REPORT
ON
FIELD PERFORMANCE TRIALS
WALTERS INJECTION PLANTER

RN X78500

REFORESTATION DIVISION
MINISTRY OF FORESTS

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Forester
Reforestation Division
Field Performance Trials

J. Walters Injection Planter

Introduction

Under contract with Supply and Services, Department Environment Canada, John Walters Forestry Consultants Ltd. developed an injection planting machine for containerized seedlings. This machine was given the name "Reforester", see Appendix II.

Machine Detail

Specifications of the "Reforester" are given in Appendix I.

The carrier is an M19 personnel carrier which was converted by F.M.C. in 1971 to use as a log skidder and used briefly in Brazil for this purpose.

The three cages for the planting gun operators (planters) and all components of the planting mechanism are firmly affixed to the carrier.

Horizontal and vertical positioning of the planting guns is by hydraulically controlled arms operating at pressures between 1720 and 2070 kPa. Each arm has an effective independent horizontal range of 1.2 m., and an effective vertical range of 1-1.8 m. depending on horizontal positioning. Control of the hydraulic arms is through Monsun-Tyson HVP3 joy stick operated pressure control valves in the planter's cab.

All actions of the planting gun are by air cylinders operating at approximately 550 kPa. The planting action is controlled by a button in the planter's cab. All ancilliary action is automatic.

The planting gun magazine holds 600 bullets. Movement down the magazine is by gravity, chiefly by an iron slab "weight" which is placed on top of the bullets. Feed to the gun barrel is controlled by three separator plates, one pressure plate and a tilting mechanism. Movement of the bullet down the gun barrel is by gravity to the point of a friction stop. A bullet is forcibly ejected from the gun dir-
ectly into the planting medium by four "fingers" which impinge on the top of
the bullet. Extension of the planting head to a point of contact with the
ground and action of the "fingers" is by air cylinder. Return of the planting
head is automatically activated by air pressure drop.

A proto-type of the planting gun was built by Mr. Walters and tested by the
Forest Service in 1976. Changes which have been made since that time are as fol-
lows:

1. Plastic tape is now used to hold the bullets in bundles of 54 for transport
to the gun magazine.

2. The gun magazine (vertical feed shute) has been refined.

3. A weight is now used on top of the bullets in the magazine. This gives a
more positive feed.

4. The final separating plate has been redesigned and now works well.

5. A tilt mechanism has been added to change the bullet from a horizontal to a
semi-vertical position as it enters the side feed shute to the gun barrel.

6. The shape of the side feed has been changed and is improved.

7. Access to the gun barrel is improved.

8. Two additional bullet ejection fingers have been added to help clear any
broken bullets from the gun.

9. A negative pressure technique has been incorporated to trigger the return
action of the planting head.

10. Air supply has been increased.

Object of the Trials

The purpose of the field trials was to determine the feasibility of planting
containerized seedlings mechanically on sites which have had a minimum of post
logging site preparation, and to evaluate the performance of the present machine.

Field Trials

Field trials of the "Reforester" were carried out on a rolling upland approxi-
mately 30 km. east and 10 km. north of Quesnel during the period June 20th to June
Photographs of the site and the machine are included in Appendix II. Film and slides are available through Silviculture Branch, Victoria.

Soil on the area is principally a clay or heavy clay which was wet during most of the trial. The original timber crop was White Spruce (picea glauca) with some Douglas fir (pseudotsuga menziesii) and Lodgepole Pine (pinus contorta).

Following logging the area was partly broadcast burned and partly windrowed to provide an alternative site for the "Reforester". The broadcast burn did not remove the duff from the site and a considerable amount of heavy slash remained on the area. See Appendix III - slash loading.

Prior to the operational trials the "planters" had been given two full days of instruction and practice. This phase was considered to be essential.

The machine was on site for a total of seven days. Of these, one full day was required for assembly after transport and two full days were required for repair. During the trial the F.M.C. skidder did not suffer any serious break-downs and performed adequately, however, other components did not perform as well. Improper connections had been supplied for the planting arm hydraulic lines and frequent failures occurred. A major hydraulic cylinder failed due to faulty manufacture. Two other hydraulic cylinders failed due to design/function faults. The feed mechanism of the gun failed repeatedly and the innermost extension tube of two of the guns became bent to the point of malfunction. Two planting head lifting catches broke and a pneumatic relay switch failed. Air supply to one of the guns was consistently below requirements.

Operations were not consistent enough to be evaluated on a true time study basis, however some periods of planting were recorded and are given in Appendix IV. These are for brief operating periods only and do not reflect prior or subsequent down time.

