Effects of Flooding and Paper Mulch on Fraser Valley Rice

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Abstract

Transplanted flooded rice production is the predominant method for rice (*Oryza sativa)* cultivation globally. The method of flooding is used as a source of irrigation and a weed management strategy due to most weeds not being able to survive under the submergence of water. Flooding creates anaerobic soil conditions favouring methanogens, releasing the potent greenhouse gas methane into the atmosphere. Further droughts associated with the climate crisis reduce water availability for flooded rice systems. Alternative options are being studied, including Dry-field (DF) production which is grown like any typical cereal crop. Dry-field production reduces water consumption and methane emissions but may increase weed pressure. Furthermore, rice production in dry production systems often leads to lower yields and less stable productivity. This experiment compares the yield in grain weight and weed pressure using paper mulch as a management tactic between flooded paddy and dry-field production systems. The flooded system produced more grain weight with 118 g/m^2 compared to the dry-field system producing 7.6 g/m^2. The paper mulch had no effects.

Introduction

Rice (*Oryza sativa),* belongs to the Poaceae family and is cultivated for its grain. Grown in more than 113 countries across the globe (Oladele et al. 2019), it has become the main caloric source for more than half of the world's population (Augustyn 2022). Therefore, it plays a significant role in food security and the livelihoods of many, especially in regions from the global south where most flooded rice production occurs (Bren d'Amour and Anderson 2020). The most common way rice is grown is through the transplanted flooded paddy system. This traditional paddy system is a method of planting that floods the rice for a prolonged period (Liu 2014). This process is primarily used as a weed management strategy, using standing water as an anoxic environment that makes it difficult for weeds to undergo cellular respiration or photosynthesis. As a result, growers can obtain more yield with less labour for weed management. However, agriculture consumes up to 70% of the available freshwater supply worldwide with up to 40% of it for rice cultivation (Bouman et al. 2007). Undoubtedly, the flooded paddy system is threatened by its high water requirements along with the increasing limitation of access to fresh water, and the occurrence of more seasonal droughts caused by climate change (Liu et al. 2015). Other means of production are being sought out such as dry-field production to combat the overconsumption of freshwater used in rice cultivation.

Dry-field production is one method of rice production being adopted in areas facing water scarcity. Dry field production saves up to 55% of water compared to flooded systems but with a decrease in yield (Peng et al. 2006). The total water use was significantly lower in dry-field production, however, it comes with the constraint of weed presence due to the absence of flooding (Mahajan and Chauhan 2013). Finding alternative ways for rice production is vital as we quickly face more intensified weather and experience an increase in droughts, thus risking access to food security in many countries, especially in areas crucial for rice production.

Paper mulch is used to control weeds in agricultural production. Weeds are responsible for the highest potential loss in vegetable production worldwide and mulch layers are one of the ways to mitigate a common issue (Oerke 2006). Black polyethylene mulch is prevalent in vegetable production due to its weed suppression ability because of its opacity (UMass Extension 2012). The colour also helps with the warming of the soil during the growing season (UMass Extension 2012). However, the environmental impacts of black polyethylene can be long-lasting, leaving debris and microplastics in the soil, eventually ending up in aquatic systems. Therefore, finding another mulching system – such as paper mulch – with less negative impacts on the environment, as well as dealing with persisting weed pressure could be beneficial in a small-scale production system. Paper mulch is a biodegradable material that naturally decomposes. A study by Cirujeda et al. (2012) found that paper mulch controlled weeds as well as black polyethylene ranging between 80% to 100% in success rate. However, one of the disadvantages one faces is avoiding rips and fractures during the installation process (Cirujeda et al. 2012).

This experiment examined the productivity of a Japanese short-grain rice variety, *Nanatsuboshi ("Seven Star")*, based on the grain weight yield and weed management in dry-field production and flooded production systems with the addition of paper mulch as a weed treatment.

Materials and Methods

The experiment used grain weight as the dependent variable and the production methods (flooded and dry-field) and paper mulch (present or absent) as the independent variable.

