and survival of mycorrhizal plants in landscape soils (9). Reduced costs for better water and fertilizer uptake and improved plant survival should create consumer demand for such plants in the landscape.

Summary and Conclusions

Mycorrhizal fungi benefit growth of several woody landscape plants under controlled experimental conditions. Cost benefit figures indicate an economic advantage to using them. Container studies are being established at nursery sites to test the feasibility of using mycorrhizal fungi under commercial cultural programs.

With successful results from such tests and growing interest, more commercial sources of inoculum should develop. Current methods of watering and fertilizing will be radically changed in the next decade because of shortages. Using alternatives like VA mycorrhizae will become common.

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HILLSIDE DITCHING

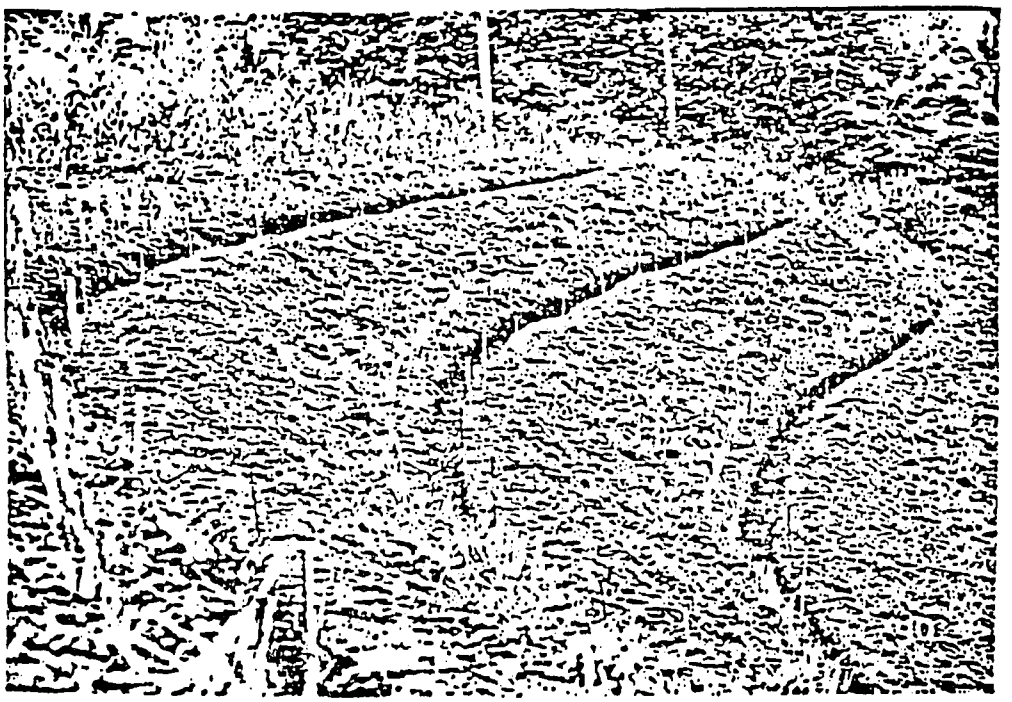


Figure 1

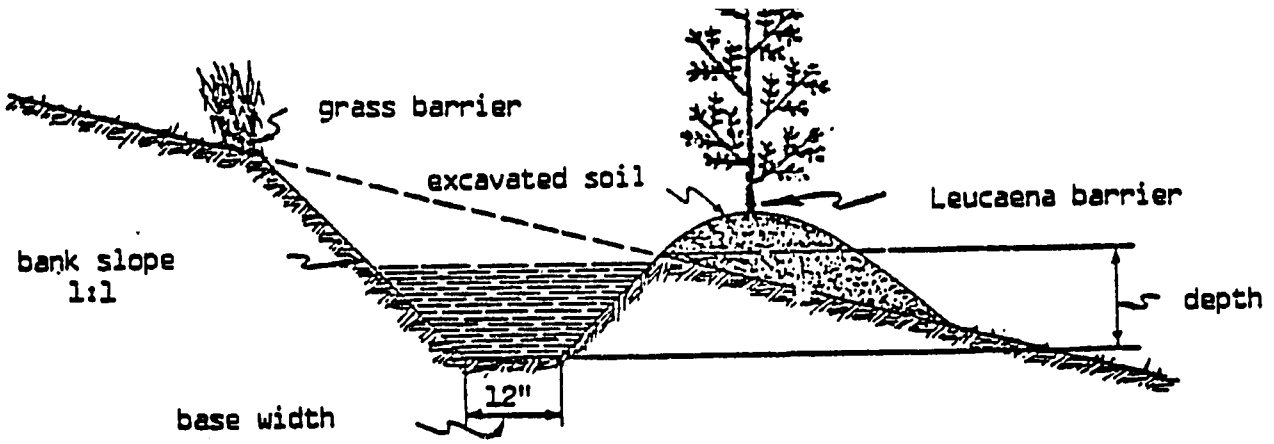
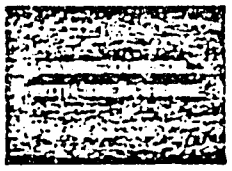


Figure 2

A World Neighbors Filmstrip

SAVING OUR SOIL WITH THE A-FRAME

World Neighbors believes that development cannot be accomplished alone, but is achieved by working and sharing together. Its goal is a better world and its means is the sharing of knowledge, talents, skills, money and most of all, love

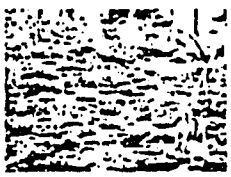


SAVING OUR SOIL
WITH THE A-FRAME

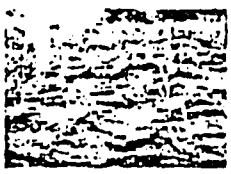
1. A handful of soil . . . how much is it worth? It's the most valuable resource on earth.

2. All the food we eat, clothes we wear and most of the things we use come from the soil.

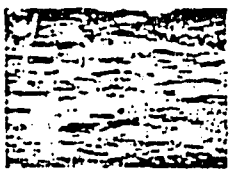
3. But if our lands are left unprotected, erosion can destroy our precious soil.



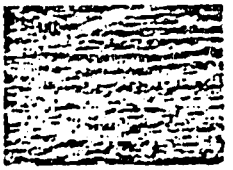
4. Rain is a blessing when it is soaked up by the soil, but long, heavy rains can also wash away the top soil and cut deep gullies in our fields.



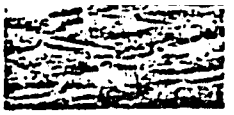
5. When planting on hillsides, we often plant rows running up and down. This is a bad practice.



6. Many farmers burn away corn stalks, leaves, grass, etc. This is also a bad practice. To make the soil better, these things should be turned back to the soil.



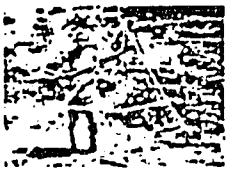
7. We need to protect our slopes and hillsides by planting all our crops on the "contour": that is, in rows running across the slopes and around the hillsides.



8. We also must construct contour canals or barriers running across the slopes and around the hillsides.

9. In rocky places, the rocks can be made into rock walls, which slow down the flow of the rain water and hold back the soil.

10. Where there are no rocks, level canals can be dug to absorb the rain water. Grass barriers on the upper side of the canals hold back the soil.



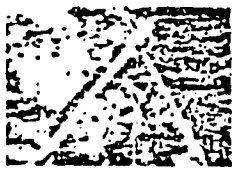
11. In order to mark level rows, we need a special tool which is called an A-frame. The A-frame is easy to make and easy to use, plus it is one of the most important tools in the world.

12. Because it can save our soil.

13. These are the only materials you need for making an A-frame: three poles, a piece of cord or vine, a rock and a machete. (Narrow boards, if available, can be used.)

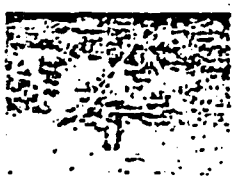
14. First, cross two poles at the top and tie them together securely. (If boards are used, nails can be used to help fasten them.)

15. Now tie a shorter pole across the other two to form the letter "A." Tie both ends securely.

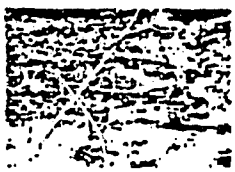


16. Now tie another length of cord to the top of the A and let it hang down below the crossbar.

17. Tie a rock to the end of the cord, below the cross bar.

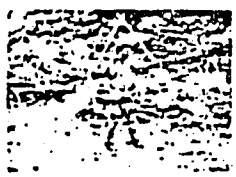


18. Now the A-frame is almost finished but before we can use it to mark level contours, we must find the point on the crossbar which will tell us when the two legs are in a level position.

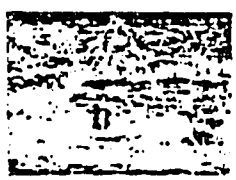


19. First, stand the A-frame upright. Using stakes, mark the points where the legs of the A-frame touch the ground.

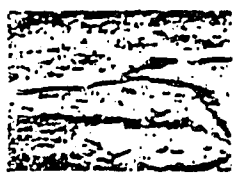
20. With a pencil, mark the point where the string passes the crossbar of the A-frame.



21. Move the frame so the placement of the legs is reversed.



22. The left leg now touches the stake where the right leg was, and the right leg touches the stake where the left leg was.

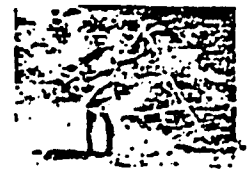


23. Again mark the point where the string passes the crossbar. Usually the two marks will be separate. If the ground is level, the two marks will be at the same place.

24. Now make a third mark halfway between the first two. This is the point on the crossbar which will tell us when the two legs are in a level position.

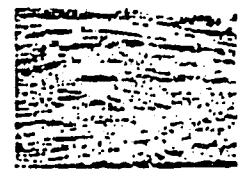
25. In order to keep from erasing this mark, cut a notch there with your machete.

26. When the weighted cord hangs directly in front of the notch, we know that the two legs are level.



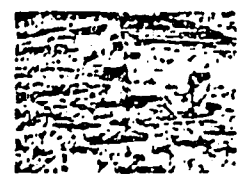
27. Now the A-frame is finished and marked, and we are ready to mark level lines on our hillsides.

28. In our country much of the land is very steep. Many other areas have gently sloping hillsides. Both should be protected with contour canals and barriers, and the crops should be planted in level rows across the slope.

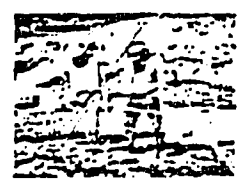


29. Study the area of your field on which you want to construct contour barriers. It is good to start near the top of your field.

30. First, cut a supply of stakes. These stakes are used for marking the level lines where the ditches will be dug or the rock barriers will be constructed.

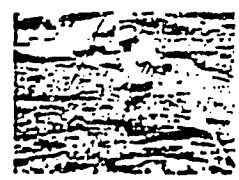


31. Drive the first stake at the edge of the field near the highest point. You will begin marking the contour lines at this point.

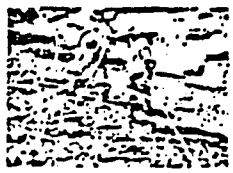


32. Place one leg of the A-frame just above and touching the first stake. Adjust the other leg so that the string passes the level position point you notched on the crossbar.

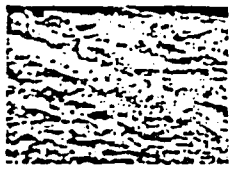
33. With the string passing exactly the point of the level position, drive another stake into the ground just below and touching the second leg of the A-frame.



34. Now pick up the A-frame and move it along, placing it so that one leg of the A-frame touches the stake you just drove into the ground.



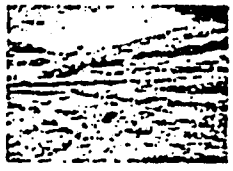
35. Again adjust the other leg of the A-frame until the string passes the level position notch. Drive another stake just below and touching the second leg.



36. Continue across the field this way. Now we have a level line of stakes which tell us where the first contour barrier will be constructed. But one contour barrier is not enough.

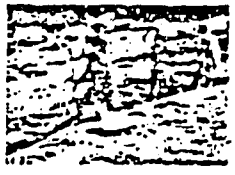
37. A hillside must be protected with one contour barrier for every five feet (1.5 meters) of difference in elevation. On steep hills, the barriers will be close together. On gentler slopes, they will be further apart.

38. Continue marking level contour lines across the field until you reach the bottom of the slope.

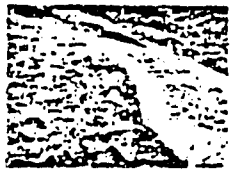


39. If the field is rocky, use the rocks to construct rock barriers along the level lines marked by the stakes.

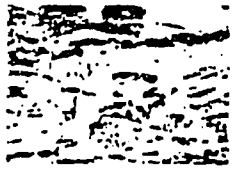
40. Some fields are not rocky, though. Use the A-frame in the same way to mark level contour lines across the field.