Approximately 5000 of Walters 10 cm. long plastic bullets (CBW 210) were processed through the guns during the trial. The quality of planting of some of these is given in Appendix V.
Evaluation

The machine did demonstrate that it was feasible to inject containerized seedlings into the ground while travelling continuously over an area of moderately heavy slash. While operations were by no means prolonged, the planters indicated that they did not suffer any discomfort and were not hindered in carrying out their required functions.

Due to the number of break-downs and malfunctions the machine did not indicate an operational capability at its present stage of development.

Comment

The mechanical performance and suggestions for improvement or modification have been detailed by Mr. R.M. Scott of Engineering Branch. See Appendix VI. While a multitude of refinements are necessary there was no apparent inadequacy in design or concept insofar as injection of the bullet is concerned. It does appear, however, that there are unlikely to be a sufficient number of suitable planting spots available on unprepared ground to inject enough seedlings to adequately stock a logged site. It would thus appear to be imperative to carry out some form of intensive site preparation on the mini-site prior to injecting the container.

Even though the planters were able to select planting spots, quite a number of bullets were broken from contact with sub-surface obstructions. Bullets were also broken by the action of the planting head during the planting process. It was difficult to determine whether breakage occurred during the injection of the bullet or following injection and prior to lift of the planting head, however it was noted that the gun which had the quicker action broke less bullets so it is very likely that speed-up of the planting action will reduce the breakage to an acceptable minimum.
Recommendations

From extrapolation whether of the small amount of data which could be obtained it is questionable that a capital investment in the total machine for tree planting purposes only, would be justifiable. For practical purposes it will be necessary to develop a planting component which can be attached with minimum modification to available logging machines.

It is very apparent that machining tolerances will have to be improved and friction will have to be reduced in sliding interfaces. These are not large items but they could be costly.

It is apparent in retrospect that more time should have been spent on refining the planting guns prior to field trials. Having now demonstrated, in a general sense, the feasibility of the principle, it is now necessary to go back to perfecting the most intricate component. Efforts should be concentrated on perfecting the planting gun to a point of at least 90% functional reliability.
## Appendix I

# Reforester

Prepared by J. Walters Forestry Consultants Ltd.

![Reforester Image](image)

### Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prime Mover</strong></td>
<td>M19 Personnel Carrier, converted to FMC Skidder (1971)</td>
</tr>
<tr>
<td><strong>Length Overall</strong></td>
<td>6.9 m (22.5 feet)</td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>3.1 m (10.2 feet)</td>
</tr>
<tr>
<td><strong>Height</strong></td>
<td>3.6 m (11.8 feet)</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>21.3 metric tons (21 tons)</td>
</tr>
<tr>
<td><strong>Track Width</strong></td>
<td>53 cm (21 inches)</td>
</tr>
<tr>
<td><strong>Tread Width</strong></td>
<td>2.6 m (8.5 feet)</td>
</tr>
<tr>
<td><strong>Ground Pressure</strong></td>
<td>0.6Kg/cm² (51 lb/in²)</td>
</tr>
<tr>
<td><strong>Ground Clearance</strong></td>
<td>48 cm (19 inches)</td>
</tr>
<tr>
<td><strong>Max. Slope</strong></td>
<td>60% up and down, 30% sideslope</td>
</tr>
<tr>
<td><strong>Engine</strong></td>
<td>V6 Detroit diesel 238 HP (gross)</td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
<td>4 speed Twin Disc Powershift transmission</td>
</tr>
<tr>
<td><strong>Compressor</strong></td>
<td>2100 cc (130 cubic inches) &quot;Hydrovane&quot; hydraulic</td>
</tr>
<tr>
<td><strong>Hydraulic Pumps</strong></td>
<td>3 with total capacity of 380 litres/min (86 gal/min)</td>
</tr>
<tr>
<td><strong>Speed when Planting</strong></td>
<td>2-4 km/hr</td>
</tr>
<tr>
<td><strong>Personnel</strong></td>
<td>1 driver, 3 planters</td>
</tr>
<tr>
<td><strong>Planting Heads</strong></td>
<td>3 (interchangeable for different size bullets)</td>
</tr>
<tr>
<td><strong>Plant Storage</strong></td>
<td>12,000 bullets</td>
</tr>
<tr>
<td><strong>Bullet Size</strong></td>
<td>2.2 cm (7/8 in) square x 10 cm (4 in) high</td>
</tr>
<tr>
<td><strong>Planting Production (Potential)</strong></td>
<td>1M seedlings/head/hr. (depending on terrain)</td>
</tr>
<tr>
<td></td>
<td>20M seedlings/8hr. day, or 12.5 ha (28 ac.)/day</td>
</tr>
<tr>
<td></td>
<td>at 2.5 m x 2.5 m spacing</td>
</tr>
</tbody>
</table>
Appendix II

