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Citation: SCIENCE CHINA Life Sciences **63**, 785 (2020); doi: 10.1007/s11427-019-9578-4

View online: http://engine.scichina.com/doi/10.1007/s11427-019-9578-4

View Table of Contents: http://engine.scichina.com/publisher/scp/journal/SCLS/63/5

Published by the Science China Press

SCIENCE CHINA
Life Sciences

•LETTER TO THE EDITOR•

May 2020 Vol.63 No.5: 785–787
https://doi.org/10.1007/s11427-019-9578-4

Genetically modified (GM) rice versus non-GM rice: Pesticide use and yield

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Received April 22, 2019; accepted May 17, 2019; published online July 8, 2019

Citation: Qiao, F., Hu, R., and Huang, J. (2020). Genetically modified (GM) rice versus non-GM rice: Pesticide use and yield. Sci China Life Sci 63, 785–787. https://doi.org/10.1007/s11427-019-9578-4

Dear Editor,

The economic benefits of genetically modified (GM) crops have been well-documented in the literature (Huang et al., 2002; Huang et al., 2005; Qiao, 2015; Qiao et al., 2016). Previous studies showed that the global economic gain that the GM crops had generated at the farm level approximated 100 billion USD in 1996–2011 (Brookes and Barfoot, 2013). More importantly, this significant benefit had helped dozens of millions of farmers, with most of them being small poor farmers in developing countries. Given their high profitability and other benefits, GM crops had been widely adopted in the world. By 2015, the cumulative sown area for GM crops reached 2 billion hm^2, with GM crops being grown in 28 countries (James, 2015).

Although GM crops could contribute to the reduction of hunger throughout the world, the commercialized GM varieties are primarily industrial crops, such as cotton, and feed crops for animals (Huang et al., 2002; Qaim and Zilberman, 2003; Huang et al., 2005). To date, none of the major GM food crops have been commercialized anywhere in the world, and little is in the pipeline in most countries. The major concern behind the stagnancy of the commercialization of GM food crops is the potential negative impact on food safety. Such doubt had emerged even before the commercialization of GM crops. In recent years, the protest against GM technology has increased consistently and rapidly, dominating the public and media debate (Kathage and Qaim, 2012; Cleveland and Soleri, 2005). Furthermore, the difficulties in commercializing GM rice causes the decline in the amount and direction of public and private biotechnology research.

China might be the only country that had put forward the commercialization of GM rice. Early in 2009, China had released biosafety certificates to two GM rice varieties, which were in their final stage before commercialization. However, the Chinese government took no further action since then, and China currently shows no sign of advancing the commercialization of GM rice. As well as in other countries, the opinion against GM technology spread rapidly in China. The GM technology had been described as a "weapon" that developed countries used to aggress China. People who are against GM technology not only include public individuals but also scientists. According to a recent survey conducted by the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences, 9% of the scientists interviewed believed that GM technology affects food safety negatively.

Would GM rice really improve farmers' welfare by decreasing pesticide use and increasing yield? Despite this important question, empirical studies focusing on this issue

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are lacking, except for that of Huang et al. (2005). Surprisingly, no other study had empirically analyzed this question 10 years since the publication of the said research.

This study aims to report the results of an economic analysis using data from the preproduction GM rice trial sites in China. Specifically, in this study, we attempt to answer two questions. (1) Does the GM rice aid in the reduction of pesticide use? (2) Is the yield of GM rice higher than that of non-GM rice?

Sample selection and data collection are discussed in the Supporting Information. Descriptive statistics illustrate that our sample of farmers is fairly typical. The data from the survey demonstrate nearly identical characteristics of GM rice and non-GM rice adopters (Table S1 in Supporting Information, columns 1 and 2). We performed a *t*-test to show the difference between the GM and non-GM rice adopters. The *t*-test showed no significant difference between GM and non-adopters in terms of the family size, per capita asset value, total sown area, and the characteristics of household heads. In addition, the magnitude of the difference between GM rice and non-GM rice adopters reaches 0.1–0.2 hm^2 (or 6%–15%) considering the average farm size, paddy size and rice sown area.

However, a significant difference was observed between the GM and non-GM rice plots (Table S2 in Supporting Information). The GM rice adopters apply the same types of pesticides but at a rate of 1.10 times per season, compared with the 1.96 times per season achieved by the non-GM rice adopters. A statistically significant difference was noted in the levels of pesticide use on GM and non-GM rice. On a per hectare basis, the quantity of pesticides used in the non-GM rice plots is 9.47 kg hm^{-2}, which is more than 3 times as high as that in GM rice plots (3.15 kg hm^{-2}). The difference is statistically significant at the significant level of 5%. Similarly, Table S2 in Supporting Information shows that the expenditures on pesticide use in non-GM rice plots are also more than 3 times as high as that for the GM rice plots (384 RMB hm^{-2} in non-GM rice plots versus 140 RMB hm^{-2} in GM rice plots).