Four treatments will be tested in a split-plot design:

1. Dry-land rice with paper mulch.
2. Dry-land rice without paper mulch.
3. Flooded rice with paper mulch.
4. Flooded rice without paper mulch.

The objective of this research is to compare yield and weed management between two crop systems: Flooded production and Dry-field production system. The two individual objectives are:

1. Compare the yield of the Japanese short-grain rice variety, *Nanatsuboshi ("Seven Star")*, in a flooded rice paddy and dry-field production system.

2. Assess the impact of paper mulch on weed suppression for dry-field production systems and flooded paddy systems.

The main hypotheses are

1.) *Null hypothesis:* There will be no difference in yield between dry-field and flooded production systems.

Alternate hypothesis: There will be a difference in yield between dry-field and flooded production systems.

2.) *Null hypothesis:* There will be no difference in the yield with the paper mulch present between the flooded production system and the dry-field production system.

Alternate hypothesis: There will be a difference in the yield with the paper mulch present between the flooded production system and the dry-field production system.

Seeding

The seven-star rice seeds have been adapted to the Fraser Valley region in BC and went through a germination period before being planted into the transplant trays. Seeds were soaked in water for 10 days at 10℃ to germinate (Shiroki 2013). The germinated seeds were sown into trays with roughly 15 cm of soil. The trays were placed inside the KPU farm dome, a passively heated greenhouse, until seedlings were 8-10 cm. Once the transplants were ready to be planted, they were taken out of the dome to harden off and acclimate to the outdoors before transplanting.

Experimental site

This experiment was conducted on KPU Research Farm at the Garden City Lands, Richmond, BC, situated on the west end of the Lulu Island peat bog. The farm contains sandy clay loamy soil sitting on top of a peat layer. The six experimental plots were excavated on the south side of the East 1 field, which has clay-dense soil that can retain more water for the flooded plots. The plots were previously dug out for educational purposes like examining profile layers of soil and were later filled back in where a mixture of field grass and weeds grew on top of it.

Experimental design

The plot design was a completely randomized split-plot design with three replicates. The six plots were 1.6 meters by 3.2 meters with 1 meter spacing between them (Figure 1). The plots were dug out with a tractor's front-end loader and manually levelled using a pick axe. Each plot was 30 cm deep after the addition of 2.54 cm of compost added to each plot. The compost used came from Net Zero Waste and was primarily made of feedstock (food waste, green waste, grass clippings, and agricultural and fish waste). There were 8 rows of rice in each plot, spaced 20 cm apart and plants were spaced 15.2 cm apart within rows, totalling 21 plants per row. Plants were spaced with a dibbler (Two Bad Cats, Rutland, VT). Three 8 cm transplants were placed in each hole. The plants were consistently soaked until they were fully established and had a well-developed root system. After establishment, dry plots were drained and flooded plots were puddled up to 20 cm.

