Reinventing Rice for Sustainability: The Importance of Growing Climate Friendly Rice

by Megan Mehta, Las Positas College
Mentor: Grisel Ponciano

Abstract

This paper explores research conducted at the Shanghai Academy of Agricultural Sciences, where scientists compared a water-saving and drought-resistant strain of rice, Hanyou 8, versus a typical strain of paddy rice, Hanyou 14, that is grown as a primary cash-crop today. The purpose of this paper is to determine which strain of rice is most beneficial for the environment, as well as conclude if developing more climate-friendly crops will negatively impact the total rice yield. Additionally, this paper will analyze the socioeconomic advantages and disadvantages of developing climate-friendly crops rice to draw a more accurate conclusion of which strain of rice is, holistically-speaking, the best option for mass production.

Keywords: rice, climate change, socioeconomic, water, greenhouse gas

Introduction

Rice, an iconic and recognizable component in countless dishes across cultures, can be paired with any food. It is not surprising that rice is one of the most popular and cheapest crops grown around the world. As the global population continues to increase exponentially, and people begin to switch to plant-based diets, rice is becoming a more fundamental part of our nutrition. However, the harmful environmental consequences of growing and consuming copious amounts of rice are becoming increasingly apparent. The climate crisis affects numerous aspects of our everyday life. The progression of environmental destruction is not an option, as we only have a few years to change our habits before the damages are irreparable. Since rice is a pivotal part of countless cultures and diets, particularly in third world countries, banning or placing any limits on the amount of rice that can be grown or consumed annually is not a feasible option. For these same reasons, placing a methane or nitrous oxide tax, similar to the "Carbon Tax" is not a suitable choice. Scientists, X. Zhang, Sun, Wang, J. Zhang, Liu, and Zhou, at the Shanghai Academy of Agricultural Sciences, research if a new strain of water and drought resistant (WDR) rice, Hanyou 8, will combat the increasing demand for rice without harming ecosystems. This paper will describe the role of water in rice growth, compare the amount and weight of grain grown from Hanyou 8, and Hanyou 14, as well as describe the significance of developing more climate-friendly crops, particularly rice.

Rice Growth and Development

Rice grows in four stages: germination stage, vegetative stage, reproductive stage, and ripening stage. After the seed planting, the rice plant prepares to enter the growth or germination process, during which the shoots and roots of the plant will begin to develop. The initial development of structures is essential because strong, healthy roots in a nutrient-rich environment will allow for maximum water and mineral absorption. Adequate nutrition leads to the maturation of a healthier plant with denser higher-quality nutritional grain. Following germination, vegetative state, the tillers, also known as the stems and leaves, will become more apparent as the plant continues to mature. Apical

