ENGINEERING CONSTRAINTS ON PLANTING MACHINE DEVELOPMENT

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Abstract.--Design problems involved in the development of mechanical planters and limitations on such development from an engineering viewpoint are discussed. A major concern is the definition of field requirements for planting machines and the translation of these requirements into engineering specifications suitable for equipment design.

Résumé.--Les difficultés de conception ainsi que les entraves techniques associées à la mise au point de planteuses mécaniques sont discutés. Par exemple, il faut déterminer les conditions d'emploi sur le terrain, puis les traduire en spécifications techniques qui conviendront à la conception de l'équipement.

INTRODUCTION

The development of tree-planting equipment is a specialized engineering problem. Historically in North America, tree-planting machines have evolved from agricultural equipment. Continuous furrow transplanters were strengthened and modified for rough ground conditions in untitled soils. The relatively low demand for mechanical planters was one of the main reasons for the slow advancement of planting machine technology. Consequently, planting machines on the market today, whether bare-root or container stock planters, are still relatively simple in design. In addition, detailed information on site preparation requirements is lacking for the various species of trees planted. Failure to translate such field requirements into engineering specifications useful to designers has resulted in a lack of understanding among equipment manufacturers of what is really needed.

This paper will outline information that is important for planting machine design and define some of the limits to technological development.

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WHY DEVELOP EQUIPMENT?

Field personnel who are having problems with existing equipment will find this an easy question to answer. A case can be made for developing planting machines to alleviate a shortage of labor for manual planting, to maintain a consistent level of acceptably planted seedlings, and to reduce or minimize the cost of planting. Why do equipment manufacturers attempt to develop a new product? Primarily to receive a fair return on money invested. This is usually in the form of profits through the sale of large quantities of machines. The benefits are shared by both user and manufacturer. If customers are happy with equipment performance then more equipment will be sold and the development costs will be justified.

How do equipment manufacturers decide when to develop a new product? In the case of tree planters, a potential user will sometimes approach a manufacturer directly, and state why such a machine is needed. Sometimes the manufacturer himself will see a need for mechanized planting and will try to interest field personnel in his ideas. In either situation a market study is required to determine the potential for equipment sales. If a company can predict potential sales that will cover development costs and bring a reasonable return on investments then it will proceed with development.

In any development program funded solely by the manufacturer, the user stands to gain the most while the manufacturer bears most of the risk. In the past it was difficult to interest equipment manufacturers in mechanical planters. Potential sales were low and the planting season was short, so that costs had to be written off on the basis of very few machines. Consequently, the selling price of a planter could be as high as that of a logging skidder, for example, and was therefore less attractive to the manufacturer. To overcome this high risk deterrent and to stimulate planting machine development it may be necessary for the users, whether government or private industry, to share the development costs.

LIMITS TO TECHNOLOGY

In view of the biological constraints imposed by species requirements and the limits imposed by extremely variable terrain, the development of equipment suitable for handling and successfully planting seedlings may require very sophisticated technology. Lawyer (1978) describes several planting machine concepts that are now on the market or are being tested. These are: injection or spot, intermittent furrow, continuous furrow, and ridge or hill planting.

Continuous furrow planting is the most common machine planting technique and the simplest in design. It is best suited to relatively stone-free and stump-free areas. The intermittent furrow concept, though more complex, is better suited to handling obstructions such as stumps or boulders because the planting dibble enters the ground only occasionally. The spot or injection planting concept encounters even less ground interference because the planting dibble enters the ground vertically until the seedling is injected and then is retracted from the same location. Spot planters are currently being tested as prototypes but are not yet commercially available.

The design problems increase substantially as one moves from continuous furrow planters through to the true spot planters. Some prototypes incorporate scarification and planting into one planting machine, or even into a single planting head. As machines become more complex, costs rise and mechanical availability tends to decrease. To justify such costs, productivity must be correspondingly high (Hatfield and McKenzie 1981).

Productivity on manually loaded planters is limited by operator comfort and safety. In the future, automatic loading may eliminate the ergonomic problems of manual loading and permit productivity increases that will help justify high equipment costs. Productivity is also affected by variable-sized and deformed planting stock from the nursery. Better quality control in the nursery will reduce this problem.