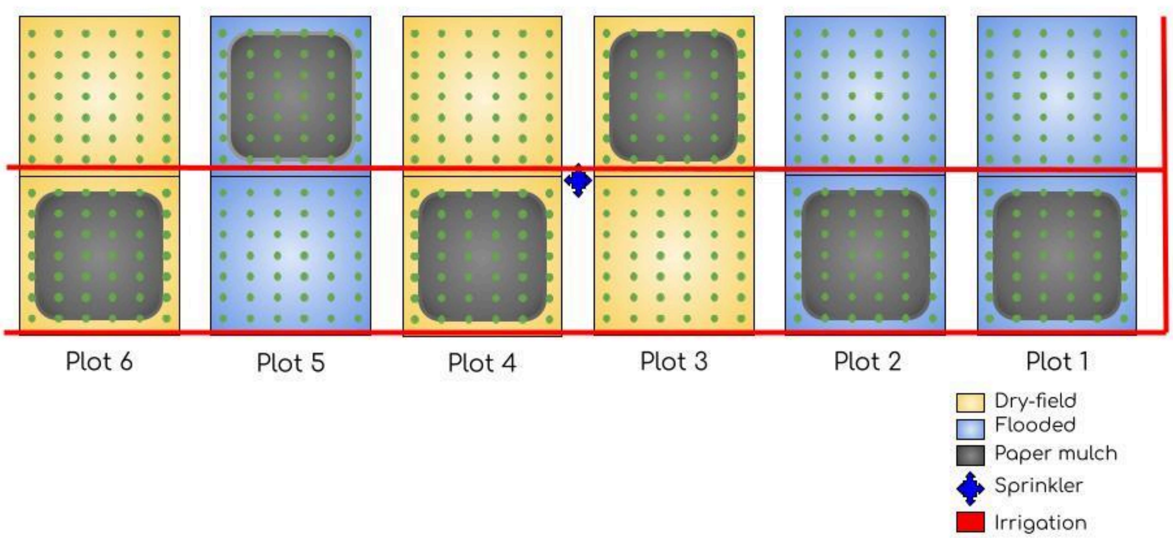


Figure 1. Completely Randomized Split Plot design with three replicates with an irrigation line going across all the plots. The sprinkler was positioned between Plot 4 and Plot 3.

Paper mulch

The paper mulch was placed in each plot and evenly punctured using the dibbler before all the transplants were planted.

Irrigation

Flooded production

The flooded plots had drip irrigation set up with one line placed in the middle of the plot and the other running through the bottom of the plot. Emitters were installed with each one dripping 3.7 litres of water per hour, running continuously. This maintained the constant flooding at approximately 20 cm for each plot. Plots that drained faster than others had more emitters placed on the line compared to plots that drained slower. The irrigation began on June 5, 2023, and was turned off on September 12, 2023, to allow the plants to dry in the field.

Dry-field production

The dry-field plots were irrigated by a timed overhead sprinkler irrigation system, placed in between Plots 3 and 4, set to run for 120 minutes every day at 3:00 AM, to reduce transpiration during the warmer months. The irrigation for the dry plots began on June 5, 2023, and was turned off on September 12, 2023, to allow the plants to dry in the field.

Fertilizer/ Amendments

Approximately 2.54 cm of compost was added to each plot before planting and was soaked with water to loosen and puddle the soil and allow the compost to infiltrate through. Feather meal fertilizer (4-4-4) was added to all the plots on June 27, 2023, to address the nutrient deficiency symptoms. All the flooded and dry plots were fertilized with a combined amount of 3.45 kg and 5.17 kg of fertilizer, respectively. The amount of fertilizer was based on Masa Shiroki's measurements for his own fields. He used "7 kg of fertilizer (18-18-18) per hectare in the wet plots and 14 kg in the dry plots" (Shiroki 2023).

Data collection

Grain weight

Yield was collected by harvesting a 1m x 1m subsample from each subplot using clippers at the base of the plant. The rice plants were harvested at 80-85% maturity with a developed straw colour and weighted down panicle (Gummert et al. 2005). The harvested stalks were hung to dry inside the dome for 15 days until fully dried. The grains were separated from the stalks by hand threshing. The hand-threshed grains were put into an air separator where the unfilled grains were separated from the fully mature grains. The yield was the weight of the fully mature grains.

Weed percentage removed

The data for the weeds was collected using the app 'Canopeo' which measures the percentage of the green canopy to the percentage of ground cover. To determine the amount of weed cover that is removed, a photo was taken parallel to the ground, two feet above the canopy before and after weeding. The weeds were removed from the dry plots (plots 4, 3, and 6) with no paper mulch.

Statistical analysis

Mixed Model analysis was used to analyze the data for the collected dried grain weight. The Dry grain weight was Log 10 transformed to satisfy the assumption of normal distribution of residuals.