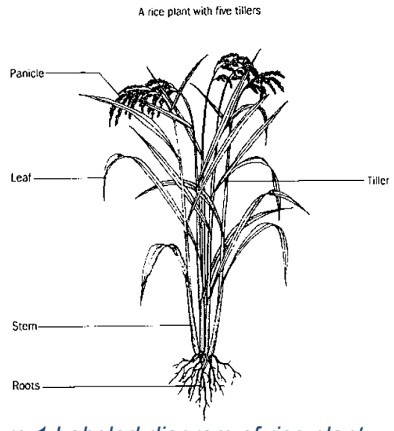

Figure 1 Labeled diagram of rice plant

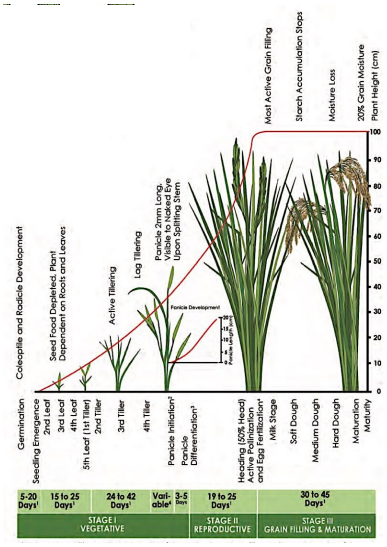

Figure 2 Rice plant development stages and purposes

meristems, the specialized cells in all plants that are responsible for the primary growth, continue to increase the height of the rice plant. After that, the reproductive phase is the most vital part of rice grain development. Throughout this stage, the rice plant begins to develop panicles until they are fully visible. Flowering begins, allowing pollination to occur. The number of spikelets will determine the quantity and quality of the grain. Strong development and maturation of tillers are essential because it allows conditions that promote healthier panicle growth. Thriving panicles are significant because healthy panicle growth promotes abundant spikelets, thus an increase in salubrious dense grain.

The final stage, ripening, allows the grains of rice to flourish. The size and weight of the spikelet can gauge how nutritious and filling the grain will be for the consumer. Although the growth and development of grain is a lateral and straightforward process, some mutations and abnormalities can occur. For example, the rice plant can have large spikelets but not hold any grain material. In these cases, the spikelet is called a false growth.

Factors Affecting Rice Growth

Numerous factors affect the growth and development of the rice plant and grain, particularly during the ripening stage. Key variables include the amount of water available, humidity and oxygen levels, temperature, soil quality, and slope of where the plant is growing. Traditional patty rice is heavily dependent on the amount of water available for panicle and spikelet growth; thus, water affects the growth of nutritious grain. Variations in temperature and humidity can negatively affect spikelet fertility, promoting false growths. A high slope can increase runoff, consequently reducing the amount of water absorbed by the plant, while washing away minerals and diminishing the quality of the soil. The growth and development of rice is a precise and delicate process. Small changes in any of these variables can lead to significant germination and reproductive stage abnormalities, therefore poor grain quality and overall health of the rice plant. Since the salary of most rice laborers is dependent on the grain weight and quality, the stability of these variables affects their financial security.

Dangerous Biproduct of Rice

Methane

The agriculture industry is a prevalent greenhouse gas emitter, meaning that it is a significant contributor to the climate crisis. Rice is one of the leading causes of environmental damage, as it releases astronomical amounts of methane and nitrous oxide per year. A destructive symbiotic cycle between the rice plant and microbes is the source of the significant release of these pollutants. Paddy rice typically grows in flat fields flooded with oxygen poor standing water; this maintains a consistent amount of heat. Rice farmers may flood their field or infuse the water or soil with carbon dioxide (CO2), as it promotes healthy rice growth. These factors create an ideal environment for methane emitting microbes to thrive. The microbes in the water also "breathe" the C02 and release methane. Since methane is up to 30 times better at trapping heat than carbon dioxide, methane is a more dangerous pollutant. This process is particularly destructive when the rice grain is dense and nutritious. It is a vicious cycle of microbes turning C02, a harmful greenhouse gas, into methane, a more devastating pollutant.

Nitrous Oxide

A similar process causes the production of nitrous oxide (N2O). Intermittent flooding, or when the water levels drop below soil levels multiple times a year, creates an ideal environment for microbes that produce N2O to multiply. In other words, an increase in intermittent flooding also increases the amount of nitrous oxide released. The EPA notes, "The impact of 1 pound of N2O on warming the atmosphere is almost 300 times that of 1 pound of carbon dioxide" (para. 1). The EPA further evaluates nitrous oxide remains in the atmosphere "for an average of 114 years before being removed by a sink or destroyed through chemical reactions," (para. 1). Compared to carbon dioxide and methane, nitrous oxide is less prevalent in the atmosphere. However, it is more environmentally harmful than methane and carbon dioxide because it superior at trapping heat in the atmosphere for more extended periods. Nevertheless, the United Nations Food and Agriculture Organization (UNFAO) recommends intermittent flooding practices to rice farmers, as it reduces the number of microbes that produce methane and saves water. Additionally, N_2O is emitted during specific intervals, unlike the constant emission of methane. Fragmented N_2O emission could be more manageable than consistent methane emission.