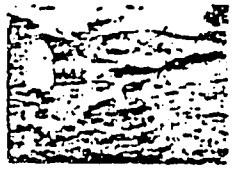
41. Then dig canals along the line of the stakes. The canal should be 1/2 meter wide and 1/2 meter deep.



42. Plant grass along the top of the canal. A tall, thick variety, such as elephant grass, napier grass or guinea grass, is best.



43. Be sure to follow the line of stakes when digging canals. Remember, these stakes mark the level lines across the field.



44. Use a hoe, or hoe and shovel to dig the canals.

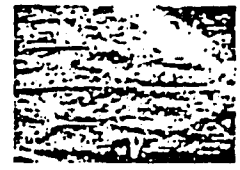
45. On some fields you can make both canals and rock barriers. In rocky areas, construct rock barriers. In other areas, dig canals.

46. When the heavy rains come, the grass or rock barriers will catch the soil and prevent it from being washed down the slope.

47. As the soil is caught behind the grass or rock barriers, terraces will gradually build up.

48. Within a few years, our contoured fields will look like this. As the terraces build up, not only is the soil saved, but the fields become easier to work because they are becoming more level.

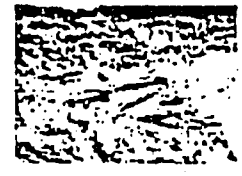
49. In many parts of our country, soils are already being protected with contour ditches.



50. Local farmers with the help of government agencies and international groups are beginning to build contour barriers and dig canals like these on their farms.

51. Farmers are beginning to protect their fields by planting their crops on the contour.

52. Even on steep rocky slopes like this the soil can be saved for reforestation.



53. Here's an example of what can be done. Slopes which are too steep or rocky for food crops can produce trees for lumber and fuel. The forests also help to conserve the soil.

54. So when we look at a hillside and see contour canals like these, we know that here lives a farmer who understands the value of his soil and how to conserve it.

55. He knows that the soil is the most valuable resource on earth.

THE END

QUESTIONS FOR DISCUSSION

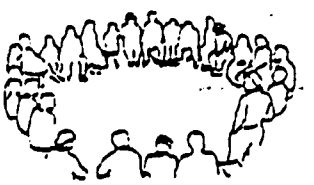
1. Why do you think soil is the most valuable resource on earth?
2. What are some good things rain does for the soil? What are some bad things rain does for the soil?
3. What are some bad farming practices which you have seen in your community?
4. What are some good farming practices which you have seen in your community?
5. What does "planting our crops on the contour" mean?
6. How can a farmer find the contour on his field?
7. Where is the best part of the field to begin marking the contour?
8. Ask someone to explain how to use the A-frame.
9. Name the different kinds of contour barriers.
10. How much difference in elevation should there be between barriers?
11. Does a steep slope have more or less barriers than a gentle slope?
12. After marking the field with stakes, what is the next step?
13. What are the dimensions of the canal?
14. How can rocks and grass be used?

NOTE: Join together with your neighbors to study recommendations given through a filmstrip or film. Many problems cannot be solved by one person working alone. These same problems can be solved when people and communities work together — with each person contributing and cooperating to achieve a common objective.

Materials for education in health, family planning, agriculture and community development.

WORLD NEIGHBORS

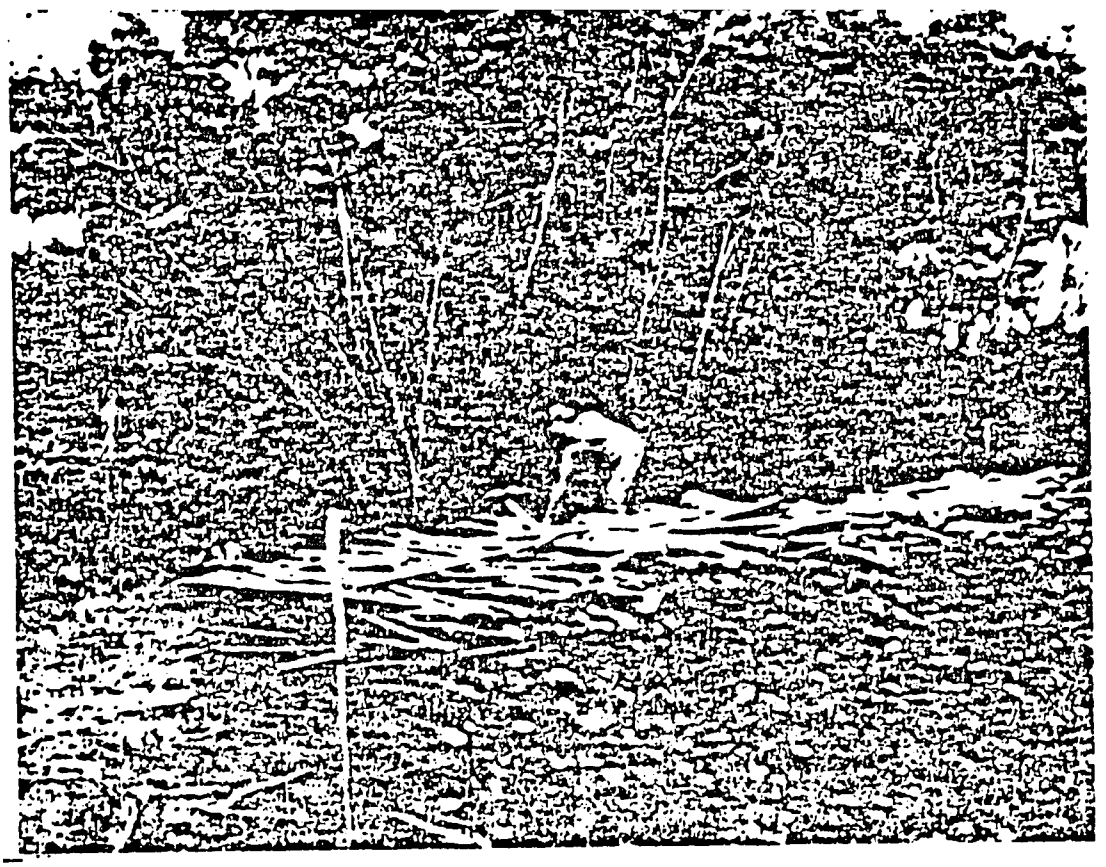
International Headquarters — 5116 N. Portland Ave. — Oklahoma City, Oklahoma 73112 U.S.A.



Overseas Development Materials

LIVING FIREBREAKS

Leucaena planted in Imperata (cogan) grass which shaded out the grass making an effective living firebreak (Cebu, Philippines).



Calliandra calothyrsus closely planted will shade out Imperata (cogan) grass making an effective living firebreak (Indonesia)

Benge

APPENDIX N

Interim rat control measures for Leucaena

Melanda M. Hoque and
Melvyn V. Garrison[1/]

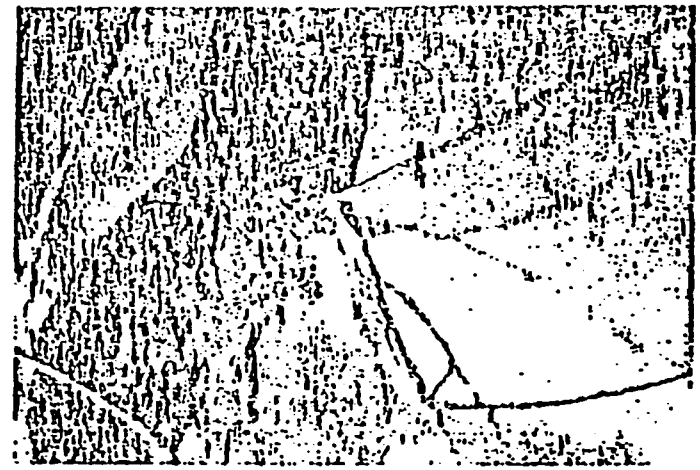


Fig. 1. Rats gnawed portions of bark of mature Leucaena.

Leucaena leucocephala, often referred to as the wonder tree, has not escaped from rat pests. Information reaching the National Crop Protection Center (NCPC) describe damage to Leucaena seedlings in some areas of the Philippines.

Halos (1980) reported that FORI researchers observed a mortality rate of 45% on Leucaena seedlings due to rat damage. NCPC had a damage count of 20 to 60% rat infected Leucaena trees at the dendrothermal pilot project of the National Power Corporation in Magsaysay, Occidental Mindoro.

We have received reports that damage was heavier during the dry than in the wet season. When we visited Mindoro in March and April this year, we observed a lot of damage on six-month to one-and-a-half-year old Leucaena trees. Younger plants were cut off and barks of older trees were gnawed close to the ground. When the bark is completely ringed, the upper portion dries up. Whenever reshooting occurs, regrowth starts where the bark is still intact, e.g., regrowth occur two inches above the collar. This damage either delays growth or completely destroys seedling.

Rat damage in Leucaena causes a growing concern among people involved in Leucaena research and production. However, good management of the pest requires a deeper understanding of the rat's ecology as it affects the crop.

Also, a sound and economical control program should be based on statistics of actual yield losses of Leucaena. This can be better measured if crop's actual losses can be quantified. Such loss may be in terms of reduced

1/ Researcher, and Research Physiologist, respectively, National Crop Protection Center, UPLB CA.

FORRI, UPLB
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timber yield or delay in maturation or both.

Rat control strategy used in food crops like rice, corn, coconut, etc. may be adopted *ad interim* in the absence of vital information on the pest vis-a-vis Leucaena losses.

This ad interim recommendation is based primarily on previous studies on such species as *Rattus rattus mindanensis*, *R. argentiventer* and *R. exulans* which also damage Leucaena. These same species which also affect food crops have been successfully managed with the sustained baiting method using anti-coagulant rodenticides.

From NCPC's preliminary rat control program in Leucaena in Mindoro comes this ad interim recommendations following the sustained baiting method.

Baiting Procedures:

1. Mix the recommended chronic rodenticides with the bait material (e.g.) rice shorts, corn grits or whole rice). Chronic rodenticides like Ratoxin, Racumin, Tomorin, Diphacin, and Liphadione are available in the Philippines.

2. Start baiting before the dry season or before food and water sources get scarce in the area or, at most, two weeks before planting the seedlings.

3. Select six baiting locations for two hectares, thus, your baiting locations are approximately 100 meters apart. Initially install two bait containers at each location and provide five to six tablespoons of bait material. Bait containers may be made from discarded oil/tin cans, bamboo tubes, etc.

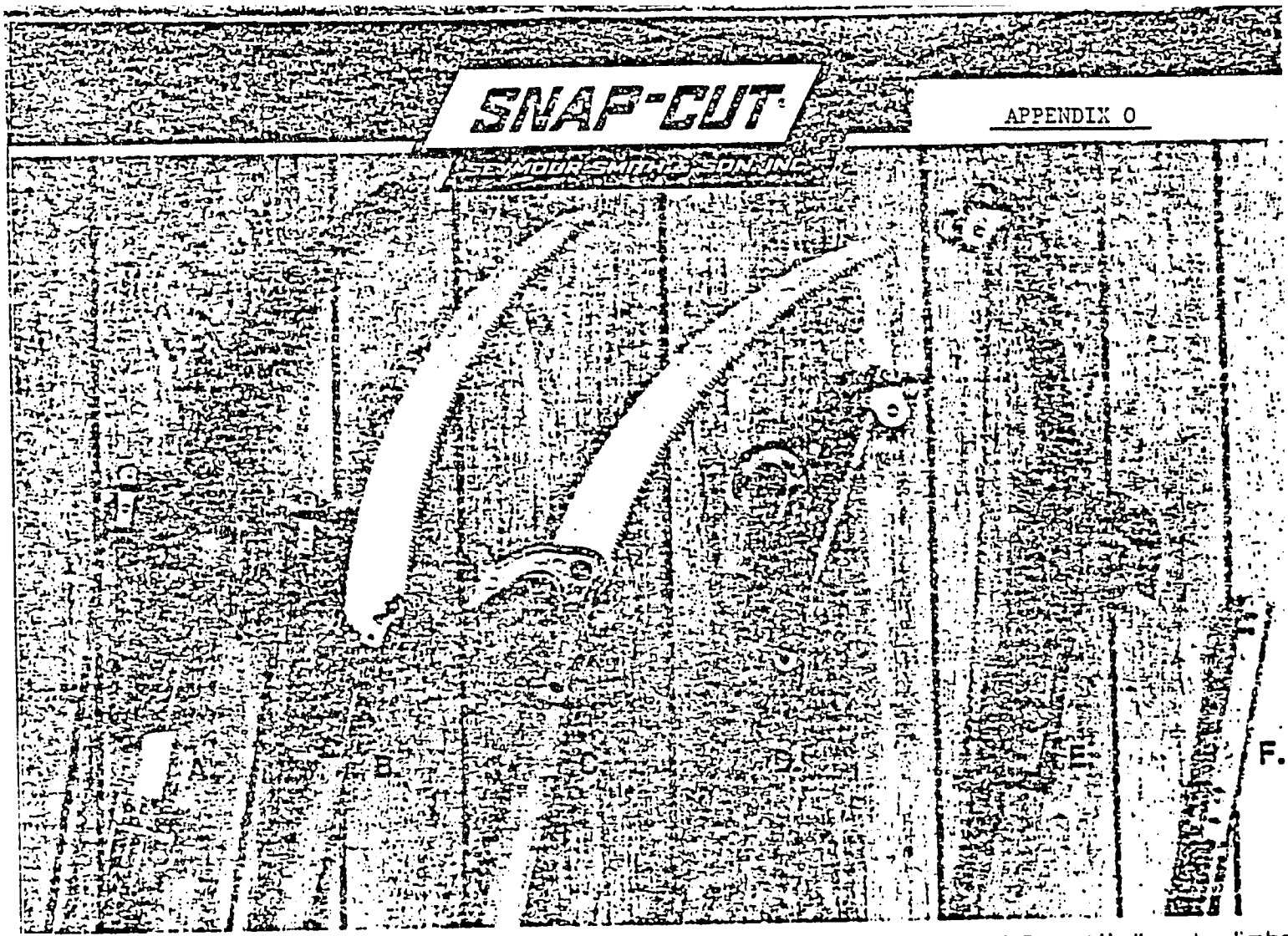
4. Check bait containers at least once a week. If all the bait has been eaten at one location, place two additional containers and provide six tablespoons of bait in all three. Check again after a week.