Results and Discussion

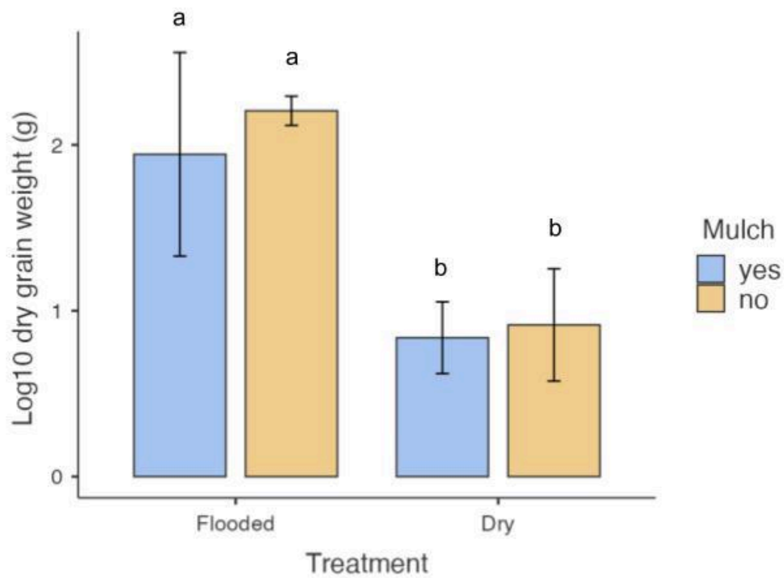
Performance of Flooded and Dry Production Methods

Flooded plots produced an average of 118 g/m² while the dry plots produced an average of 7.6 g/m². The paper mulch did not affect the yield.

The lower yields in the dry plots may have been due to inconsistent watering during the establishment period for the transplanted rice in the dry plots. Each dry plot drained at different rates making it difficult to assume how much water each plot needed to maintain a 2-3 cm of flooding for the transplant to initiate root growth. Trying to keep water in the plots had proven to be difficult as we had tried multiple different watering methods for the dry plots such as hand watering, drip line irrigation going down each row of the plot, drip line irrigation sitting perpendicularly across the plots (same as the flooded plots) with fewer emitters putting in less water, and an overhead sprinkler running for a couple of hours each day. Each method was trialled for approximately a week to see which one kept a consistent amount of water level in each dry plot. The overhead sprinkler was observed to be the best method for consistent watering with the lowest amount of maintenance. However, each dry plot showed inconsistent growth methods. This might have been due to the overhead sprinkler being placed approximately in between all the dry plots (plot 4 and plot 3), which may have caused plot 6 to not receive sufficient water compared to the plots that were closer.

There was also difficulty in levelling the plots after excavating them, making it hard to keep an even distribution of water throughout. This was mainly due to the thick clay layer at the bottom of the plots, making it hard to break apart and loosen the soil using a pickaxe. For many of the plots, both dry and wet, the north side of the plots was more depressed. This prompted taller stalks and more developed grains on the southernmost side of the plots. Levelling each plot with more loose soil would have been a viable solution to this issue, providing more opportunities for the plant to thrive while retaining an even distribution of water.

Furthermore, lower yields in the dry plots could have been caused by the later planting period. Rice grown in the Lower Mainland of BC is usually planted at the beginning of May to take advantage of the full growing season. We planted our rice on June 7, 2023, which was a month later than what is to be expected. This could have been the cause of the underdeveloped seeds for some of the plots, especially the dry plots that had to deal with many stress factors such as low water levels and a later planting period. The dry plots also experienced stunted growth which may be due to the lack of water availability during the early stages of establishment. The late planting period did not allow some of the rice plantings to become fully developed, leaving them exposed to the first frost period that hit Richmond, BC on October 19, 2023, which could have had an impact on the maturing grains and browning on the stalks. Also, harvesting them later in the season had an impact on the number of daylight hours the plants were exposed to and the temperature lowering significantly since their peak growing period during the summer months. This could have had an effect on the lower yield rates and unevenness in the maturity of



the crop.

Figure 2. Dry rice grain yield from the flooded plots and dry plots. Error bars denote standard error. Means labelled with the same letter do not differ significantly. (Bonferroni test. n = 3, a = 0.05).