F.M.C. Skidder

Preliminary construction stage
Appendix II

Construction complete

Bullets in magazine
Right side planting gun

Right side planting gun
Gun in planting position showing hydraulic arm mechanism

Underside of bell housing slightly protruding bullet ready for planting
Rear gun in travelling position showing bell housing in retracted position

Rear gun in travelling position showing bell housing in extended position
Rear gun in travelling position displaying full 30" extension of middle air-controlled tube.

Left side gun and operator (planter) ready to plant.
Gun operator's controls
Bullet trays behind

Gun operator's chair and controls
Reforester in action
Reforester in action

Note horizontal stability riding over stump
Reforester in action
Three guns at the ready

Planted bullet
Appendix II

Panorama of planting site
Broadcast burned only
Appendix II

Panorama of planting site

Slash windrowed/piled for burning
<table>
<thead>
<tr>
<th>Plantation Age</th>
<th>0-90°</th>
<th>90-180°</th>
<th>Not Damaged Damaged</th>
<th>Not Damaged Damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantation Area</td>
<td>60-90°</td>
<td>90-180°</td>
<td>60-90°</td>
<td>90-180°</td>
</tr>
<tr>
<td>Percent Damaged</td>
<td>12</td>
<td>11</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Damaged Percent</td>
<td>11</td>
<td>9</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Total Planting Depth</td>
<td>15</td>
<td>14</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Total Planting Area</td>
<td>17</td>
<td>16</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Total Damaged Plants</td>
<td>12</td>
<td>11</td>
<td>12</td>
<td>11</td>
</tr>
<tr>
<td>Total Non-Damaged Plants</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>

Appendix A
"REFORESTER"
MECHANICAL PERFORMANCE,
1978 QUESNEL INJECTION PLANTING TRIALS

The mechanical performance of the Refrester has been broken down into the following categories:

A PLANTING GUN - PNEUMATICS
B HYDRAULICS
C FMC, PLANTING AND MISCELLANEOUS
D FEATURES THAT WORKED PARTICULARLY WELL.

The following critique at times focuses on individual parts and pieces which may be hard to visualize without drawings, sketches or a working knowledge of the machine.

A PLANTING GUN

1. The bottom separation plate catches the bullet row and jams them against the feed row side-rail.

   This problem can result from the trees not being in the center of the bullet. The dropped row is supported by the "off-center" tree/s, allowing the bottom separator plate to catch on the interlock lugs, pushing the entire row forward and jamming.

2. All pneumatic circuits to be traced, identified and recorded, so that what is now there is easily understood and evaluated. Color coding is essential, especially in gun control enclosures.

3. The "vacuum" or pressure-drop gun return mechanism should be evaluated and/or replaced by an alternate means, i.e. an electric 12/24 vac system.

   Electricity is immediate and either it works or it doesn't. Something like this should remove the problem of pneumatics working too slowly. Also, repair can be by prefabricated replacement.

4. Strengthen both tubes that make up the lower part of the gun by at least two times. The weight of the planting head does not greatly affect the speed of planting.
A 5. Speed up gun action to the maximum rate.

This could include raising the gun operating pressure and increasing the intake and exhaust sizes. This will also reduce the chance of gun damage from debris and will greatly improve planting quality as "walking" and "side-slip" will be reduced.

6. Redesign entry of bullets into gun "barrel" to stop bullets from coming apart and jamming, yet allowing free fall entry. Less of an angle between the side chute and the gun tubing would help.

Allow speedy removal of side chute for cleaning.

7. A method of clearing two or more bullets from the gun head by the planter from his seat is required.

Lack of this interrupts planting and/or requires a fifth person to be present, i.e. mechanically stop feed mechanism until planting head "catches up".

8. A method of holding the bullets loaded in the gun magazine in place to allow the guns to be stored horizontally when moving them any distance, should be devised.

9. Replace all "crimp" type and plastic hose clamps on the pneumatic system with either ferrule type connections or gear clamps.

10. Install planting cylinders with a longer stroke to allow planting from a higher point. Rolling of the machine can leave one side one to two feet higher than the other.

Alternative - more responsive and further reaching hydraulic arms to get a shorter stroke gun closer to the planting site.

11. The walking action of the gun should be either:

   i) Lockable in the upright position when the air is off

   ii) Based on another principle that does not require the FMC to be running and air pressure to be present at all times.