5. Continue adding bait and bait containers if you notice increase in rat activity, i.e., if consumption increases during your weekly visits.

6. If bait consumption decreases after several weeks of baiting, you may not add bait containers anymore. Visit the area once a week to keep track of animals immigrating to the area. This will help you determine when to resume adding bait/bait containers.

7. Remove and replace bait that becomes moldy or excessively wet.

Fig. 2. Twigs showing signs of rat damage.



A. 12 Foot Telescoping Fiberglass Tree Pruner

Cord-actuated pruner blade cuts limbs to 1-1/8" diameter. (A multipower leverage system increases your pull on the cord 15 times for quick, easy cuts.) The 16" needle point saw blade cuts on pull stroke to reduce binding. Telescoping fiberglass pole adjusts from 5' to 12'. Complete with pruning head, 12' cord, pole and saw.

81160	Model 333T. Complete. Sh. Wt. 7 lbs	$43.30
81165	Model 33. Repl. head w/saw, cord. Sh. Wt. 2 lbs.	17.40
81161	Model 302. Repl. pole (6'-12'). Sh. Wt. 4 lbs.	27.30
81038	Model 2011B. Repl. saw blade Sh. Wt. ½ lb.	6.40

B. 15 Foot Tree Pruner with Wood Poles

Cord-actuated pruner blade cuts limbs up to 1-1/8" diameter. (A multipower leverage system increases your pull on the cord 15 times for quick, easy cuts.) The 16", needle point, teflon-coated saw blade cuts on pull stroke to reduce binding. Three 5' wood poles may be quickly assembled and taken apart. Complete with pruning head, cord, three 5' poles, and saw.

81044	Model 34S-10. Complete. Sh. Wt. 7½ lbs.	$31.25
81045	Model 134H. Repl. head pole, 5'. Sh. Wt. 1½ lbs.	5.70
81046	Model 134E. Repl. ext. pole, 5'. Sh Wt. 1¾ lbs.	5.70
81038	Model 2011B. Repl. saw blade. Sh. Wt. ½ lb.	6.75

C. Pole Pruning Saw

Durable, 16" saw blade adjsuts to three different positions on the aluminum head. Large hook for pushing branches, raising ropes, etc. Built-in paint brush holder for applying tree wound paint. **Sawhead only. Order poles separately.**

81048	Model 20 Sawhead. Sh. Wt. 1 lb.	$12.35
81050	Model 102 Head pole for 81048. Length: 5¾'. Diameter: 1¼". Light, durable spruce. Sh Wt. 2 lbs.	15.40
81051	Model 103. Extension pole for 81048. Length: 6'. Diameter: 1¼". Light, durable spruce. Sh. Wt. 2 lbs.	17.60
81052	Model 1P12. Single section pole for 81048. Length: 12'. Diameter: 1¼". Light, durable spruce. Sh. Wt. 3¾ lbs.	25.30
81146	Model 106FG. Fiberglass pole. Fits 81048 head when equipped with 81147 adapter (below). Fits 81050 head pole directly. Sh. Wt. 2 lbs.	18.80
81147	Model 3FG. Adapter for attaching 81146 to 81048. Sh. Wt. ½ lb.	5.30
81049	Model 20B. Repl. blade for 81048. Sh. Wt. ½ lb.	6.00

D. Tree Trimmer Head Cuts 1" diameter limbs

Strong, malleable iron pruner has steel chain working through a ball bearing pulley for a powerful "center-cut" action. **Trimmer head only. Order poles separately.**

81030	Model 111. Trimmer Head. Sh. Wt. 1½ lbs.	$15.0
81050	Model 102. Head pole for 81030. Length: 5¾'. Diameter: 1¼". Light, durable spruce. Sh Wt. 2 lbs.	15.4
81051	Model 103. Extension pole for 81030. Length: 6'. Diameter: 1¼". Light, durable spruce. Sh. Wt. 2 lbs.	17.6
81052	Model 1P12. Single section pole for 81030. Length: 12'. Diameter: 1¼". Light, durable spruce. Sh. Wt. 3¾ lbs.	25.3
81146	Model 106FG Fiberglass pole. Fits 81030 trimmer head when equipped with 81147 adapter (below). Fits 81050 head pole directly. Sh. Wt. 2 lbs.	18.3
81147	Model 3FG. Adapter for attaching 81146 pole to 81030 trimmer head. Sh. Wt. ½ lb.	5.3

E. Tree Trimmer Head Cuts 1½" diameter limbs.

Heavy-duty, malleable iron pruner head has steel cable chain working through a ball bearing pulley for a powerful, "center-cut" action. **Trimmer head only. Order poles separately.**

81031	Model 12 Trimmer Head. Sh. Wt. 4 lbs.	$31.7
81032	Model 202. Head pole for 81031. Length: 5¾'. Diameter: 1¾". Light, durable spruce. Sh. Wt. 1½ lbs.	18.5
81033	Model 203. Extension pole for 81031. Length: 6'. Diameter: 1¾". Light, durable spruce. Sh. Wt. 2¼ lbs.	23.0
81107	Model 21. Tapered pole for joining 1¾" wood poles to 1½" wood pole. Length: 6'. Sh. Wt. 3 lbs.	22.0

F. Fiberglass Tree Pruner Pole

Fiberglass with foam core for greater dielectric strengh. Length: 6' Diameter: 1¼". Fits 81048 Pole Pruning Saw and 81030 Tree Trimmer Head when equipped with the 81147 adapter (below). Fits 81050 head pole directly.

81146	Model 106FG. Sh.Wt. 2 lbs.	$18.8
81147	Model 3FG. Adapter for attaching 81146 pole to 81048 saw head or 81030 trimmer head. Sh. Wt. ½ lb.	5.3

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INSTRUCTIONS FOR BUILDING A ZIG ZAG AIR SEED SEPARATOR

You can build a Zig Zag Air Separator easily from materials available on the market. In these instructions, the terms for specific parts refer to terms used on page 3 of the enclosed brochure, "Solve Your Separator Problems." These terms are underlined.

If you sell a Zig Zag Air Separator that you build, based on the design of Scientific Separators, Inc. you may be infringing on patent rights.

Make the Zig Zag Air Separator column from 3 inch PVC plastic pipe and 60° angle elbow/couplers (also PVC). The straight pieces should be approximately 14 inches long.

Make the cyclone collector from a metal can or wooden box with the bottom open. Make the bottom portion of the cyclone collector from canvas or rice bags (to control the seed cleanings) hung around the open bottom of the can or box.

Make the input hopper from a metal can, a plastic container or a wooden box. A wooden box is better, for the bottom should be slanted, narrowed to a one inch opening to feed the seed into the open portion of the tube housing the auger. A plastic or metal tube with a portion of the tube cut out 6 inches in length (top cut out to ½ the diameter of the tube) in which a 1 inch auger is inserted (could be slightly larger or smaller) to serve the same function as the air seal rotary feed. A "geared" motor is suggested as the power source for the auger, which would provide a slow-adjustable speed to regulate the rate of seed being fed into the air separator column.

Insert a one inch plastic pipe into a hole made in the air separator column and make it air tight to serve as the gravity discharge. Fit a window or hardware screen over the end of a straight piece of PVC plastic pipe (no. 10) and into a sleeve or coupler (no. 12) to prevent seed from going into the blower pipe. Connect the flex-tubing comming from the air source to the other end of the PBC plastic pipe (no. 11).

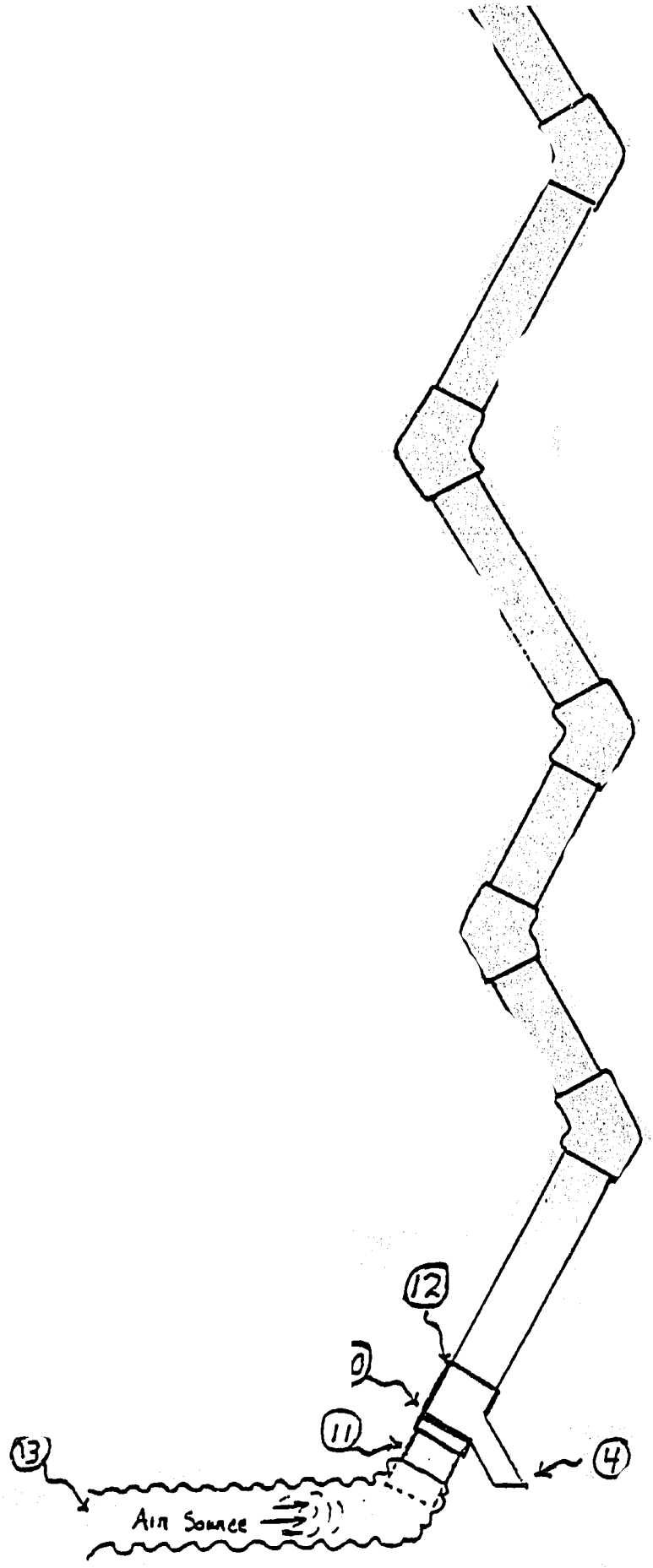
The air source (blower) can be provided by a gasoline powered ECHO - SOLO Back Pack Power Air Blower, Model PB400, or, if electricity is available, a similar electric air blower (see attached).

The throttle on the blower motor controls the speed of the motor, which in-turn regulates the air flow. The speed of the auger and rate of seed fed into the separation column is regulated by changing the gear ratio of the gear motor. The two are adjusted until the desired seed separation is obtained.