Experimental Design

As stated previously, the experiment conducted by X. Zhang et al. compared Hanyou 8, a water and drought resistant (WDR) rice, and Hanyou 14, a typical high-yield Japonica paddy rice. The experiment was conducted in an outdoor setting to mimic traditional rice fields for the most accurate results. A rectangular plot of land is separated into five subplots, as shown in figure 3. Additionally, each section is partitioned off from the adjacent subplot using a waterproof panel that is 0.35 meters underground and 0.15 meters above the ground, a total of 0.5 meters of vertical paneling. Subplots labeled W5 through W2 has a north to the south slope. Subplot W1, the experimental control, simulates the traditional rice-growing practices, including controlled flooding mid-season drainage. Subplots W2 through W5 do not experience traditional field flooding or other controlled irrigation practices. The WDR rice, Hanyou 8, and the traditionally paddy rice, Hanyou 14, are grown on all subplots (a total of 10 plants), with W5 having the highest slope. Instead, those subplots survive on rainwater. Consequently, the amount of rainwater can fluctuate, potentially causing intermittent flooding. This experiment was conducted during the 2014 and 2015 rice growing seasons.

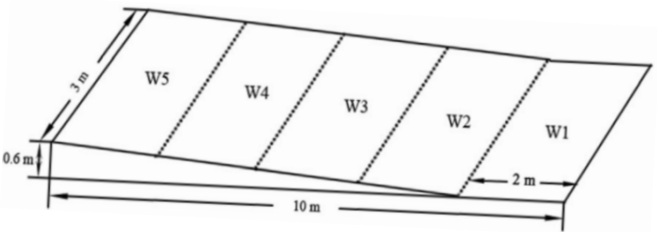

Figure 3 Layout of rice field experimental design

Measuring Methane and Nitrous Oxide Emissions

To measure and compare the quantity of methane and nitrous oxide released by Hanyou 8 and Hanyou 14, the scientists collected air samples and tested them in a gas chromatographer. Between 8:00 AM and 10:00 AM, the sealed each plant using a Plexiglass chamber. Next, they inserted four 1-liter gas bags (shown in figure 4) to collect the samples, allowing about 2 hours for gas collection. After that, the scientists sealed each bag, removed the chamber, and tested the samples of gas in the gas chromatographer. Figure 4B represent how the gas chromatographer works. The sample is attached to a port where a syringe will withdraw a sample. This sample injected into the chromatographer, which adds heat energy and spins it to separate molecules of the gas. This process is similar to a centrifuge. Table 1 shows the results of this experiment. To summarize the results, subplot W1 for Hanyou 8 and Hanyou 14 released the most methane. However, in the same subplot, Hanyou 8 emitted significantly less methane than Hanyou 14, meaning that Hanyou 8 is more beneficial for the environment. Since subplot W1 is a flooded

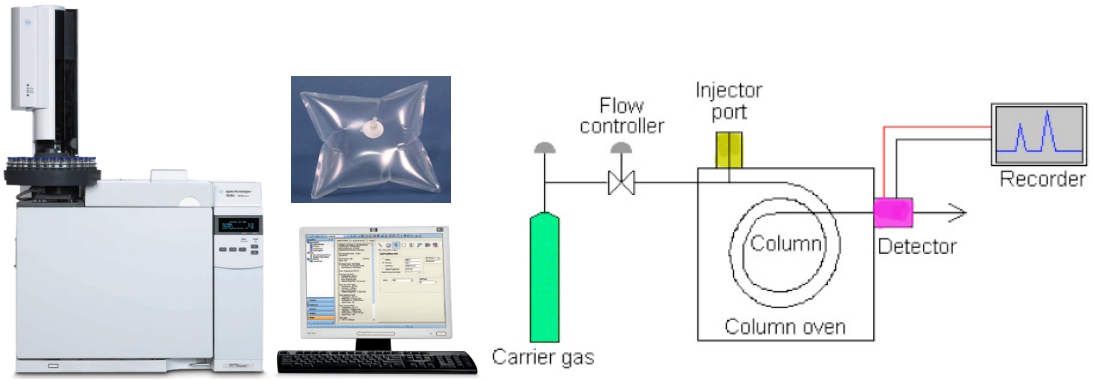

Figure 4A shows the centrifuge machine, computer, and gas bag used in this experiment. Figure 4B shows how the gas chromatography process, including separating the different molecules in the gas sample and how data is recorded.