If "ii" is retained, the air pressure in the return cylinder must be easily read and adjusted without having to open the control panel. The return cylinder must be cushioned at both ends and "full extension" should have a mechanical stop that protects the cylinder from damage if the gun were to get caught and overextended.
A 12. The side guns can be hydraulically maneuvered so the planting head is either up against the FMC fender or against the crawler track. The tracks are extremely dangerous when moving in this regard.

The rear gun can be pulled in so the planting head is against the screen support bar. This is not a desirable feature, although immediate damage is not probable.

13. Exterior pneumatic hoses should be evaluated and, if required, relocated for safety or wear reasons. Color coding will help to trace lines through bundles, coils, etc.

14. Install individual manual air shutoff valves for each gun, to allow repairs on one gun's air system without shutting down the compressor.

15. More visibility is required of the bullet storage on the left side gun (left facing front).

16. Install counters either on each gun or on each firing button, to give a total of number of bullets.

17. Planting cylinders seem to "hammer" somewhat, especially if you are too high to plant and extend to the bottom of the cylinder.

18. The "hooks" that retain the inside planting tube seem to get involved in a lot of debris, etc., about the planting head.

Perhaps this action between the two inner tubes could be located further up the gun. These hooks failed in service but were easily replaced.

19. The rods that retain the inner tube, when it drops to the ready position, appear to be too flimsy as they do get bent and restrict the gun's action.

Perhaps they could be moved away from the head along with #18.

20. Provide a safety air shutoff valve, operable from each operator's seat (complete with off/on indicator light), to shut off the air to each gun's feed works and planting mechanism during the clearing of jammed bullets.

21. Extend the bell on the planting head so that the head is better protected and supported against impact. Nos. 18 and 19 can be included so that as few operations as possible occur at the planting head level.

22. Investigate extending the stroke of the planting fingers past the bottom plate so each bullet is planted further into the soil. Having the top of the bullet slightly below the surface of the ground would tend to reduce frost heave effects. (J. M. Kinghorn)
A 23. Reduce the thickness of the single bullet separator so it will more easily push back the single bullet row.

24. Evaluate the planting gun unit from the standpoints of friction, allowable wear and fatigue. A number of parts presently operate solely metal to metal.

Lubricants, rollers, etc., must be incorporated into this machine if any degree of reliability is to be attained.

B HYDRAULICS

1. Replace all clamped hydraulic hoses with ferrule-type connections. Color coding and labelling will greatly help repairs.

2. Provide stops for both cylinders on the hydraulic arms at both ends so that the ends cannot be pushed out again. Use only cylinders cushioned at both ends.

3. Relocate the oil lines for the hydraulic arms from the front to the rear of the arm mounts.

4. Evaluate the pressure relief valve installed in the field.

5. Investigate increasing the speed of the hydraulic arms.

6. Investigate the problem of low engine rpm and subsequent air compressor stopage.

Perhaps higher operating pressures and an air receiver may serve to balance the air supply. A flashing red indicator light at all stations could warn sooner or more visibly of low air or a sudden drop in air pressure. A system may have to be devised by which the compressor is unloaded immediately when its rpm slows to a certain level or stops. This should be done immediately without disturbing gun air pressure and allowing the compressor to restart under no load.

7. Hookup the hydraulic cooling system to a larger hydraulic line, so it circulates more fluid.

8. The problem of the hydraulic arms jamming the guns against the tracks or FMC fender, as per Planting Gun, Item #12.

9. Shield hydraulic hoses near operators.
B 10. Relocating the oil cooler, possibly below the feet of the rear operator, would leave the right rear fender free.

11. More vertical movement of the hydraulic arms (and subsequently of the planting head), would be advantageous for planting.

At times one was "raising" and "pulling in" the guns to avoid obstacles where simply raising them may have been enough, given more movement in the arms. A longer inner arm that may accomplish this could produce a more jerking control response at the same time.

C FMC - PLANTING AND MISCELLANEOUS

1. Provide more roof cover and/or side curtains for rain protection of the operators. Caulk all sheet metal structural tubing edges to waterproof the cab, as the screw-holes attaching the roof panels leak.

2. Evaluate the rear operator's safety in his planting position.

Any reversing of the machine puts him and his gun in jeopardy, as he has only one way out of his "cage". Rear entry to his position might be considered.

3. Replace the 3" x 3" angle-iron screen support at the rear, with something much stronger. Also, the steel mesh is not heavy enough nor is it used for visibility and could be replaced with sheet steel.

4. Backs of seats could be higher and more of a wrap-around type, to give better sideways support (re rocking action) and some protection against whiplash.