When assembled, fasten the Zig Zag Air Seed Separator to the side of a building, a large sheet of plywood or a tree for operation.

MDB

(CUT ALONG DOTTED LINE AND ATTACH TO FIGURE 1 on NEXT PAGE)



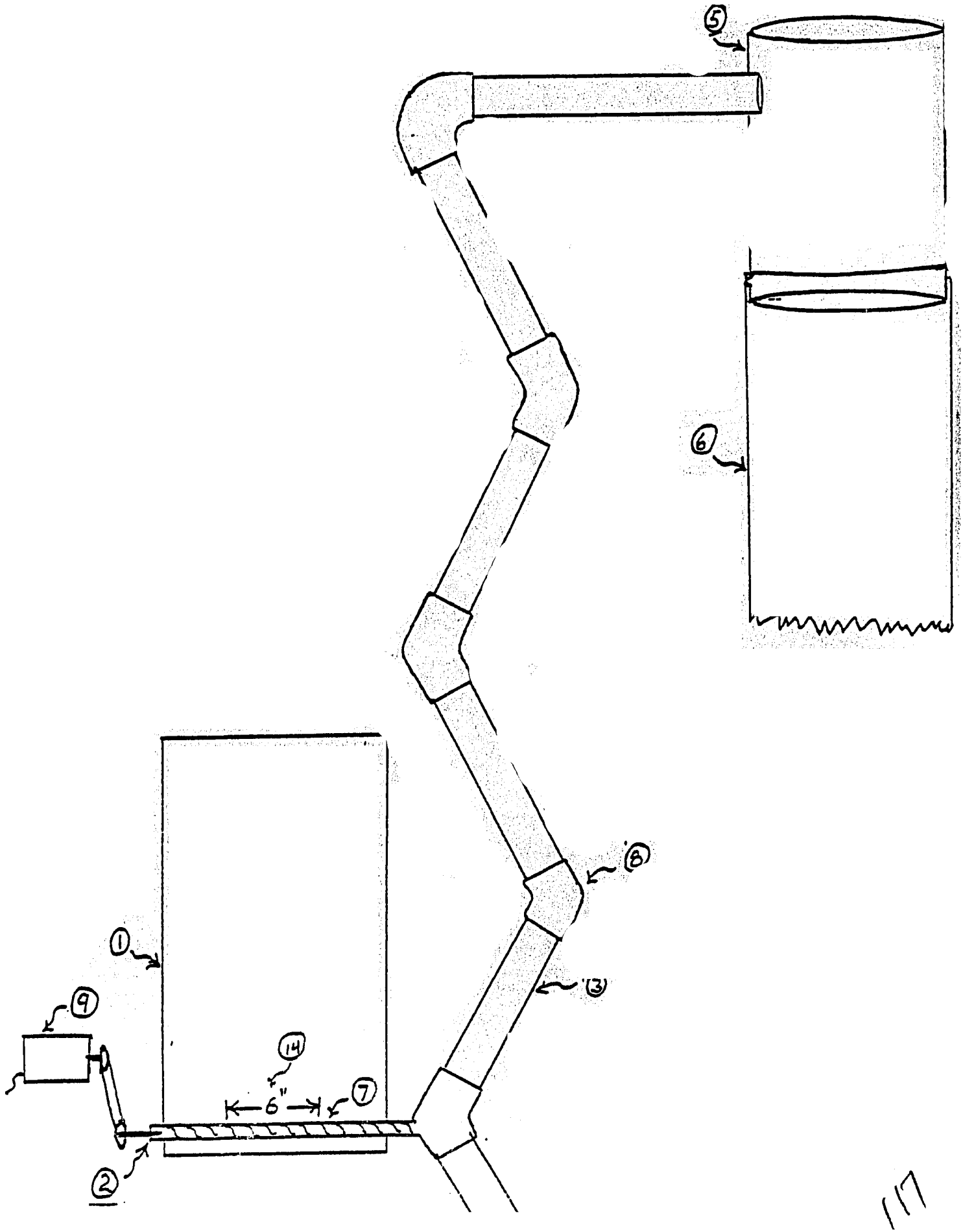
NOT DRAWN TO SCALE

LEGEND ON ATTACHED PAGE

FIGURE 2

116

FIGURE 1



LEGEND

1. Imput hopper made from wood and slanted at bottom so that seeds feed into auger.

2. Rotary feed made from a one inch auger (or from a wood drill bit or similar tool).

3. Zig Zag air seperation column made from straight pieces of PBC plastic pipe.

4. Gravity discharge for seed.

5. Cyclone collector made from a metal can or wooden box with open bottom.

6. Lower part of cyclone collector made from rice bags or canvas.

7. Auger housing made from a metal or plastic tube which has a 6 inch section cut out (top half of tube) to allow seed to enter the auger.

8. 60° angled elbows/couplers.

9. A gear motor (suggested) as the power source to drive the auger.

10. Screen (window or hardware screen) to keep seed out of the blower tube.
11. St
11. Straight piece of PBC.

12. Sleeve or coupler.

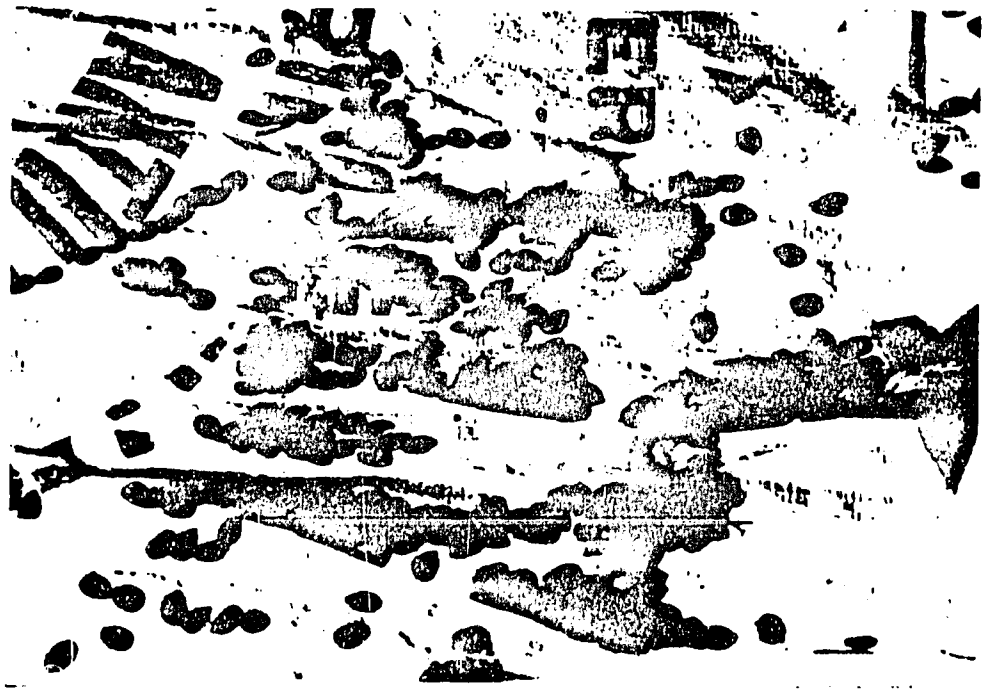
13. Source of air from blower (see attached for sample blowers).

14. A 6 inch opening in the auger housing to allow seed to flow into the auger.

The picture to the left shows a side view of the Zig Zag Air Separator secured to a tree and in operation. In the lower right of the picture, the air source - blower - is shown (#13), the lower left the gravity discharge container for the seed (#4), the middle (in the fork of the tree) the input hopper (#1), and the very top middle the cyclone collector - discard discharge (#5) to which a polyethelene tube is fastened , feeding the discards into a plastic container (#6). In the picture to the right, the input hopper (#1) is being refilled with seed.

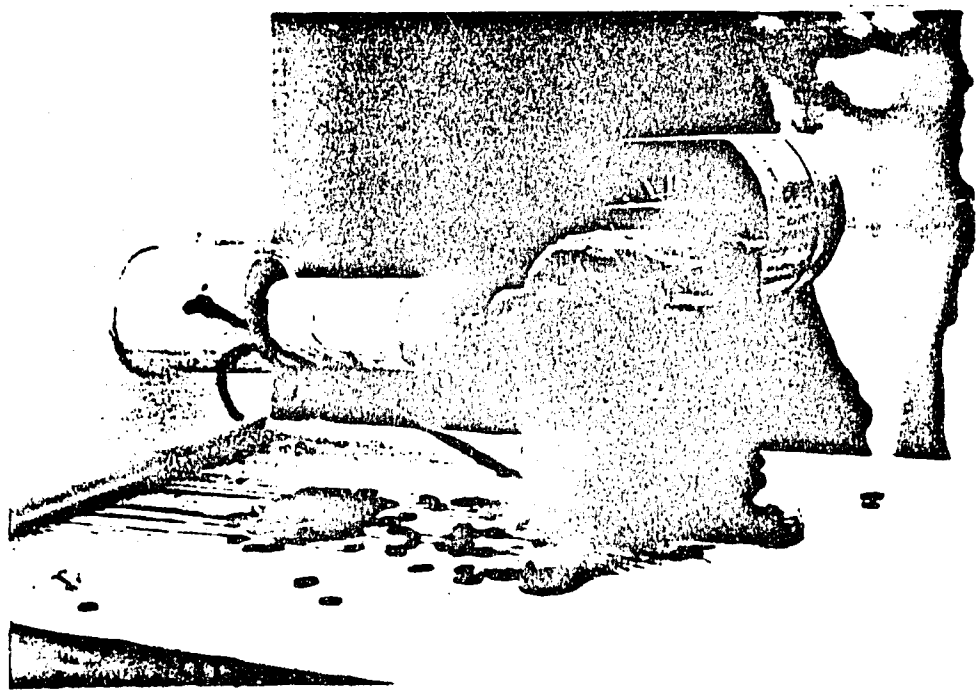
BEFORE -- Leucaena seeds before cleaning by Zig Zag Air Separator. Notice high concentration of trash and small, broken, fungus-covered, mutated and insect-damaged (small bore holes caused by tamarind weevils) seed.

AFTER -- Seeds are free of trash and damaged seeds. Also, the seeds are relatively uniform in size.



DISCARDS -- Although it is hard to see in the upper picture, all of the seeds were either damaged by insects, covered with fungus, broken, small or mutated. Approximately 8-10 % of the seed becomes discards when the seed is processed through the Zig Zag Air Separator. If the seed is sized by screening and processed through the separator, approximately 15 % becomes discards.

The picture below is of a AC-DC 1/15 HP gear motor with an electric speed control (#9). This is the power source for the auger (#7) which feeds the seed from the input hopper (#1) to the separation column (#3).



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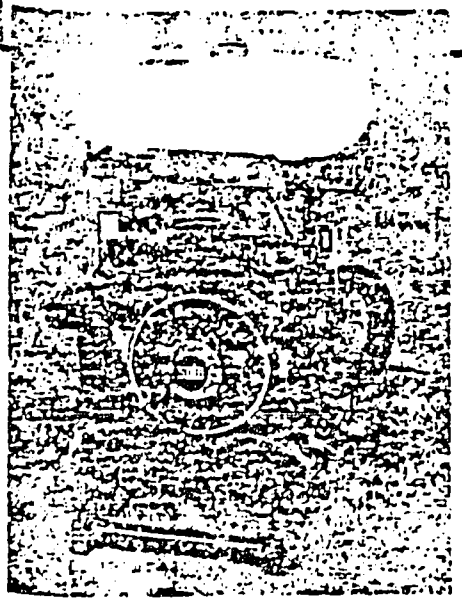


High Concentrate Mist Blower

Consists of engine/blower unit only. (You supply formula tank and transportation.)

Discharges mist through 8 moveable nozzles; reach is 20' up or across. DISCHARGE RATE: 1 quart to 4½ gallons/min. Powered by 12½ hp, 1 cylinder, 2 cycle SOLO engine. FUEL: two cycle mix of 1.25 to 1:50, fuel tank holds 3½ gallons. Available with teleblast gun nozzle for 35' reach in whatever direction nozzle is pointed.