field, it provides the ideal environment for the methane-producing microbes to thrive. Due to its high slope, water cannot stand still in subplot W5, preventing the methane-producing microbes from thriving. On the other hand, Hanyou 8 and Hanyou 14 produced significantly fewer kilograms of nitrous oxide than methane. Subplot W5 produced the most nitrous oxide emissions, because runoff mimics intermittent flooding, promoting the growth of nitrous oxide producing microbes. Subplot W emitted the least amount of nitrous oxide. These results prove that intermittent flooding, especially on high slopes, leads to the production of nitrous oxide. It also proves that the high production of methane requires lots of standstill water on a low slope, thus results in a lower production of nitrous oxide. An increase in methane results in a decrease of nitrous oxide, while an increase in nitrous oxide results in the decrease in methane. Fields similar to subplot W1 will produce the most methane, and fields similar to subplot W5 will produce the most nitrous oxide. The irrigation practices, amount of water, and slope affect the release of greenhouse gases.

Treatment		CH_4 emission (kg CH_4 ha^{-1})		N_2O emission (kg N_2O ha^{-1})	
		2014	2015	2014	2015
Hanyou 8	W1	124.0 ± 26.9ab	17.6 ± 1.9b	0.5 ± 0.0 cd	8.0 ± 1.7bc
	W2	54.9 ± 27.3bc	4.3 ± 0.8 cd	7.0 ± 0.6ab	11.9 ± 2.1ab
	W3	53.8 ± 20.0bc	1.0 ± 0.7de	5.5 ± 0.3ab	6.9 ± 0.5bc
	W4	37.6 ± 13.5c	− 0.1 ± 0.7de	2.9 ± 0.1bcd	7.9 ± 0.3bc
	W5	15.2 ± 3.9c	4.2 ± 2.0 cd	6.6 ± 0.1ab	7.1 ± 0.9bc
Huayou 14	W1	168.5 ± 40.0a	26.9 ± 3.4a	0.0 ± 0.2d	2.9 ± 0.3c
	W2	73.4 ± 12.3bc	6.9 ± 0.7c	8.7 ± 0.5a	16.0 ± 2.7a
	W3	73.7 ± 45.2bc	0.8 ± 0.1de	6.9 ± 4.0ab	9.8 ± 4.3abc
	W4	86.3 ± 3.0bc	1.1 ± 0.5de	4.6 ± 0.0abc	9.9 ± 2.9abc
	W5	21.7 ± 6.2c	− 1.2 ± 1.0e	4.3 ± 1.2abcd	8.4 ± 2.8abc
Sources of variance					
RS		***		***	
RV		ns		ns	
MG		***		***	
RS × RV		ns		ns	
RS × MG		**		ns	
RV × MG		ns		ns	
RS × RV × MG		ns		ns	

W1, no slope; W2–W4, progressively steeper slopes; W5, steepest slope

Values are mean ± SE. The same letter in a column indicates that the differences were not significant when tested by Duncan's test ($p < 0.05$). *RS* = rice season, *RV* = rice variety, *MG* = moisture gradient; *n.s.,* not significant; **, significant at $p = 0.01$; ***, significant at $p = 0.001$

Table 1: Data comparing methane and nitrous oxide emissions in all subplots for Hanyou 8 and Hanyou 14 in 2014 and 2015

Figure 5 shows peak soil moisture levels towards the beginning of the summer in 2014 and the end of the summer in 2015. This data indicates that 2014 and 2015 W5 subplots of Hanyou 8 and

Hanyou 14 had the most soil moisture variability. On the other hand, W1 had consistently high soil moisture levels in both rice varieties in 2014 and 2015. Again, consistently high soil moisture levels, like subplot W1, resulted in the production of more methane and less nitrous oxide. When the soil moisture levels varied over time, similar to subplot W5, they produced less methane but more nitrous oxide. This data contrasts nitrous oxide and methane production among different irrigation techniques. The link among irrigation practices, slope, methane, and nitrous oxide emission is undeniable.