As the genetic characteristics of different rice varieties might affect pesticide use when comparing GM and non-GM rice varieties, we compared the pesticide use between the plots planted with GM rice varieties (i.e., GM II-Youming 86) and II Youming 86 (the base category). As shown in the first and third columns of Table S2 in Supporting Information, significant differences were also observed in terms of spray times, quantity, and expenditure on pesticide use.

Table S2 in Supporting Information also shows the difference between the yields of GM and non-GM rice varieties. The average yield of the GM rice plots (8,020 kg hm^{-2}) is higher than that of non-GM varieties (7,763 kg hm^{-2}) by 3.31%. When examining the effects of specific varieties, the yield of GM II-Youming 86 was shown to be 4.99% higher than that of II Youming 86.1

Table S3 in Supporting Information shows the comparison of inputs and outputs of GM rice and non-GM rice production. As shown in the first row of Table S3, the yield advantage of GM rice led to a similar output value advantage. On the other hand, the GM and non-GM rice plots showed no significant difference in all the inputs (such as labor and fertilizer) except for pesticide use. The pesticide use reduction and yield increase obtained with the GM rice indicated that the net profit of planting GM rice is much higher than that of non-GM rice. According to our data, the net return of GM rice is 4,936 RMB hm^{-2}, which is 27% higher than that of non-GM rice (3,756 RMB hm^{-2}). We obtained a similar result when we compared the GM rice (i.e., GM II-Youming 86) with the non-GM II Youming 86.

To isolate the impact of GM technology on the pesticide use, we then developed a multiple regression model (details in Supporting Information). As shown in Table 1, the esti-

Table 1 Impact of GM technology on pesticide use in rice production[a)]

	Amount of pesticide use (kg hm^{-2})				
	Estimated coefficient	Standard error	95% confident interval		*P*-value
			Low	High	
GM rice variety plot dummy (1=yes)	–5.23***	1.71	–8.63	–1.84	0.00
Other non-GM variety plot dummy (1=yes)	1.12	1.67	–2.20	4.43	0.51
Pesticide price (RMB kg^{-1})	–0.12***	0.03	–0.17	–0.06	0.00
Perception of yield loss (%)	0.04	0.03	–0.02	0.09	0.20
Age of household head (years)	0.10	0.08	–0.06	0.25	0.20
Education of household head (years)	0.17	0.30	–0.44	0.77	0.59
Village dummy (1=Shixi village)	–1.01	1.65	–4.27	2.26	0.54
Constant	5.81	5.62	–5.35	16.97	0.30
Observation	104				
Adj. R^2	0.26				

a) ***, $P<0.01$. The *P*-values are based on the results of *t*-test. Source: Authors' survey.

mated coefficient of GM technology is negative and statistically significant. According to the estimation results, the pesticide use in the GM rice plots is 5.234 kg hm^{-2} lower than that in II Youming 86 rice plots. Thus, the GM technology adoption led to a reduction of 70% of pesticide use ((5.234/7.43)×100%=70%), similar to the findings of previous studies (such as Huang et al., 2005).

The farm-level benefit that GM rice could generate can be translated into a substantial number nationally. After discussing the estimation results of the impact of GM technology adoption on the inputs and yield, we calculated the total impact in China. According to this study, if GM rice were commercialized in China, the saving of expenditure on pesticide use is 238 RMB hm^{-2}, which can be translated into a national pesticide reduction of more than 3.36 billion RMB if half of the 30 million hectares were planted with GM rice in China (Table S4 in Supporting Information). Similarly, the 915 RMB hm^{-2} benefit from yield increase can be translated into 13.73 billion RMB nationally. By aggregating the benefits, we estimated that the total value could be as high as 18 billion RMB per year if the GM rice were released to the farmers in China. The results from this study coincide with the findings of previous studies in China (Huang et al., 2005).

Notably, this study focused only on the impact of GM rice on the economic benefit of farmers. Previous studies showed that GM rice adoption would feature substantial implications for the alleviation of poverty, hunger, and malnutrition of both the rice producers and consumers worldwide. The pesticide reduction led by GM rice adoption will not only benefit farmers by reducing the production cost but also contribute to the improvement of environment and farmers' health (Huang et al., 2005; Qiao et al., 2012).

Compliance and ethics *The author(s) declare that they have no conflict of interest.*

Acknowledgements *We thank Zhurong Huang for her help in collecting and analyzing data. This work was supported by the National Natural Science Foundation of China (71773150, 71273290, 71742002, 71333013) and the National Key Program on Genetically Modified New Varieties (2016ZX08015-001, 2018ZX08015-001).*

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SUPPORTING INFORMATION

Table S1 Characteristics of households and household heads

Table S2 Production and pesticide input of GM- and non-GM rice in trial farmers' fields, 2010

Table S3 Revenue, cost and profit of GM- and non-GM rice production, 2010 (RMB hm^{-2})

Table S4 Predicted economic benefit of GM rice adoption in China

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