13200 MIST BLOWER w/o FORMULA TANK. Supplied with 10mm (3/8") i.d. hose to connect to formula tank. For connecting hardware, see Formula Tank Connecting Set. Sh. Wt. 83 lbs **$953.50**

13201 MIST BLOWER with TELEBLAST GUN NOZZLE. For 35' reach in direction selected. W/o formula tank. With 10mm (3/8") i.d. hose to connect to formula tank. For connecting hardware, see Formula Tank Connecting Set. Sh. Wt. 95 lbs. **1,069.50**

Formula Tank Connector Set. All hardware needed to connect tubing from the 13200 or 13201 mist blower to the formula tank. Includes 2 nipples, 2 nuts, 2 O-rings and 2 clamps.
13202 Sh. Wt. 4 lbs. **7.50**

Formula Agitation Kit. All tubing and hardware needed to extract some moving air from mist blower and inject it into the formula tank for agitation.
13203 Sh. Wt. 1 lb **23.95**

OPTIONAL ACCESSORIES

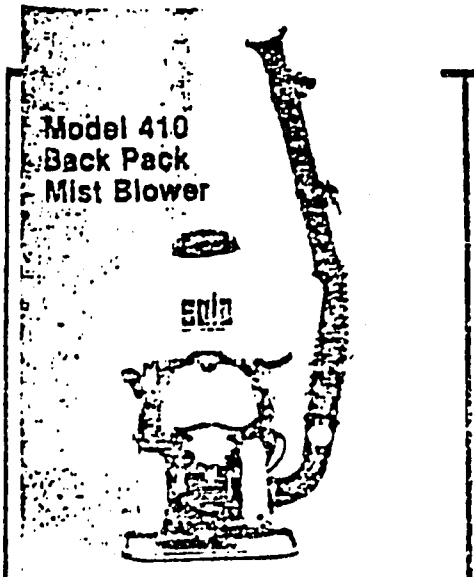
Hand Spray Gun Attachment. For low pressure (up to 30 psi), directional spraying. Includes wand with nozzle, on-off spray control, pressure gauge and 30' of tubing for connecting to mist blower.
13204 Sh. Wt. 10 lbs. **$72.95**

Herbicide Boom. Mounts on mist blower for no-drift herbicide applications. Boom is 7' long. Each end has a spring-loaded, flexible extension with 1 flat, fan-spray nozzle. Boom is fed by the mist blower hydraulic pump while the 6 blower nozzles are capped (see nozzle caps at right). 3 additional nozzles (optional, order separately) may be added for complete 7' wide coverage.
13205 Sh. Wt. 3 lbs **$165.95**

Optional Boom Nozzle.
13206 Sh. Wt. 4 ozs. Each **$19.25**

Nozzle Caps. Eliminate air blow from mist blower during boom usage. (8 required.)
13207 Sh. Wt. 1 oz. Each **.75**

Teleblast Gun Nozzle Only. Interchanges with 8-nozzle attachment on 13200 mist blower.
13208 Sh. Wt. 21 lbs. **269.95**



Discharges mist 25' horizontally, 19' vertically. Single-cylinder, air-cooled, two-cycle engine produces 3 HP and has fuel tank holding 9 U.S. quart. Formula tank holds 2.6 U.S. Gallons. Corrosion-proof plastic frame over tube steel reinforcements. Translucent formula tank with content level marks. Padded, adjustable carrying straps. DIMENSIONS 24" x 16" x 8". WEIGHT: 16 lbs. empty.

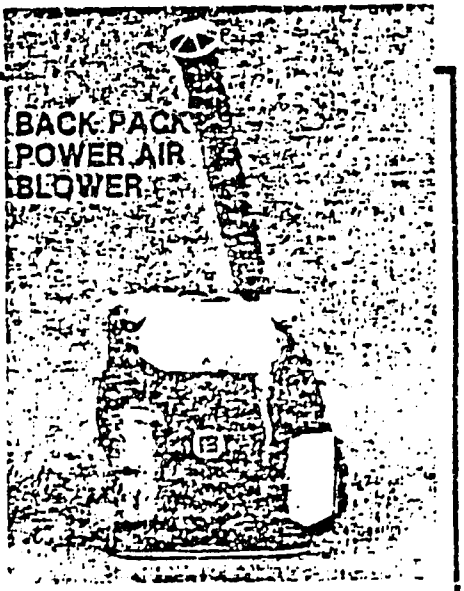
13194 Sh. Wt. 23 lbs **$411.50** PG
13197 Dusting Kit. Sh. Wt. ½ lb **13.95**

Dosage Pieces for Granulate Chemicals.
Use with 13197 to apply granular chemicals. Includes 9 dosage pieces for regulating output from 10 oz./min. to 148 oz./min.
13185 Sh. Wt. ½ lb. Per set of 9 pieces **$5.50**
13192 Flame Thrower Attachment for Model 410. Sh. Wt. 3½ lbs **84.50** PG

Discharges mist 33' horizontally, 25' vertically. Single-cylinder, air-cooled, two-cycle engine produces 5 HP and has fuel tank holding 1.6 U.S. quarts. Formula tank holds 3 U.S. gallons. Corrosion-proof plastic frame over tube steel reinforcements. Translucent formula tank with content level marks. Padded, adjustable carrying straps. DIMENSIONS 27" x 18" x 12". WEIGHT: 25 lbs., empty.

13196 Sh. Wt. 32 lbs **$537.50** PG
13198 Dusting Kit. Sh. Wt. 1¼ lbs. **34.95**

Dosage Pieces for Granulate Chemicals.
Use with 13198 to apply granular chemicals. Includes 9 dosage pieces for regulating output from 10 oz./min. to 148 oz./min.
13185 Sh. Wt. ½ lbs. Per set of 9 pieces **$5.50**
13193 Flame Thrower Attachment. Sh. Wt. 3½ lbs **84.50** PG



A 5 HP (SAE), 2-cycle, air cooled SOLO engine creates a powerful 225 mph air blast. Designed to be carried like a backpack, the Power Blower weighs a comfortable 22 lbs. With the accessory 5 foot extension tube attached, foresters can construct fire lines by blowing away the leaves, litter and duff from the forest floor - in much less time than is required when using fire rakes. Horticulturists can clean lawns, flower beds, and rock gardens. Maintenance personnel can "sweep" litter from around seats in theatres or sports arenas.

13175 Sh. Wt. 24 lbs **$427.50** PG
13176 SOLO 5' Extension Tube. Sh. Wt. 1½ lbs. **11.95**

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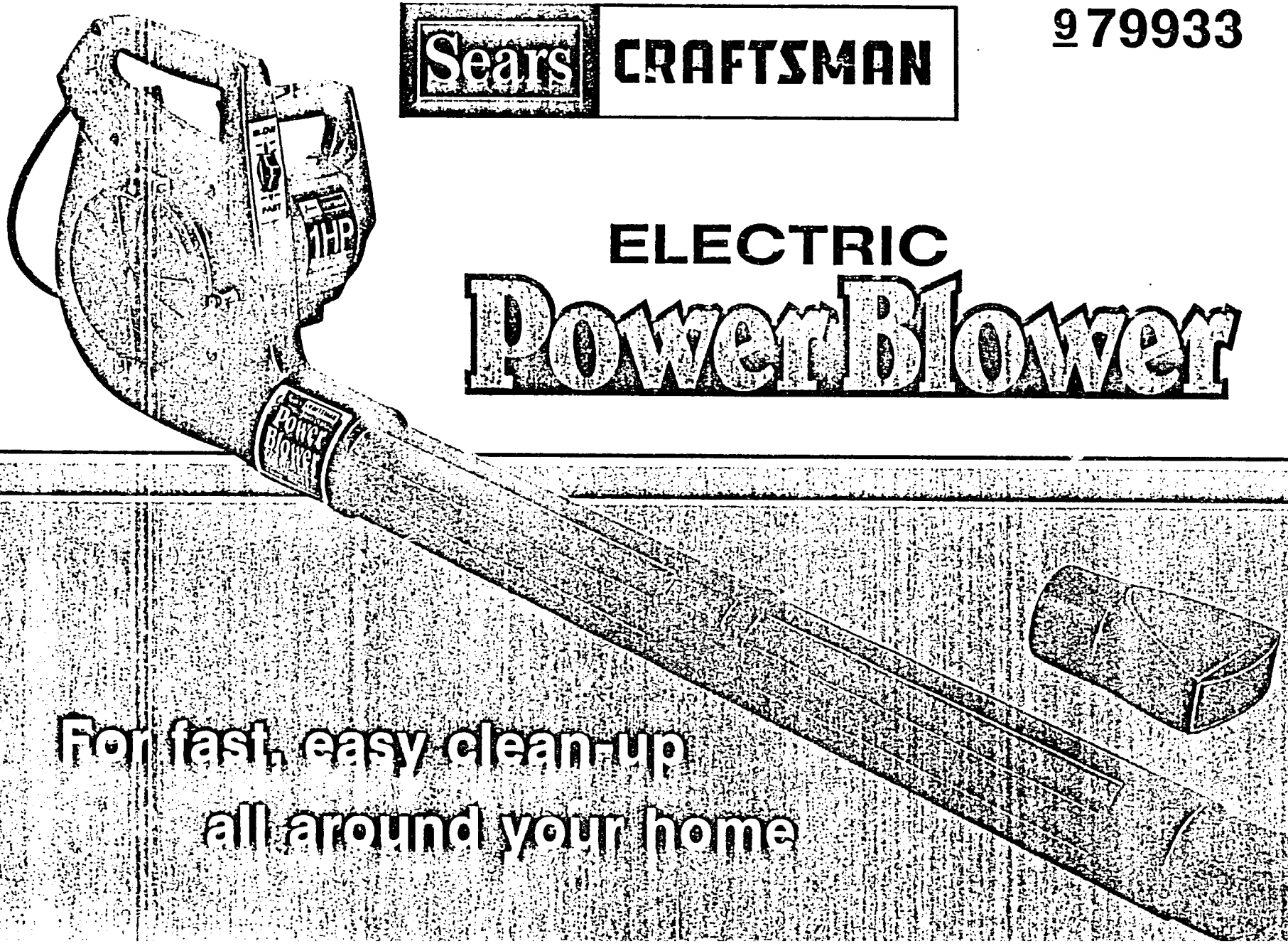

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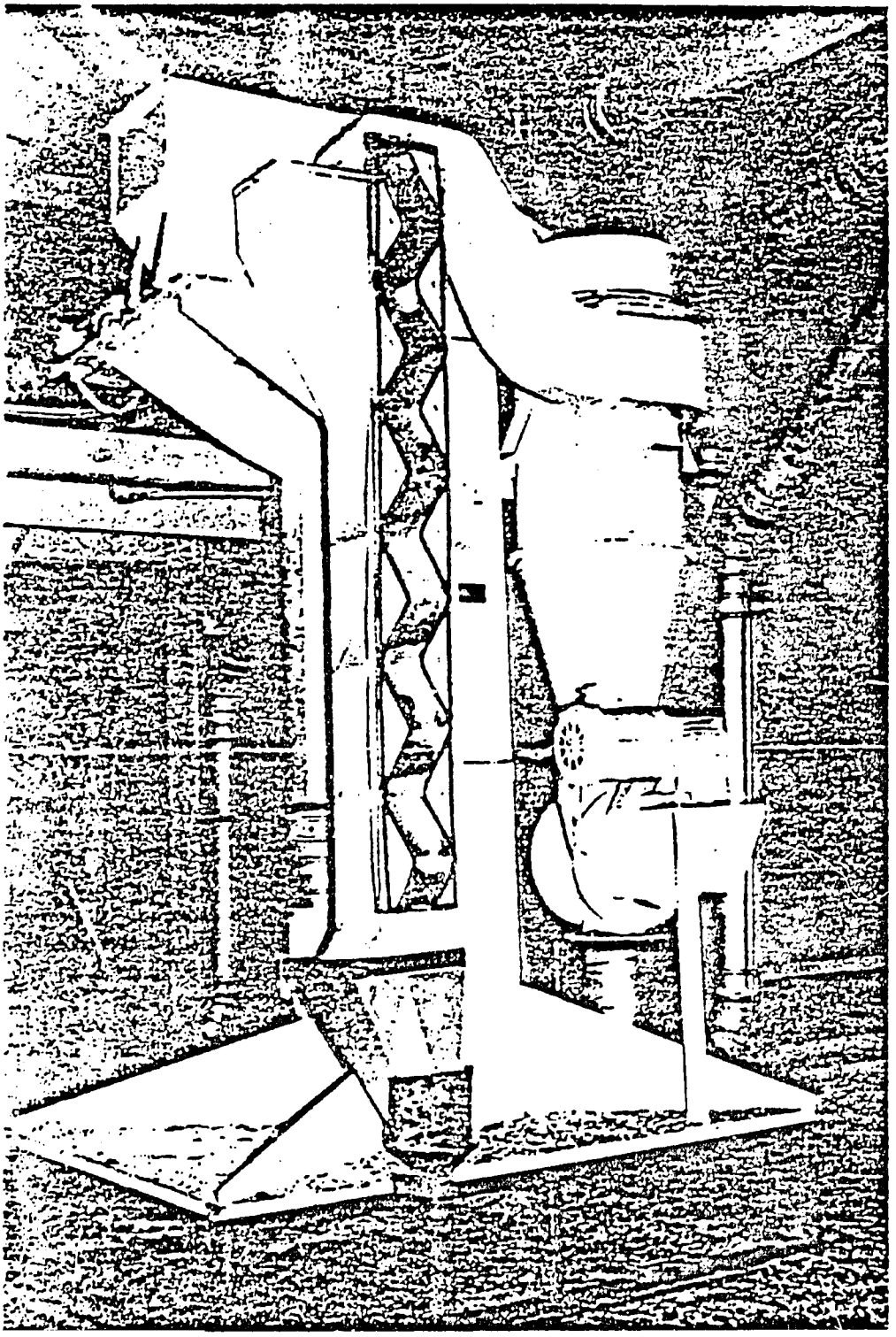