Weeding performance

Weeding took place when young weeds had started to cover a mat on the ground. Some of the weeds that appeared in the plots are smartweed *(Polygonum pensylvanicum)*, clover (*Trifolium repens* and *Trifolium pratense)*, Canada thistle *(Cirsium arvense)*, hairy vetch *(Vicia villosa)*, lambs quarter (*Chenopodium album)*, purslane (*Portulaca oleracea)*, quack grass *(Elymus repens)* and broad-leaved dock (*Rumex obtusifolius)*. The percentage of weeds removed was from dry plots (plots 4, 3, and 6) on the side with no paper mulch. The weed percentage that was removed shown in Figure 3, had a mean of 11.0% with a minimum of 1.32% and a maximum of

20.4%. Weed amounts varied in each plot depending on the seed bank that was present there in the soil from before. The paper mulch had no significant effect on the yield. Initially, the paper mulch was intended to slowly decompose back into the soil as the rice plants had become well-established enough to create enough canopy cover to prevent light from filtering through, impeding the growth of weeds. The fine-textured, biodegradable product lost its effectiveness faster than the rice could build its canopy cover. This was caused by the tearing of the mulch paper from the degradation of the mulch due to a mixture of wetness, the wind, pressure from the weight of rocks placed to weigh the mulch down or from people walking on the plots, thus adding more pressure and ripping the pieces apart. A better system like placing soil on top of the paper mulch would evenly distribute the weight and would have better constrained the weeds from coming through.

A weeding event only took place on the dry plots on the non-paper mulch side. But weeding should have taken place on all the plots, including the wet plots on both sides with and without the paper mulch as well as the paper mulch side in the dry plots. This would have properly compared the amount of weeds removed from each plot and witnessed how much both the flooding method and the paper mulch realistically prevented the weeds from growing and competing with the rice plants. For future research, it is encouraged to go through the weeding process for all plots to compare the impacts of the tested factors. To add on, some of the weeds that were growing out of the flooded plots such as smartweed, had adapted to the flooded effects and had their roots growing along the stalk and above the water similar to nodal roots on corn.

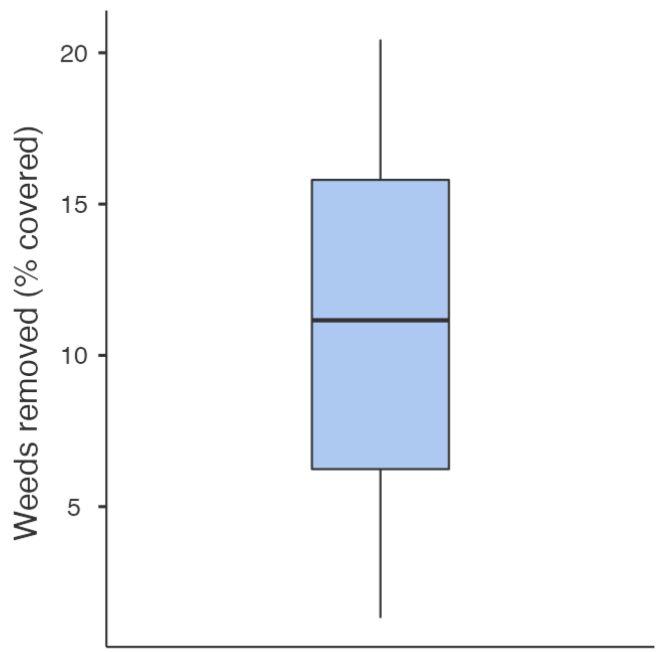


Figure 3. Average percentage of weeds removed.

Conclusion

In conclusion, flooding produced a higher rice yield than dry-field production. Paper mulch did not affect the yield, although more data is needed to properly analyze the full impact of the mulching system in contrast to the flooding methods. The mulched side of the plots in both flooded and dry fields must be weeded to compare the impacts of the paper mulch. Flooding benefits rice, however, methods to reduce water use in flooded systems should be considered in light of freshwater consumption of flooded systems, especially as we experience the current climate crisis with warmer weather and, in turn, witness more droughts occur.

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