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Fabrication of Fertilizer-Impregnated Boards from Low Quality Thinned logs using the High-Pressure Steam Method

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Thinned logs from plantations in Japan are usually left in the forest due to their low quality and market values. In order to utilize these biological resources effectively, the high-pressure steam and mechanical pressing method was used to fabricate chipboards from low quality thinned Sugi (*Crpytomeria Japonica* D. Don) logs. Knowing that the nutrient content of wood is naturally low, urea was impregnated into some of the chips with the purpose of fabricating urea-impregnated boards. By using these two types of boards as mulches, field experiments were conducted on a maize plot on the campus of Gifu University. The results obtained indicate that the total biomass yield on an area of 1.44 m^2 were 2.1 kg for the plot mulched with urea-impregnated boards, 1.7 kg for chipboard mulched plot and 1.4 kg for the bare plot. Weed weight (dry matter) after one month of cultivation was found to be highest for the bare plot (71 g), while very low figures of 12 g and 8 g were obtained for the urea-impregnated board mulches and chipboard mulches respectively. These findings suggest that impregnating boards with fertilizer and using them as mulches will not only reduce soil moisture loss but also serve as a means of effectively supplying nitrogen to crops. Furthermore, the use of such mulches in small-scale farming systems can have both economic and environmental benefits by increasing agricultural production, eliminating the cost of weeding and the need to apply weedicides.

Keywords: Compost boards, Urea-impregnated boards, High-pressure steam treatment, Mulches

1. INTRODUCTION

Mulches are materials placed on a soil surface purposely to reduce evaporation or as a weed control measure. By serving as barriers, mulches prevent soil moisture evaporation and help in the conservation of soil moisture. They can be either natural (e.g. rice straw, wood chips, grass, sand [1], etc) or artificial (e.g. opaque or transparent plastic sheets). Plastic sheets are not biodegradable, act as a barrier to infiltration of water from rainfall and also their means of disposal poses a threat to the environment. Furthermore, the future of plastic sheets cannot be guaranteed given the current trends in oil prices. Most natural mulches on the other hand, are either easily washed away by runoff after heavy storms or blown away by strong winds. To provide solutions to the issues addressed above, an investigation was carried out to assess the possibility of using boards fabricated by the high-pressure steam and compression method as mulches. The production of boards from bioresources is not a new idea [2,3,4]. However, most of these production processes involve the use of adhesives and the final products are hardly used for mulching purposes.

In Japan, low quality thinned logs, especially from sugi (*Crpytomeria Japonica* D. Don) plantations, are usually abandoned in the forest due to their low market values. Converting these unutilized but abundant biological resources into mulches through the pressurized steam and mechanical pressing method could be an effective way of realizing the potential value in these types of resources. As the nutrient content of wood chip is naturally low, nitrogen was impregnated into some of the chips with the purpose of fabricating mulches that can also be a source of nitrogen for agricultural crops. These two types of boards were used as mulches in a maize field on the campus of Gifu University and experiments were conducted to investigate their effectiveness in suppressing weeds as well as in increasing biomass production.

2. MATERIALS AND METHODS

2.1 Board fabrication process

The main raw material used was dry wood chips obtained from thinned (whole trees) sugi (*Crpytomeria Japonica* D. Don) logs. With the high-pressure steam method [5,6,7], the chips are initially placed in a metallic frame and compressed to a target thickness of 2 cm, after which they are placed in an autoclave where steam at 180℃ is injected for a 30-minute duration. The steaming process, referred to as permanent fixation, is carried out to ensure that the boards become dimensionally stable after pressing. To fabricate the urea-impregnated boards, some of the chips were first soaked in urea solution for a period of three days after which the procedure described above was followed.

2.2 Laboratory experiments

In accordance with JIS A5908-2003 specifications, samples were cut from the boards for physical tests such as water absorption capacity (WA), calculated as the percentage increase in weight in after soaking samples water for 24 hours. The water retention property was determined by soaking samples in water for 24 hours and then allowing them to dry in the open air while their moisture contents were gradually monitored. As a strength indicator, the internal bonding strength (IB) of both types of boards was also determined.

The mulching effect of the two types of boards was estimated in the laboratory by the following simple method. Flowerpots were partially filled with equal weights of soil and then covered by test samples as shown in Fig. 1. Equal amounts of water was applied to all the treatments, including the control which was not covered while monitoring of the soil moisture content was periodically done for 78 hours.

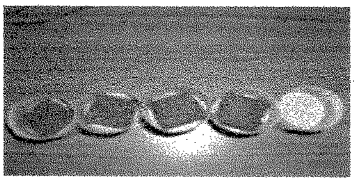


Fig. 1 Determination of the mulching effect of boards

2.3 Field experiment

A field within the campus of Gifu University, Japan was demarcated and divided into small plots each of area 1.44 m^2 and the following mulching treatments made on the plots, before maize seeds were sown:

(i) Three Plots mulched with urea-impregnated boards, (ii) Three Plots mulched with ordinary boards and (iii) Three bare plots (Fig. 2). The board mulches were cut into dimensions of 30 cm×30 cm and each plot in the treatments described in (i) and (ii) above was covered with sixteen boards, leaving a gap of about 2 cm between them. The maize seeds (three per hole) were sown in these gaps. After germination, unhealthy seedlings were removed to ensure that only healthy ones remained in each hole. After this treatment, each plot was left with a total of 33 equally spaced healthy seedlings. The experiment was set up at the beginning of August 2005 and allowed to continue until the maize crops attained their full maturity and were finally harvested at the end of October 2005. After one month of cultivation, the weeds on all plots were removed, dried and weighed to estimate the dry biomass. At the end of every month, samples were removed from the boards to determine the total nitrogen and carbon contents.