Containerization of seedlings holds the most promise for automation as it eliminates the problem of variability in seedling size. Some of the most sophisticated fully automatic planters currently being tested in Scandinavian countries, and to a lesser extent in Canada and the United States, use container-grown stock.

A major problem in the development of handling mechanisms for containerized seedlings is the wide variety of container designs that are available. Some equipment manufacturers hesitate to embark on a development program when they cannot get a clear consensus on which container is the most commonly accepted. One solution would be a planting system which accommodates a range of sizes. The problem of container planting can best be solved by a total systems approach, in which all aspects of nursery production, containerization and handling are considered as well as field equipment to plant the seedlings.

New technology in various fields of engineering is being made available to equipment manufacturers. To derive the most benefit from these new concepts a designer relies on detailed specifications from the field as to what is required in a tree planter.

DEFINING THE PROBLEM

In defining the requirements of a planting task for an equipment designer it is not sufficient to speak in generalities. Silvicultural prescriptions for various species on a range of sites are necessary for proper definition of the planting requirement. Site variability is common, especially in the boreal forest region of Canada. Numerous site characteristics can affect machine design and operation. Some of the more important questions to be answered are:

- How will soil texture vary on the sites to be planted?
- What will be the range of penetrative forces required to plant the seedling?

- What type of ground pressure and clearance limits exist for the carrier?
- If the sites contain rock, what degree of stoniness and size classes might be expected?
- How much logging debris and how many residuals and stumps will be present?
- What is the proper microsite in which to plant?
- Will the scarification required to produce an ideal planting site be incorporated into the planter or be carried out in a separate operation?
- Should the equipment be designed to incorporate attachments for herbicide sprayers or fertilizer spreaders?
- If container-grown stock is to be planted, how much deformation of the container is acceptable during handling, planting and subsequent packing?
- What spacing is required for planted seedlings and what angle and depth of planting?

Once the details of site and biological requirements have been defined, such information should be made available to the equipment designer.

INFORMATION TRANSFER

All too often the field requirements for planting seedlings are not clearly defined or understood and the translation of these requirements into engineering specifications is based only partly on experience while the remainder is based on judgment. It is also necessary to translate the requirements into a form that equipment designers can work with. For example, a specification for planting depth should be given as a range above and below an optimum figure. This permits the designer to design around a target value and includes acceptable limits as well. Every detail which could affect machine function or performance should be brought to a designer's attention at the outset. Changes in concepts or thinking are relatively easy and inexpensive to incorporate at this time. It is advisable that a request for a planting machine be made with a good understanding of the range of conditions in which it will be expected to work. Variability in terrain or drainage problems can limit the use of equipment. To develop a planting machine flexible enough to handle a wide variety of ground and moisture conditions is usually impractical and often impossible. For example, a planter designed to penetrate dense clay soils may end up being too heavy for moist sites on which light-weight equipment and little soil compaction are desired. Spot planting in heavy soils may create problems for root egress from the container unless a localized area around the seed spot is tilled or a furrow planting concept is used. Designers need to know how much tilling of the microsite is required for a particular soil type.

Another consideration not related to site is the power source for the proposed planting machine. If the power to operate the planter is supplied by the prime mover then the selling price of such a machine will be lower. However, it may be difficult to find a prime mover with the proper hydraulic or electric hookups. A good understanding of machine capability by both field staff and equipment designers will help promote the use of equipment only where it is most suitable.

SUMMARY

Silvicultural equipment development is a high-risk proposition for equipment manufacturers. In the past, low market potential has resulted in minimal development of equipment such as tree planters. Research efforts have been isolated and to some extent based on judgment rather than experience. To initiate a development program, foresters and other field personnel must familiarize themselves with all requirements and conditions for planting trees of various species and be able to present this information to equipment designers in a form the latter can understand. This is the best way to ensure that the resulting equipment stands a good chance of success.

A recent survey of agencies across Canada indicates that machine planting is one of the most pressing needs for improved or increased mechanized silvicultural treatment (Riley 1981). To achieve the goal of better equipment, successful machine development programs depend heavily upon effective communications between equipment manufacturers and users.

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