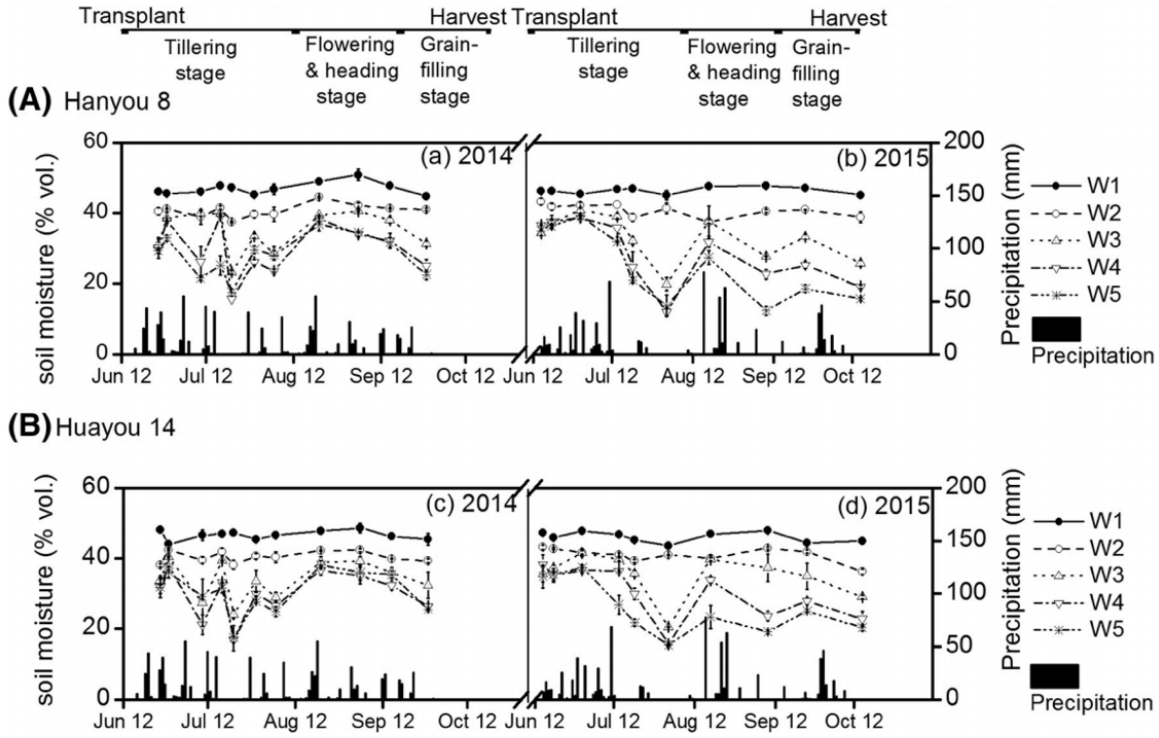

Figure 5 Comparison of soil moisture levels (measured in % volume) for all subplots of Hanyou 8 and Hanyou 14 throughout the 2014 and 2015 season.

The Effect of Soil Moisture on Nutrition and Greenhouse Gases

As stated previously, soil moisture affects greenhouse gas emissions. Rice plants depend on water to produce nutritious rice. Table 2 presents the effective panicle numbers and total rice yield compared to the 1000 grain weight. Effective panicles indicate healthy development during the reproductive stage, and rice yield indicates grain-filled panicles. The 1000 grain weight determines the nutritional value of rice. Although the effective panicle numbers and rice yield of Hanyou 8 and Hanyou 14 varied greatly among subplots, when comparing among the same rice variety, each subplot had nearly identical 1000-grain weight. This is especially in 2014. Overall, Hanyou 14 had about three and a half more grams 1000-grain weight; however, three grams are not significant when considering mass rice plantations and sales of rice in bulk. When considering the impact of growing rice on the environment and its contribution to the climate crisis, it is clear that growing Hanyou 8 in subplot W5 environments, is safer for the.