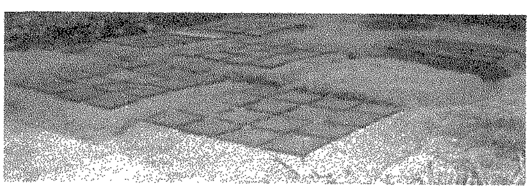


Fig. 2. A photograph of the field experimental layout

3.RESULTS AND DISCUSSION

3.1 Physical properties of the boards

The average densities of the boards and urea-impregnated boards were 0.66 and 0.65 respectively and were not significantly different. As no chemical adhesives were used in the fabrication process, the internal bonding strength (IB) of the boards was not expected to be generally high as in the case of boards fabricated for construction purposes. Nevertheless, the impregnation with urea resulted in an increase in the average IB values as shown in Fig 3. The bonding between urea and wood constituents, especially vanillin might have contributed to the increase in strength.

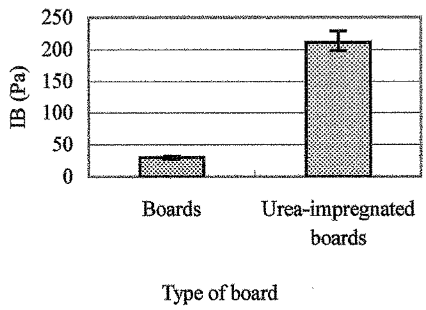


Fig. 3 Internal bonding strength of the boards

3.2 Water absorption capacity and retention rates

After soaking samples in water for 24 hours, it was found that the urea-impregnated boards absorbed more water (77%) than the boards (67%) as shown in Fig 4. It can also be seen from the graph that urea-impregnated boards could retain more moisture for longer durations than the boards. This is an indication that impregnating urea into boards will improve their capacity to function as mulches.

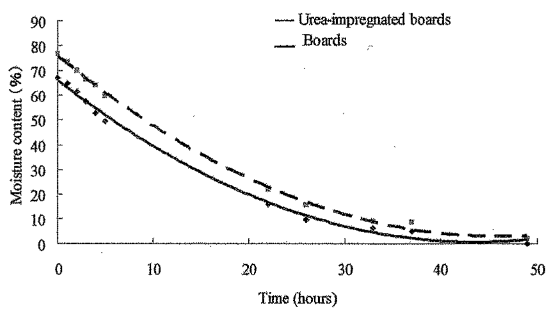


Fig. 4. Effect of urea addition on moisture absorption capacity and moisture retention of the boards

3.3 Mulching effect of the boards

The accumulated evaporation (E) from the pots mulched with the two types of boards and the control was measured after 5, 22, 33 and 78 hours as shown in Fig. 5. It can be clearly seen that the moisture loss through evaporation was much higher for the control compared with the boards. Although there was not much difference in the evaporation amounts between the pots mulched with the two types of boards, the urea-impregnated boards exhibited a better mulching characteristic by suppressing more soil moisture compared with the boards. This result is in agreement with the earlier finding that the moisture retention property of urea-impregnated boards is slightly higher and as a result prevents moisture from leaving the soil-board interface.

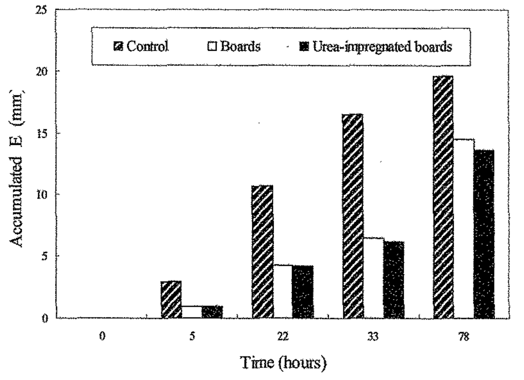


Fig. 5. Accumulated evaporation loss from soil

3.4 Changes in total nitrogen and total carbon contents

Table 1 shows the total nitrogen content (TN), total carbon content (TC) and C/N ratios for the wood chip and the two types of boards. The quantity of urea initially impregnated into the chips had been calculated to produce boards with a target C/N ratio of 20 but the compression and steam application processes could have resulted in some slight changes in the chemical constituents of the chips, thus resulting in a figure of 23.3. All the same, literature shows that a C/N ratio of 20-25 is the optimum range for most compost applications. There were significant reductions in the total carbon contents after the fabrication process.