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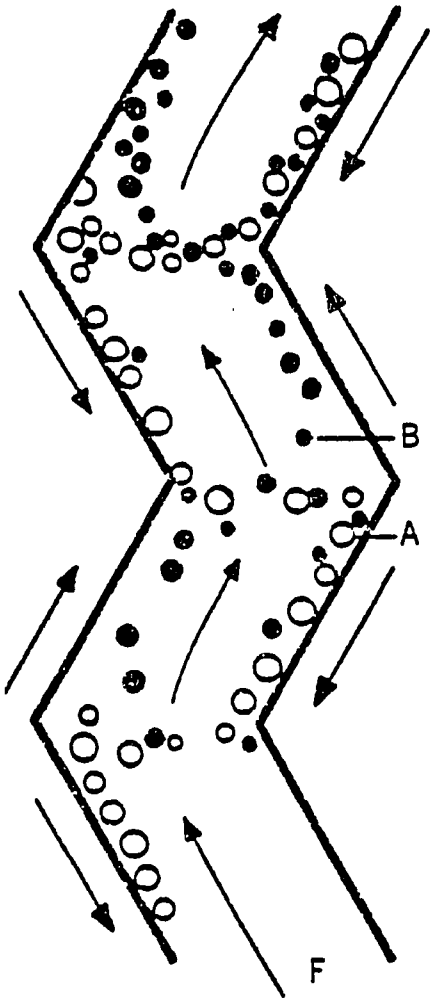

The sketch above depicts how separation of dry, particulate materials are made. Arrows on each side of the column indicate direction of material flow. Coarse, heavy, material, "A", cascades down the zig-zag column. Finer, lighter material, "B", is carried upward in the air stream.

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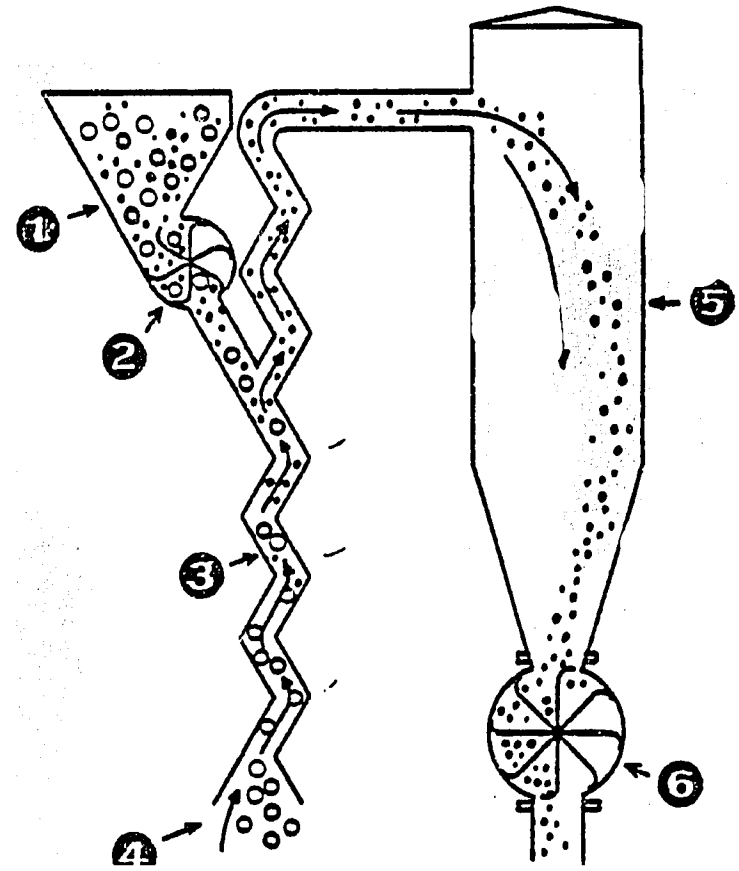
1. Input hopper
2. Air seal rotary feed
3. Zig-zag air separation column
4. Gravity discharge (heavy material)
5. Cyclone Collector
6. Air seal rotary discharge (light material)



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Lbs. Per Hour*	250	500	1,500	3,000	7,500	16,000	25,000
Column Cross Section	1½" x 4"	2" x 6"	3" x 12"	4" x 18"	6" x 30"	8" x 48"	10" x 60"
Blower:* H.P. CFM	½ 65	1 130	2 390	3 780	5 1,950	10 4,150	15 6,500
Cyclone:* Diameter Height	12" 3'	14" 3'8"	16" 4'3"	23" 5'10"	33" 8'8"	51" 14'4"	62" 17'2"
Overall: Length Width Height	4'4" 2'8" 5'2"	5'3" 3'9" 6'6"	6' 4'3" 7'4"	8' 4'9" 12'9"	10' 5'6" 14'	11' 6' 18'4"	12' 7'3" 21'6"
ADDITIONAL FEATURES Rotary Feed and Discharge	Std.	Std.	Std.	Std.	Std.	Std.	Std.
Variable Feed	Std.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.
Plexiglass Front	Std.	Opt.	Opt.	Opt.	N/A	N/A	N/A
Air Meter	Std.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.
Stainless Steel	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.	Opt.

*Capacities are based on average material encountered (bulk density 30 lbs. per cubic foot). Actual capacity, cyclone size, and blower horsepower will depend on actual material to be separated. Actual capacities will range from ½ to 3 times the listed capacities depending on bulk density and aerodynamic character of the material.

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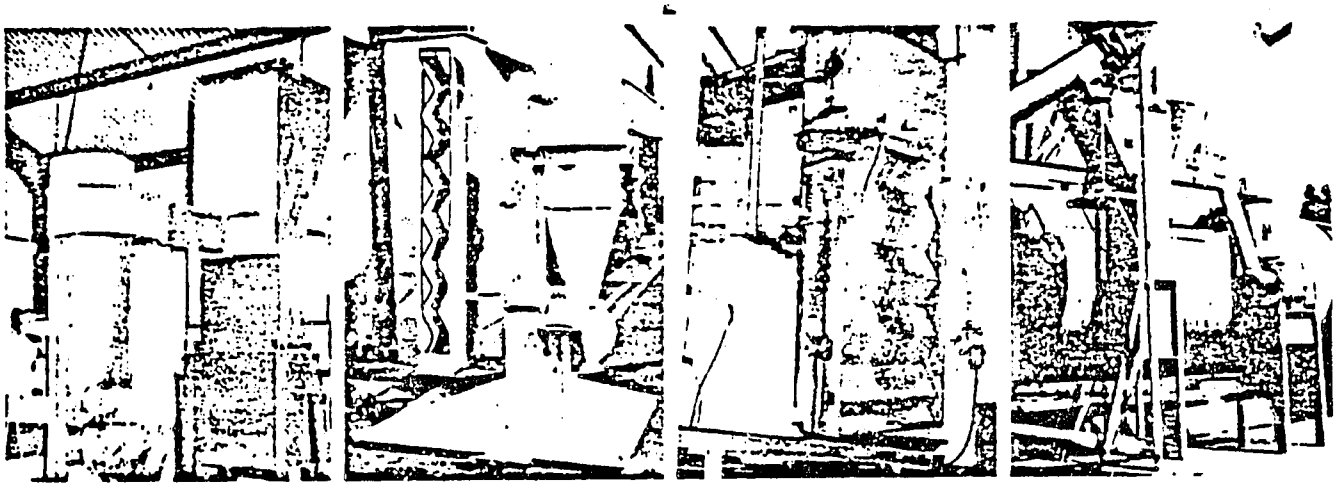

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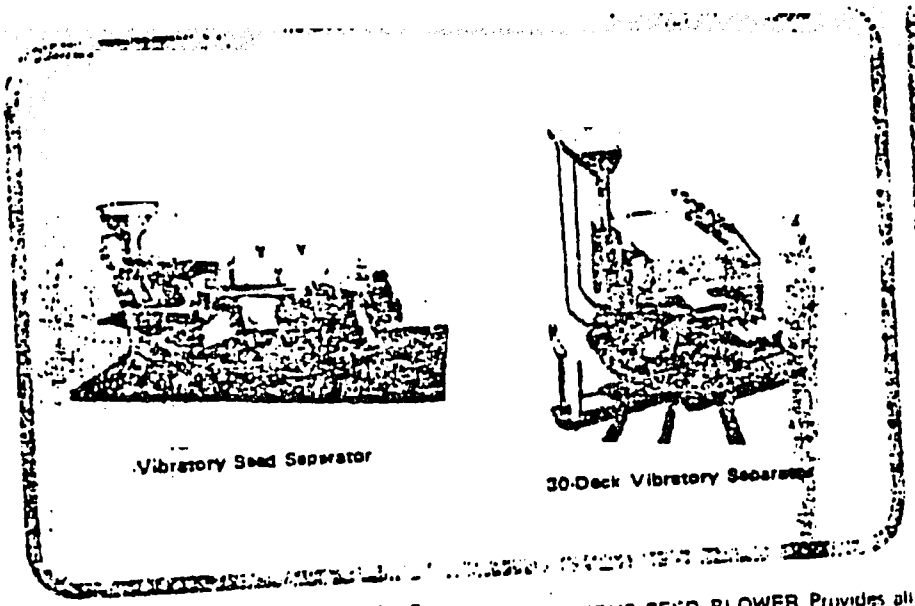

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TAIWAN

Hu, Ta-Wei and Chih-Cheng Liu. Division of Silviculture, Taiwan Forestry Research Institute, 53 Nan-Hai Road, Taipei, Taiwan, R.O.C.

VEGETATIVE PROPAGATION OF LEUCAENA BY LEAFY CUTTINGS UNDER MIST SPRAY

Due to some hybrids of Leucaena leucocephala with other Leucaena spp. are fast-growing but sterile, research for practical methods of vegetative propagation is necessary. In August, 1980, twigs were taken from 1- and 3-year old trees of leucaena (K72) and cuttings of 15 cm long were made into the following 3 categories: 1. Leafy twig cuttings with 3 leaves and the terminal shoot retained, 2. Leafy twig cuttings with 2 to 3 leaves retained and 3. Leafless twig cuttings. A 2 x 3 factorial test in complete randomized block design with 5 replications was conducted in greenhouse under intermittent mist spray. Twenty cuttings of each plot were inserted in coarse sand of the propagation bed in two rows. The spacings of each cutting in one row is about 6 cm and row to row is 15 cm apart.

Thirty-five days after the establishment of the test, number of rooted cuttings was examined and the results are shown as follows:

Age of ortet trees	Category of cuttings	No. of cuttings tested	Cuttings rooted (%)	Ave. % for age class
1-Yr	Leafy twig cut. with shoot	100	100	
	Leafy twig cut. without shoot	100	97	
	Leafless twig cut.	100	52	83
3-Yr	Leafy twig cut. with shoot	100	50	
	Leafy twig cut. without shoot	100	37	
	Leafless twig cut.	100	0	29

The figure shows that vegetative propagation of leucaena by leafy twig cuttings under mist spray is highly possible. Twigs from younger trees have higher percentage of rooted cuttings. Juvenility of ortet trees seems an important factor for vegetative propagation by cuttings. Ramets from adult ortet trees may be rejuvenized under cultivation and can be used for supply of cutting materials for vegetative propagation.

LEUCAENA RESEARCH REPORTS, Vol. 2, July, 1981, Council for Agricultural Planning and Development, Taiwan.

Best Available Document

APPENDIX R

Planning Agroforestry and Fuelwood Production on the Basis of Soil Taxonomy

B. G. Cabanan Jr., G. Y. Tsuji and H. Ikawa

DEPARTMENTAL PAPER 61

Hawaii Institute of Tropical Agriculture and Human Resources
College of Tropical Agriculture and Human Resources - University of Hawaii

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PLANNING AGROFORESTRY AND FUELWOOD PRODUCTION ON THE BASIS OF SOIL TAXONOMY[1]

B. G. Cagauan, Jr., G. Y. Tsuji, and H. Ikawa[2]

Summary

Whether an environment is suitable for tree crop production can be predicted on the basis of soil taxonomic names. These names imply certain attributes such as the general nutrient status of the soils, relative amounts and kinds of clay and clay minerals, and the range of soil moisture and soil temperature. In the tropics, soil information on land available for tree crop or fuelwood production is generally insufficient because many detailed soil surveys are usually concentrated on the level or nearly level arable lands, which are traditionally planted to food crops. Thus, on hillsides, rocklands, and swamps, the marginal lands which are available for tree crops, soil surveys are usually of the reconnaissance type or do not exist at all. If fuelwood production is to take place on a regional and global scale, some policy directions by governments are needed to classify these areas in greater detail.