Treatment		Rice yield (t ha^{-1})		Effective panicle numbers (× 10^4 ha^{-1})		1000-grain weight (g)	
		2014	2015	2014	2015	2014	2015
Hanyou 8	W1	9.20 ± 0.39 b	8.09 ± 0.43 a	226 ± 6 a	222 ± 6 a	26.3 ± 0.3 b	27.9 ± 0.3 b
	W2	7.67 ± 0.50 c	7.64 ± 0.59 ab	188 ± 7 c	158 ± 13 bc	26.6 ± 0.2 b	28.3 ± 0.3 ab
	W3	6.85 ± 0.25 c	4.86 ± 0.27 c	162 ± 10 ef	114 ± 4 cd	26.9 ± 0.1 b	27.1 ± 0.3 b
	W4	7.21 ± 0.25 c	4.76 ± 0.33 c	179 ± 2 cd	117 ± 8 cd	26.5 ± 0.1 b	25.7 ± 0.1 b
	W5	7.30 ± 0.26 c	3.32 ± 0.44 c	182 ± 7 cd	91 ± 9 d	26.3 ± 0.2 b	24.7 ± 0.3 b
Huayou 14	W1	11.02 ± 0.74 a	9.54 ± 0.08 a	207 ± 8 b	199 ± 9 b	30.5 ± 0.1 a	31.1 ± 0.1 a
	W2	9.11 ± 0.19 b	9.28 ± 0.95 a	160 ± 7 f	161 ± 8 bc	30.6 ± 0.1 a	32.0 ± 0.4 a
	W3	8.01 ± 0.08 c	6.45 ± 0.63 b	173 ± 6 de	108 ± 8 cd	30.1 ± 0.3 a	31.4 ± 0.3 a
	W4	7.41 ± 0.28 c	3.62 ± 0.05 c	156 ± 3 f	94 ± 6 cd	30.5 ± 0.3 a	29.3 ± 0.4 ab
	W5	7.17 ± 0.25 c	4.54 ± 0.32 c	165 ± 9 ef	103 ± 4 cd	30.2 ± 0.2 a	28.7 ± 0.1 ab

Table 2 Statistics comparing effective panicles, rice yield, and 1000 grain weight in all subplots of Hanyou 8 and Hanyou 14 in 2014 and 2015

Results of The Experiment and Conclusions

Figure 6 indicates the Global Warming Potential (GWP) of Hanyou 8 and Hanyou 14 across all subplots in 2014 and 2015. The GWP is a numerical value that indicates the potential harm each subplot of both rice varieties can cause during both years. Figure 6 proves that subplots Hanyou 8, particularly W3-W5, has significantly lower GWP compared to Hanyou 14. The lowest GWP in 2014 is Hanyou 8 subplot W4, and in 2015 it is Hanyou 14 subplot W1. The unique and irregular weather conditions and temperatures in 2015 can explain why Hanyou 14 subplot W1 was better in 2015; however, other subplots of Hanyou 14 are significantly more harmful than Hanyou 8. Overall, this experiment was successful because it helps scientists prove the benefits of developing climate adaptive WDR rice. Although Hanyou 8 may not have been as beneficial as expected, it is an improvement compared to Hanyou 14. The development of Hanyou 8 is a step towards building a more sustainable future, a future that can feed the exponentially growing population without causing severe long-term harm to the environment. With adequate funding and support from the government, private organizations or nonprofits, and the United Nations, scientists can continue to develop more drought-resistant and environmentally friendly plants. Sustainability without significant sacrifice is the key to a successful future for all species on Earth.