Table 1 Total nitrogen and carbon contents of the chip before and after fabricating boards

Type of material	TN (%)	TC (%)	C/N
Chip (Original material)	0.55	36.24	65.9
Board	0.51	24.95	48.9
Urea-impregnated board	1.05	24.44	23.3

The changes in total nitrogen content of the boards were measured at the end of every month for a period of three months. Another measurement was made three months after harvesting the maize crops. The results are illustrated in Fig. 6, which shows similar patterns in the changes in TN for both types of boards. One interesting observation to be made from the graph is that TN throughout the cultivation period of three months remained higher than the initial value for both boards but dropped after the sixth month. This could imply that nitrogen was probably not in the available during the first three months and needs further investigation.

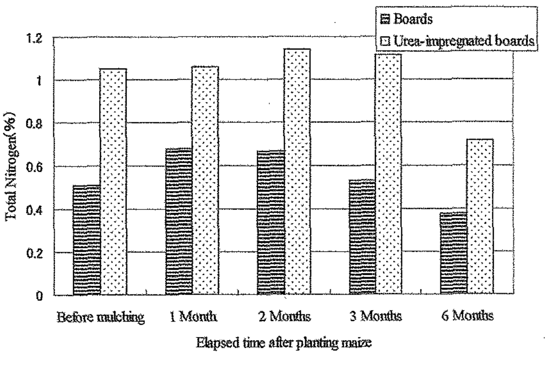
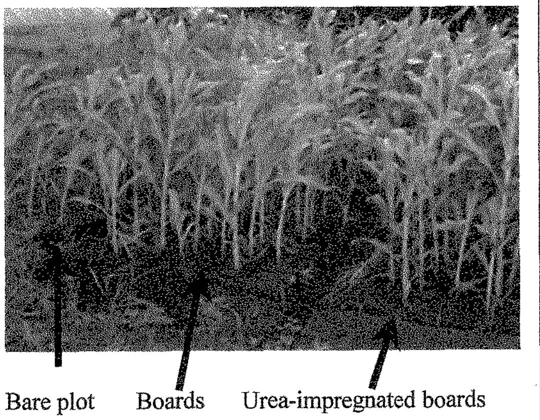


Fig. 6 Changes in total nitrogen content of both boards

3.5 Biomass yield

Fig. 7 shows a photograph of the maize plot after 5 weeks of cultivation. All the crops had fully grown to maturity at the end of 3 months of cultivation, so the experiment was discontinued and the crops dried and weighed to determine their dry matter content. Results in Fig. 8 indicate that the average total biomass yield on an area of 1.44 m^2 were 2.1 kg for the urea-impregnated mulched plot, 1.7 kg for chip board mulched plot and 1.4 kg for the bare plot.



Bare plot Boards Urea-impregnated boards

Fig. 7 Maize field after 5 weeks of cultivation

3.6 Weed suppression effect of boards

Weed weight (dry matter) after one month of cultivation was found to be highest for the bare plot (71 g), while very low figures of 12 g and 8 g were obtained for the urea-impregnated board mulches and chipboard mulches respectively. Using boards as mulches in small-scale farming systems can eliminate or significantly reduce the cost of weeding and the need to apply weedicides.

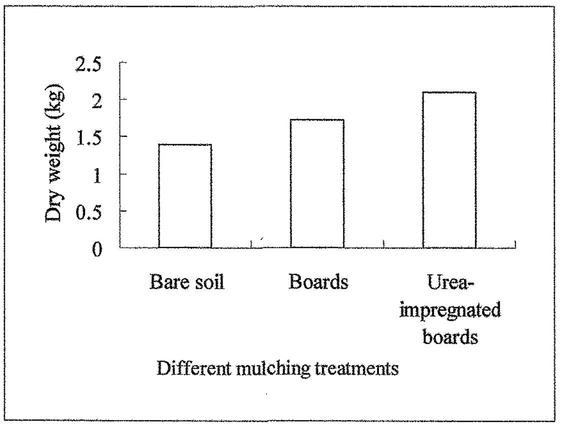


Fig. 8 Total weights of maize crops harvested on each plot

4. CONCLUSIONS

Without using chemical adhesives, it was possible to fabricate urea-impregnated boards that have several economic and ecological benefits such as yield improvement, prevention of soil moisture loss, and elimination of weeding or herbicide application. The concept of impregnating boards with fertilizers and using them as mulches will be very useful in areas where soil nutrients are easily leached or washed away by surface runoff and in places where evaporation rates are very high. It has been reported that soil management practices that keep soil particles in place should be preferred to ones that are designed to intercept eroded sediment after it has moved a considerable distance [8]. Board mulches encourage raindrops to infiltrate, slow down surface runoff, shield the soil and plant roots from solar radiation and provide moist conditions that promote microorganisms and worm populations. Apart from on-farm applications, these boards could be used as integral components of land restoration or rehabilitation projects. In the near future, we intend to investigate how these boards can be used to slow overland runoff, allow water to soak into the ground, and trap sediments and nutrients before they are discharged into nearby streams.

Further studies are also needed to investigate the rates at which nitrogen is released from the boards. This information will be very useful in predicting the most suitable time the boards should be installed for crops to take full advantage of the released nitrogen.

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