5. When using the winch, all personnel, except the driver, should be off the machine and standing well away.

The consequences of a broken cable, uprooted or broken stump, or a slipped cable, should be considered.

6. The battery appeared weak, as if it was not being charged at low engine revolutions.

Check the charging system and the drive belt or, provide two batteries?

7. Provide longer headset cords for the operators, preferably the coiled type.
C 8. A slightly farther reach away from the FMC by the hydraulic arms would eliminate the problem of bullet coverage by material thrown up from the tracks when turning the FMC.

Locating the guns at or behind where the tracks leave the ground may also prevent this.

9. Mud, rain, oil, etc., make the steel deck extremely slippery. Some alterations are required to provide traction under these conditions.

10. Time spent training new operators on the operation of both the guns and the hydraulic controls proved beneficial. A knowledge of tree planting is helpful when choosing planting spots.

Carrying hand guns on the FMC would enable the operators to "fill in" while repairs were effected.

11. Drawings of the existing machinery should be prepared so what now exists can be further evaluated and future changes can be properly detailed. Drawings should eliminate existing problems being designed into future machines.

12. At least two people somewhat familiar with the mechanics of the machine, should be present when it is operating. One person thoroughly trained in the hydraulics and pneumatic circuits and another person to assist. The driver and one planter could fill these roles.

D FEATURES THAT WORKED PARTICULARLY WELL

1. The single bullet separator worked efficiently and was easy to clear whenever a problem arose.

2. The four planting fingers on the planting head did a good job of clearing broken bullets.

3. The visibility of the side operators was good as far as planting spots, debris, etc., were concerned.

4. The planting controls for each operator worked well for avoiding debris, hitting isolated planting spots, etc. Control of the planting head is good.

5. The intercom system proved a very necessary and reliable tool.

6. The plastic strip on the bullet block held the bullets together without mishap. Removal of the straps when loading the guns was fairly easy, provided a sharp knife was used.
D 7. The FMC seemed to be able to move about well in all types of logging slash; be it mud, semi-windrowed slash or burned slash.

The winch seems to be an unbalancing problem during planting until you get stuck and require its help. The stumps posed no special problem aside from learning which ones to avoid and which ones to go over.

8. The ride on the FMC was fairly comfortable, as long as you sat back in your seat, wearing your seat belt and hard hat.
Appendix III

Computation of fuel loading delayed indefinitely.

See photographs for visual estimate.
## Appendix IV

### Rate of Planting *

<table>
<thead>
<tr>
<th>Number of Trees</th>
<th>Time (minutes)</th>
<th>Trees/minute</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1.32</td>
<td>11.4</td>
</tr>
<tr>
<td>20</td>
<td>2.26</td>
<td>8.85</td>
</tr>
<tr>
<td>18</td>
<td>3.30</td>
<td>5.45</td>
</tr>
<tr>
<td>14</td>
<td>2.80</td>
<td>5.00</td>
</tr>
<tr>
<td>18</td>
<td>3.00</td>
<td>6.00</td>
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<tr>
<td>38</td>
<td>3.89</td>
<td>9.8</td>
</tr>
<tr>
<td>20</td>
<td>3.31</td>
<td>6.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>143</strong></td>
<td><strong>Average 7.2</strong></td>
</tr>
</tbody>
</table>

*For selected periods of continuous operation only. Down time is not included. Left side gun only.*
Appendix V (1)

Planting Quality: Cleared (windrowed/piled) Site

<table>
<thead>
<tr>
<th>Tree Number</th>
<th>Planting Quality</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>2</td>
<td>Satisfactory (bullet shattered)**</td>
</tr>
<tr>
<td>3</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>4</td>
<td>Satisfactory (bullet shattered)</td>
</tr>
<tr>
<td>5</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>6</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>7</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>8</td>
<td>Not satisfactory, shattered on rock</td>
</tr>
<tr>
<td>9</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>10</td>
<td>Not Satisfactory, hit log</td>
</tr>
<tr>
<td>12</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>13</td>
<td>Not satisfactory, tilted 60° off vertical</td>
</tr>
<tr>
<td>14</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>15</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>16</td>
<td>Not satisfactory, shattered</td>
</tr>
<tr>
<td>17</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>18</td>
<td>Not satisfactory, too high</td>
</tr>
<tr>
<td>19</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>20</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

Total satisfactory 14 trees (70%)

* This data is not as comprehensive as the data listed on page (2) and is therefore listed separately.

** Planting is shown as satisfactory if seedling is planted at acceptable depth even though bullet is shattered from hitting underground obstruction.