Measurements		GWP (kg CO_2-eq ha^{-1})	
		2014	2015
Hanyou 8	W1	3252.82 ± 680.74a	2836.45 ± 565.97ab
	W2	3463.34 ± 851.35a	3654.4 ± 659.83ab
	W3	2987.07 ± 403.08a	2086.56 ± 176.18b
	W4	1816.95 ± 371.59a	2339.49 ± 77.39b
	W5	2344.02 ± 64.74a	2235.34 ± 325.96b
Huayou 14	W1	4208.94 ± 1068.49a	1525.22 ± 184.56b
	W2	4433.97 ± 442.08a	4929.7 ± 825.61a
	W3	3888.74 ± 2318.37a	2930.91 ± 1288.94ab
	W4	3536.94 ± 65.62a	2987.98 ± 841.91ab
	W5	1837.53 ± 525.31a	2462.4 ± 815.86b

Different letters represent significant differences among treatments at 0.05 level. W1, no slope; W2–W4, progressively steeper slopes; W5, steepest slope

Figure 6 Comparison of Global Warming Potential (GWP) of Hanyou 8 and Hanyou 14 among all subplots in 2014 and 2015.

Overall, Hanyou 8 reduces methane emissions but increases nitrous oxide emissions. However, nitrous oxide emission occurs at specific intervals, thus is less harmful than the constant emissions of methane. On top of this, Hanyou 8 requires less water and is more resistant to changes in temperature and weather conditions, meaning it has a higher chance of surviving poor seasons and could save farmers lots of money. The development of Hanyou 8 is a steppingstone to creating a more sustainable agricultural industry. It is a step towards a greener future.

Alternative Solutions to Feeding the Growing Population

Another solution to feeding the growing population is developing GMO rice plants. GMOs, or Genetically Modified Organisms, are made when a scientist modifies the genetic material of an organism via various genetic modification techniques. GMOs allow scientists to solve complex agricultural issues efficiently, as they can directly change specific genes of the top polluting crops. Altering genes will change or establish new traits or characteristics, allowing the organism to fit the environment better. Scientists can make numerous GMOs of the same crop to fit the specific needs and goals in different environments. For example, GMO rice grown in India may be resistant to fluctuating temperature conditions while another version of that GMO rice in China may be resistant to a region-specific disease. Multiple versions of GMOs can solve agricultural complications or resolve environmental consequences that vary based on the different regions.

Plausible traits for GMO rice include requiring less water to thrive and resistance to common diseases. These traits could help farmers could save a significant amount of money, as the cost to grow rice would dramatically fall. Destructive weather seasons or harmful diseases that would destroy the yield of traditional rice plants would not affect GMOs. This eliminates a majority of the risks that could damage rice yield, thus ensuring the supply meets the demand. It also maintains rice yield; therefore, farmers can anticipate a steady income, and consumers can expect costs to remain relatively the same or drop.

The development of GMOs is a straightforward and more efficient solution to meeting the growing demand while, potentially, reducing the environmental consequences of agriculture. However, the GMO solution will not be effective until consumers understand that no scientific evidence proves that GMOs are harmful. Contrary to popular belief, GMOs do not harm health, and scientists have researched a majority of the “effects” of eating GMOs. There are no side effects caused by eating GMOs, and humans have been eating them on almost a daily basis for decades. The only potential “harm” of eating GMOs is allergens; but allergens are prevalent in every type of food and are not specific to or a consequence of eating GMOs. Since the majority of the Western world fears GMOs, and most third-world countries do not have GMOs, the majority of the world eats organic food. The toxic chemicals used to maintain the quality of organic foods can severely damage the soil quality, permanently poison freshwater sources, as well as destroy food webs and ecosystems. Organic foods can be extremely harmful to the environment. Since consumers continue to eat organic under the misconception of it being “healthier” and fear GMOs, farmers avoid growing GMOs. On top of this, due to their astronomical production price, production time, and lack of market, biotechnology companies avoid producing new GMOs. For these reasons, until we educate the public on the truth behind organic food and the benefits of GMOs, GMOs are not an adequate solution

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