Matching a crop to the soil and climate depends on the crop's specific growth requirements. Like other legume crops, leguminous fuelwood trees have high requirements for soil-derived elements, such as calcium, phosphorus, and sulfur. Therefore, in evaluating land for growing leguminous trees, careful consideration must be made to select soils that are supplied with these nutrients since fertilizer applications to supplement these nutrients might not be economical. Soil Taxonomy provides a tool for planners and decision makers to assess the capability of a soil to support the establishment of tree species.

1. Prepared for presentation at the Workshop on Agroforestry and Fuelwood Production, Environment and Policy Institute, East-West Center, Honolulu, Hawaii, November 12-20, 1981.
2. Research Associate, Project Manager, and Associate Soil Scientist, Benchmark Soils Project, Department of Agronomy and Soil Science, University of Hawaii at Manoa, Honolulu, Hawaii 96822.

Introduction

Location of land for a tree species and the management of the area to satisfy the requirements for that tree crop are key planning decisions that must be made before establishing large-scale fuelwood production projects. Knowledge of the tree crop and its environmental requirements are needed. Compared to many traditional crops, agronomic information on fuelwood trees is limited. The National Academy of Sciencer (1980) compiled the environmental requirements for 60 fast-growing fuelwood trees and grouped them according to their suitability to the humid tropics, the tropical highlands, and the arid and semiarid regions. The report is a pioneer effort to compile the climatic and soil requirements of fuelwood tree species. The objective of planning for fuelwood production is to select the appropriate environment to match these requirements. A system is now available to achieve this objective. It is called Soil Taxonomy, (Soil Survey Staff, 1975), a system of classifying soils and interpreting soil surveys. In this system, soils are given names that indicate their properties and the soil moisture and temperature regimes in which they occur. The nomenclature system was designed so that these properties and climatic classes can be inferred or extracted from the taxonomic names. This paper discusses how Soil Taxonomy can be used to determine whether a soil is suitable for tree crops, and interpretations are given for identifying soils that are judged desirable for nitrogen-fixing leguminous fuelwood trees.

The need to identify similarly classified soils is also emphasized so that similar management practices may be applied to achieve predictable results. This is based on the objective of the Benchmark Soils Project (1978) that agrotechnology can be transferred on the basis of soil classification. This concept may aid in comparing predicted with actual crop performance.

Transfer of Fuelwood Production Technology

It should be easier to adopt or accept the transfer of a developed technology than to discover a "new" one. In many parts of the world, the technology for growing a great number of economic crops has been established through years of testing and experimentation. Individuals or groups desiring to grow any of these crops need not go to the tedious and expensive process of rediscovery. This transfer process can also be applied to fuelwood trees. The success of transfer depends on what the user is willing to accept in terms of measureable results. One task of planning, therefore, is to maximize the success of transfer, which, in addition to the socioeconomic, political, and administrative conditions, depends greatly on the relationship of the crop to the environment where it grows or will be grown. It is axiomatic that the closer we are in meeting the environmental requirements of the crop, the higher would be the level of successful transfer.

Transference of agricultural practices or technology has generally been made by the farmer based on his experience and that of his forefathers. It is done routinely, especially if the farmer continues to farm in the same area. The problem of transfer arises when the experience is applied or used in another location. Agrotechnology developed in the temperate region, for example, is not usually directly transferable to the tropics. It is apparent that similarity of agroenvironments is a prerequisite to the successful transfer of agricultural experience.

The technology being referred to in this paper is the management used to grow fuelwood trees. This definition is confined to the practices which are influenced by the specific climate and soil. Examples of such practices are the use of hybrid seeds, irrigation, fertilizers, soil amendments, tillage, and planting density practices.

Crop information is needed to make a successful transfer. This information must be matched with the environment where the crop will be grown. Agronomic or silvicultural information on most of the recommended fast-growing leguminous trees (Brewbaker, Van Den Beldt, and MacDicken, 1981; National Academy of Sciences, 1980) is lacking, when compared to information available for traditional crops. This problem is further aggravated by the long period that is required to obtain and monitor tree-crop performance from field experiments. Despite these limitations, however, there is sufficient knowledge on the general requirements of leguminous trees that the appropriate agroenvironmental niche for their optimum growth can still be predicted. The basis for this prediction is Soil Taxonomy. Soil names given by this system are descriptions of these environmental niches, which include both the soil environment and the general conditions of that space above the soil where the plant grows. Hence, environment, as used in this discussion, includes both soil and air space where the plant is grown.

The Benchmark Soils Project (1978) has used Soil Taxonomy to identify similar soils in Cameroon, Hawaii, Indonesia, and the Philippines and to test the concept of agrotechnology transfer. These sites represent three soil families. Based on soil analyses and behavior, phosphorus was identified as limiting. For example, maize yield data obtained from sites of the Hydric Dystrandept soil family had similar grain yield responses to applied phosphorus. The same management practices were imposed in the experiments. The experimental results substantiate the observation that similar environments provide the basis for expecting similar or even identical results; hence, the transferability of agrotechnology is possible.

In order to determine the long-term effect of a specific environment on the growth and development of selected nitrogen-fixing trees, the Benchmark Soils Project is now installing fuelwood tree experiments on its network of experimental sites belonging to three soil families. The environment, by design, is characterized and designated by the soil family as defined in Soil Taxonomy. Growth performance data of 16 fuelwood tree species, mostly

legumes, will be measured. Such information can then be used to predict the performance of these species when grown on soils with similar soil taxonomic names. The following discussion will illustrate how Soil Taxonomy can be used to plan agroforestry and fuelwood production projects. It does not attempt to cover the whole subject of Soil Taxonomy. Readers who may be interested in a more detailed discussion of this subject are referred to Soil Taxonomy (Soil Survey Staff, 1975) itself or to textbooks such as those by Steila (1976) and Buol et al. (1980).

Description of Soil Taxonomy

Soil Taxonomy is a system of classifying soils and is used in many parts of the world today. It was designed to make precise interpretations of soil surveys for agricultural and nonagricultural uses.

The classification is based on soil properties. These properties can be measured which leads to a uniform interpretation of soils data and a better management and utilization of the land. A very useful attribute of Soil Taxonomy is its nomenclature system. It provides a basis for estimating soil properties and for extracting accessory properties from the taxonomic names. Information related to soil moisture and fertility properties such as particle size, mineralogy, and soil temperature are condensed in a soil's name. In general planning, therefore, we may obtain soil information, even though the soil data may not be available, if we know the soil taxonomic name.

The soil names are universal. This means that all soil names (taxa) are the same, irrespective of location. A soil identified in India, for example, which is identical to a soil identified in Cameroon will bear the same name under Soil Taxonomy. This is another attribute that provides a uniform basis for communicating (or transferring) information about soils and their management.

To classify soils in a systematic manner, six categoric levels of classes, arranged in a multicategoric fashion, are established in Soil Taxonomy. The highest categories, with the smallest number of classes, are defined in broad general terms, whereas, the lowest categories, with the largest number of classes, are described in specific terms. These categories are listed in Table 1. Soils in the highest category, the soil order, are grouped according to the presence or absence of diagnostic horizons that are related to some soil-forming processes. These horizons may reflect certain properties, such as the amount of organic matter, the amount of clay movement, the accumulation of clay, or the chemical composition. These properties or accessory characteristics are evident in the taxonomic names (Table 2). The fifth category, the soil family, includes all soils in the same subgroup that have similar particle size or textural class, mineralogy, and soil temperature. The soil family is the category that relates soil

Table 1. Categories in Soil Taxonomy and their dominant features.

Soil category	Number of taxa[a]	Dominant features[b]
Order	10	Presence or absence of different kinds of soil horizons, which are related to soil-forming processes.
Suborder	45	Presence or absence of properties, such as those associated with moisture, parent material, or vegetation.
Great group	187	Similarity of horizons, base status, soil climatic parameters, and presence or absence of different kinds of soil layers or pans.
Subgroup	990	Differentiation according to a central concept or gradation to other great groups, suborders, and orders.
Family	5,603	Information on the particle size (textural) class, mineralogy, soil temperature class, and other properties such as soil depth and consistency.
Series	12,002 (U.S. only)	Information on the kind and arrangement of horizons with morphological, chemical, and mineralogical properties.

a. From Soil Survey Staff (1980).
b. Adapted from Buol et al. (1980).

properties to the management and the manipulation of soils for specific uses. It contains most of the information needed to transfer agrotechnology among and between similarly classified soils (Benchmark Soils Project, 1978).

The last category is the soil series and it is primarily used to relate soil map units to taxonomic units. The soil series name is usually a local geographic name and no longer connotes soil properties. Unless one is familiar with the properties associated with a particular soil series, one may not be able to infer properties of that soil from the series name alone. The soil series category, however, carries all the taxonomic features of the higher categories, and the range in the characteristics of the soil series is more precise, or narrower, than ranges in the higher categories.

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Table 2. Soil orders in Soil Taxonomy and brief descriptions.[a]

Soil order	Description
Organic soils	
Histosols	Soils with very high content of organic matter; histos = tissue.
Mineral soils	
Alfisols	Soils with clay movement and accumulation of clay in subsoil and with a high base status; alfi = associated with Pedalfers[b], soils with aluminum and iron, in contrast with Pedocals, soils enriched with calcium.
Aridisols	Dry soils with water limitation for plant growth; aridus = dry.
Entisols	Youthful soils with little or no formation of soil horizons; ent = associated with the last syllable in "recent," connoting recent soils.
Inceptisols	Soils with minimum soil horizon differentiation but showing changes in chemical and physical properties; inceptum = beginning, associated with the minimum amount of horizon development.
Mollisols	Dark-colored soils with good physical and chemical characteristics for plant growth; mollis = soft, referring to the soft nature of surface soil horizon.
Oxisols	Weathered soils of the tropics with low nutrient retention; oxide = oxide, like that of iron and aluminum.
Spodosols	Acid soils with accumulation of organic matter and oxides of aluminum with or without oxides of iron in subsoil; spodos = wood ash, referring to the horizon leached of humus, aluminum, and iron.
Ultisols	Soils with clay movement and accumulation of clay in subsoil and with low base status; ultimus = last, referring to ultimate in leaching of bases.
Vertisols	Clayey soils with definite shrink-swell characteristics; verto = turn, referring to churning in the soil.

a. Adapted from Soil Taxonomy (Soil Survey Staff, 1975).
b. Pedalfers and Pedocals are soil names associated with an earlier classification system of the United States and are not used in Soil Taxonomy.

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Interpreting Soil Taxonomic Names for Planning Nitrogen-fixing Tree Projects

Information that can be extracted increases from the highest category to the lowest category, and, as mentioned previously, it is the soil family that is most appropriate and useful for technology transfer and in land use planning. The properties unique for a particular soil or a group of soils are reflected in their taxonomic names.

In the order category, for instance, the name Aridisol indicates the lack of moisture (Table 2) and, therefore, is a soil that would not support plants with moderate water requirements. The names Mollisols and Alfisols suggest high native fertility (high base status), while Oxisols, Ultisols, and Spodosols suggest low native fertility (acid and usually low base status). The shrink-swell characteristics of Vertisols indicate poor internal drainage or waterlogged conditions during wet periods. Histosols are usually saturated with water and have low base saturation. Very little information about plant growth factors can be inferred from the names Inceptisols and Entisols.

In the suborder category, many of the names connote moisture regimes: There are the Aqualfs (wet Alfisols from aqua, water); Ustox (dry Oxisols, from combust, to burn); and Udults (udic from humid moist Ultisols). Some suborders connote temperature regimes: The Borolls (cool Mollisols from a boreal climate) and Torrox (hot and dry Oxisols, from torrid), for example. Other suborders indicate an abundance of certain materials such as the Humults (humus-rich Ultisols); and the Ferrods (iron-rich Spodosols)—or the type of parent material, such as the Andepts (Inceptisols developed from volcanic ash, from Andosol, volcanic ash soil in another classification system).

Table 3 shows how there can be an increase of information that can be extracted as we go down the taxonomic categories. It is this attribute of Soil Taxonomy which enables planners to make an assessment of the capability of a soil to support the establishment of a tree species. In planning the use of leguminous trees for fuelwood production projects, soils that are inherently high in bases should be given preference over acid, low fertility soils. Although certain legumes will grow in acid soil conditions, leguminous plants, in general, require neutral to slightly alkaline conditions. It is not acidity per se that is the problem, but the lack of sufficient calcium which is necessary for nodulation (Munns, 1978). Most acid soils are low in bases, phosphorus, and sometimes sulfur (except acid sulfate soils) and are exemplified by most of the Oxisols and Ultisols. Exceptions in the Oxisols are the Eutrustox and Eutrorthox both of which have high base saturation.

It is worth noting that out of the 18 nitrogen-fixing tree species selected for testing by the University of Hawaii (Brewbaker et al., 1981)

Table 3. Interpretation of soil properties from Soil Taxonomy names.[a]

Soil cateogry	Example of taxonomic name in each category	Explanation or interpretation of the taxonomic name
Order	Oxisol	The name connotes presence of oxide minerals, such as those of iron and aluminum. Abundance of these minerals sometimes indicates low fertility status of the soil.
Suborder	Ustox	This is still an Oxisol, but there is additional information about the soil with the prefix ust, from combust, meaning, to burn. This is, therefore, an Oxisol with a dry environment.
Great group	Eutrustox	The prefix eutr is related to such a word as eutrophication, which means enrichment. This is a dry Oxisol that is enriched in bases.
Subgroup	Tropeptic Eutrustox	An adjective is now introduced in the subgroup name to indicate a gradation from a central or typical Eutrustox. Tropeptic describes an Eutrustox with a moderate to strong aggregated structure in the B horizon and/or one that is somewhat shallow.
Family	clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox	There are three more adjectives added to denote the family name of this particular Tropeptic Eutrustox. These adjectives indicate that the soil has a clay texture with a mineral composition of kaolinite and an average annual temperature greater than 22°C (isohyperthermic) at a depth of 50 cm. The mean annual summer and mean annual winter temperatures do not vary by more than 5°C.
Series	Wahiawa	The soil series name Wahiawa itself does not give information on any soil properties. Thus, a person encountering the soil series name for the first time would require additional information for interpretation.

a. Adapted from Soil Taxonomy (Soil Survey Staff, 1975).

only three species were reported to be well adapted to acid soils. These are Acacia auriculiformis, Acacia mangium, and Casuarina equisitifolia.

Leucaena leucocephala, the well-known "wonder" tree of this decade, is rated poor in adaptability to acid soils. Forage trials on two soil families (one acid, the other non-acid) illustrate this fact (Table 4). Large amounts of lime and phosphate fertilizer were applied to the clayey, ferritic, isothermic Typic Gibbsihumox, an acid and infertile Oxisol, in order to equal the forage yield of a fine, mixed, isohyperthermic Cumulic Haplustoll, a nearly neutral and inherently fertile Mollisol. The latter received neither lime nor phosphate fertilizer.

Matching of fuelwood requirements with soil characteristics and climatic regimes derived from soil taxonomic names is essential in order to extrapolate performance of tree species to another location. The environment from which a set of production data were obtained can be identified from the soil name. The soil name may give important clues in judging the performance of tree species when they are to be grown in another location.

Table 4. Forage yields of Leucaena leucocephala grown on two soil families.

			Average forage yield[a]		
			Green		Dry 12% moisture
Soil family	Location	Lime and fertilizer treatments	(kg/ha/day)	(t/ha/yr)	(t/ha/yr)
Fine, mixed, isohyperthermic Cumulic Haplustolls	Waimanalo, Island of Oahu	None	189	69	22
Clayey, ferritic, isothermic Typic Gibbsihumox	Kapaa, Island of Kauai.	5.6 t/ha crushed coral stone; 278 kg P/ha rock phosphate	171	62	20

Source: Brewbaker et al. (1972).

a. Average of 11 varieties.

The reportedly outstanding performance of the K-varieties of Leucaena relative to other fast-growing trees (Brewbaker et al., 1981) is a function not only of the varieties but also of the environment where these data were collected (Table 4). Obviously, it would be a mistake to apply these production figures in projecting the harvests from marginal, infertile, and steeply sloping fuelwood farms. In the Philippines, for example, the difficulties in establishing Leucaena leucocephala on agriculturally marginal lands are known (Halos, 1980). These areas have soils which are generally acid and are low in nutrients or native fertility. Plants which survived were stunted and spindly. These difficulties point to a mismatch of species requirement with soil and environment.

For wildlife, soil conservation, or for green manure, selected leguminous tree species can adapt, over a period of years, to marginal and highly infertile, even acid, tropical soils. In fact, legumes are very desirable plants that can be grown to improve soil fertility. For example, if used as a green manure, the K-8 varieties of Leucaena can produce large amounts of nitrogen, and can cycle high quantities of phosphorus, and potassium to the soil surface (Table 5). The same quantity of nutrients except for nitrogen, however, will be withdrawn from the soil if Leucaena is used as forage. Under long-term cropping, potassium, phosphorus, and calcium must be added to maintain high forage yields. Sound planning, therefore, should also match land capability with intended use.

High production of food crops can only be sustained with the application of commercial inorganic fertilizers even on soils with high native fertility. Whether the return from fuelwood production can be greater than the cost of fertilizers has not yet been established. In the tropics, priority for using available fertilizer is given to food crops. It is necessary and desirable,

Table 5. Nutrient composition and the fertilizer material equivalent of a 20-ton per ha harvest of dry forage from Leucaena leucocephala.

Fertilizer nutrient	Composition %	Composition kg/ha	Fertilizer material equivalent per ha
N	3.0	600	1,304 kg urea (46% N)
P	0.27	54	675 kg single superphosphate (8% P)
K	1.4	280	560 kg muriate of potash (50% K)
Ca	0.8	160	410 kg calcium carbonate (39% Ca)
S	0.14	28	—

Source: Calculated from data by Brewbaker and Hutton (1979).

therefore, to select areas with soils that have relatively high base status (native fertility) or to select leguminous tree species that can tolerate acid soils. These soils can be easily identified from their taxonomic names.

Up to this point, our discussion has been based on the premise that soil survey and soil classification data or soil maps are available. Most of the land areas that may be available for fuelwood production today, especially in the tropics, are the hillsides, swamplands, rocklands, and even desert areas that are not suitable for food crop production. These areas are usually designated on soil maps as mountain soils or undifferentiated soils and lack the detail that is found for the arable level lands. Soil information on these marginal areas is generally lacking to make meaningful interpretation for agroforestry planning. In order to undertake large-scale utilization of these lands for fuelwood production, government planning should include as a prerequisite, initiation and undertaking of soil survey activities with subsequent classification of soils to allow a meaningful soil resource inventory assessment of land areas for intended land use.

Soil Taxonomy can be a very useful tool to pinpoint major soil constraints and may serve as the basis for determining the need for production inputs such as fertilizers, erosion control measures, irrigation, drainage, and so on. Where these inputs are required but may not be economically feasible, it is imperative during planning to lower expected performance. Modifying the intensity or frequency of harvest or increasing land quantity are some alternatives that may be used to make up for lower output due to inferior soil quality.

An example of matching tree requirements to soils and environment is provided in the Appendix of this report.

Conclusion

Soil information on land available for tree crop or fuelwood production in the tropics is generally insufficient or completely lacking. Detailed soil surveys, where available, are usually confined to the level or nearly level arable lands, which are traditionally planted to food crops. Soil surveys of sloping uplands, rocklands, and swamps, marginal lands which are available for tree crops are usually of the reconnaissance type or lacking altogether. If planning for agroforestry and fuelwood production is to proceed on a national, regional, or global scale, a soil survey is needed; the soils must be classified and soil maps must be prepared. To maximize the use of the soil survey data and maps, knowledge of Soil Taxonomy and taxonomic names is essential. The appropriate environment needed for tree crop production can be predicted by using soil taxonomic names. These names connote specific soil and environmental conditions that can be matched to the requirements of a specific tree crop. The transfer of agroproduction technology and information for agroforestry and fuelwood production programs can then be logically and economically implemented.

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Appendix

Matching Tree Requirements To Environment: A case example for Oahu, Hawaii

It is known that certain environments are more suited for a fuelwood species than others. Hence, fuelwood crops can be classified according to their suitabilities to various environments (National Academy of Sciences, 1980). To illustrate this, the environmental requirements of three fuelwood crops are summarized in Table 6. One of the first tasks is to identify which species will be most suitable (or vice versa) to the environmental characteristics of the two soil associations described in Table 7. These are soils in Windward Oahu, Hawaii. The Kaena-Waialua series are soil associations in the lowlands, and the Lolekaa-Waikane series are soil associations in the uplands. A map showing soil associations is useful for providing a general idea of the soils in a region. A more detailed map with on-site investigation, however, is necessary to plan for the farm or field itself.

The Kaena soils are Typic Pelluderts (Vertisols with shrink-swell characteristics) with a udic moisture regime (meaning, in most years, the soils are not dry for as long as 90 cumulative days). They have clayey texture, montmorillonitic clay mineralogy, and have an isohyperthermic temperature regime (which means a tropical mean annual soil temperature of over 22°C). The Waialua soils are Vertic Haplustolls (Mollisols that are generally dark and fertile soils with good structure but with some characteristics of the Vertisols). They have an ustic moisture regime (meaning, in most years, the soils are dry for more than 90 days but less than 180 days). The soil texture is clay, which is dominantly kaolinitic in mineralogy, and the temperature regime is isohyperthermic.

Both the Lolekaa and Waikane series are Humoxic Tropohumults. These are Ultisols. Considerable leaching has already taken place in these soils, hence, the low content of plant nutrients, and the moderate amounts of organic matter (humoxic modifier) is due to the udic moisture regime. The texture is clay, the mineralogy is kaolinitic, and the temperature is isohyperthermic.

By examining the characteristics of the four soils and the environmental requirements of the three fuelwood trees, we can see that three of the soils meet the crop requirements for elevation, rainfall, and temperature. The Leucaena is better suited to the Pelluderts and Haplustoll because of the neutral pH. Leucaena grows poorly in acid soils such as the Lolekaa and Waikane soils. The Eucalyptus species will most likely do well in the Tropohumults but may have difficulty adapting to the poorly drained or moderately drained Pelluderts and Haplustolls.

Table 6. Crop requirements: Reported environmental adaptation of three fuelwood crops.

Environmental attribute	*Leucaena leucocephala*	*Eucalyptus grandis*	*Eucalyptus globulus*
Optimum altitude (m)	below 450	0-750	1000-1800
Optimum rainfall (mm)	630-1650	2000-2500	1300-2000
Temperature	restricted to the tropics and subtropics	temperature limiting above 1200 m; cannot take frost	can tolerate -7°C for short periods when mature; seedlings are frost-susceptible
Minimum soil depth (m)	2-3	1	1
Soil texture	light to heavy	light to medium	light to medium
Soil drainage	moderately well-drained	well-drained	well-drained
Soil pH	neutral to alkaline	acid to neutral	acid to neutral
Soil fertility limitation	sensitive to low calcium, molybdenum, and zinc	can adapt to infertile, low-phosphate soils, but sensitive to boron deficiency	(information unavailable)

Source: Adapted from National Academy of Sciences (1980) and R. G. Skolman (personal communication).

Table 7. Soil conditions: environmental descriptions of four selected soils of Windward Oahu, State of Hawaii.

Environmental descriptors	Soil series			
	Kaena	Waialua	Lolekaa	Waikane
Soil family classification	Typic Pelluderts very-fine, montmorillonitic, isohyperthermic	Vertic Haplustolls very-fine, kaolinitic, isohyperthermic	Humoxic Tropohumults clayey, kaolinitic, isohyperthermic	Humoxic Tropohumults clayey, kaolintic, isohyperthermic
Elevation (m)	15 to 50	3 to 30	0 to 170	65 to 350
Rainfall (mm)	750 to 1100	650 to 1250	1800 to 2300	1250 to 1800
Mean annual temp. (°C)	23	23	22	22
Soil depth	very deep	deep	deep	deep
Soil texture	stoney clay	silty clay	silty clay	silty clay
Soil drainage	poorly-drained	moderately well-drained	well-drained	well-drained
Soil pH	6.6 to 7.3	6.1 to 7.3	4.0 to 5.5	4.5 to 5.0
Slope (%)	mostly nearly level and gently sloping	mostly level and gently sloping	nearly level to very steep	nearly level to very steep

Source: Adapted from Foote et al. (1972)

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Soil fertility requirements of the three species are not fully known. If soil fertility is critical, the choice of a site should be confined to the Pelluderts and Haplustolls which have relatively better inherent fertility than the Tropohumults. The poor drainage of the fertile soils, however, may seriously limit the adaptability of the Eucalyptus species. At this point the planner must make an on-site inspection to confirm the drainage factor. He must then seek expert advice as to whether it is feasible to alleviate this condition, or consider another tree species more suited to the soil and environment. A resource inventory of both soils and crops will provide the planner with alternatives for effective land use planning.

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