

The Role of Agronomic Factor

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REVIEW ARTICLE

The Role of Agronomic Factors in Salibu Rice Cultivation

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Abstract:

Background:

Salibu rice cultivation is one of the technologies that have been developed in Indonesia but not continued. This technology has great potential to increase land productivity. The unsustainability of the salibu rice cultivation is due to the lower yield than the parent rice. Not many farmers are aware of the agronomic factors that can increase the growth and yield of the salibu rice.

Objective:

This review article aims to explore the role of agronomic factors in salibu rice cultivation.

Results:

The review article shows that agronomic factors play a major role in salibu rice cultivation. The soil water availability for one year could be determined by the number of stages of SR cultivation. Two weeks before and after harvesting parent rice, soil water content should be estimated in terms of field capacity. Stem cuttings as high as 3-5 cm from the soil surface at 7-8 days after harvest are the right SR cultivation methods. The fertilizer dose should be determined according to site-specific recommendations. 40% fertilization should be carried out at 14-21 days after stem cuttings, and the second at 60% at 30-40 days after stem cuttings in salibu rice cultivation.

Conclusion:

Among the agronomic factors that affect salibu rice cultivation are soil water availability, the time and height of stem cuttings, and the dose and time of fertilization. Three agronomic factors need to be considered and applied by farmers to get the maximum growth and yield of salibu rice.

Keywords: Cultivation, Fertilizer, Parent rice, Superior variety, Salibu rice, Soil water, Stem cuttings.

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1. INTRODUCTION

Various innovations are continuously made to increase national food self-sufficiency and farmers' income. One of the innovations is using salibu rice (SR) cultivation technology. Salibu is an abbreviation from 'salin ibu' (change parent in English). However, SR cultivation has been developed in various Indonesian regions but has not received a good response from farmers. As a result, SR cultivation is stagnant in Indonesia. Indeed, SR production is considered less effective

than the transplanting system (TS). The low production as a result of using this method is because farmers are not aware of the impact of agronomic factors on the growth and yield of SR.

Rice is a food crop that has been cultivated from generation to generation by Indonesian farming communities. The technology of SR cultivation is more efficient in cost and labor than the TS because it does not involve tillage, seeding, and planting. Not many rice farmers understand the benefits of using this technology. The SR cultivation can increase land productivity and farmer income, and increase cropping intensity, make efficient use of resources, and lower the production costs. According to Surdianto *et al.* [1], the SR is

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effective enough to be developed so that farmers can have the opportunity to adopt this technology to increase the cropping index (harvest index) and rice production.

The SR cultivation provides hope as a climate-smart technology and resource. The SR provides an opportunity to increase harvest intensity per year because the growth duration is shorter than the parent rice. Besides, it can be cultivated with less than 50% labor, 60% lower water availability, and lower production costs than the parent rice [2]. The effectiveness of water use in SR cultivation is also higher [3]. This technology is feasible to be developed because it has a benefit-cost ratio > 1. The SR cultivation has a short crop maturity period (a decrease by 45.66%), thus it is a technological breakthrough to anticipate climate change (drought) [4].

According to Erdiman *et al.* [5], the harvest age of the main crop could be ten days earlier than TS to be prepared as parent SR. The activity differences in SR and TS are presented in Table 1.

Table 1. The activity differences in SR and TS cultivation.

Activity	Cultivation System	
	SR	TS
Land preparation	Stem cuttings after TS harvest	Cleaning the leftover straw
Soil tillage	-	Plowing and harrowing
Seeding	-	Yes
Planting	-	Yes
Fertilization	Following site-specific recommendations and increase in N (25-50%)	Following site-specific recommendations
Thinning and embroidery	20-25 days after stem cuttings (DASC) of parent rice	25-30 days after planting (DAP)
Maintenance	Standard of plant pests	Standard of plant pests
Harvest age	20% earlier than the age of TS harvest	Following harvest age

Note: - = No activity, SR = Salibu rice, and TS = Transplanting system.
Source: Erdiman *et al.* [5].

Table 1 shows that SR requires no soil tillage, seeding, and planting, so SR involves more efficient use of labor than TS. N fertilizer should be increased to stimulate vegetative growth because the SR lifespan is shorter. The first and second fertilization is done earlier than the TS. The harvest age of SR is 20% faster than TS.

The SR cultivation has not been much in demand by the farming community because of its low production. The slow development of this technology was due to the lack of information on its results due to which the farmers did not dare to speculate about trying SR cultivation. A study focused on the agronomic factors affecting the growth and yield of SR needs to be carried out. Thus, SR cultivation could be developed again to maintain food production in Indonesia. A literature review is necessary to provide complete information regarding SR cultivation. This review article aims to explore the role of agronomic factors in SR cultivation.

2. SALIBU RICE

The first SR was developed in West Sumatera (Indonesia).

SR is a form of local wisdom-based technology that can solve the increasing need for food in Indonesia. Its harvest life is shorter than the parent rice, so it is possible to harvest four times in one year. Appropriate technology for rice harvesting is needed to increase time efficiency. According to Hasan *et al.* [6], the application of appropriate technology for rice harvesting in developing countries is urgently needed to increase cropping intensity, crop productivity, and reduce time, effort, and input costs.

SR is a modification of rice cultivation from ratoon rice. The stem cutting of the parent rice shorter or closer to the soil surface is more suitable for SR cultivation technology [7]. SR grows from the remaining stems that are cut after harvest. New shoots emerge from the remaining stems near the soil surface and form new roots. Initial growth and strength of tiller formation depend on the carbohydrate reserves of the stem and root of the parent rice. Furthermore, the tiller is supported by new leaves so that the supply of carbohydrates is no longer dependent on the previous parent plant. The shoots then form new tillers again like TS.

The growth and yields of SR are influenced largely by rice variety [8]. The superior varieties of seed are more important and beneficial for rice productivity [9]. In the selection of parent rice seeds, superior varieties with high production and short life are prioritized. Short-lived types can increase the cropping index. Superior varieties with high production, resistance to pests and diseases, and tolerance to abiotic problems can increase the rice yields. According to Bui *et al.* [10], tolerant varieties have higher survival rates and less shoot elongation but longer root elongation during immersion compared to sensitive varieties.

According to Sastro *et al.* [11], several inbred and hybrid rice have high production and shorter harvest lives in Indonesia; the superior rice varieties are shown in Table 2.

Table 2. List of superior varieties of inbred and hybrid rice in Indonesia.

Superior Varieties	Harvest Age (Days)	Average Yields (ton ha ⁻¹)	Potential Yield (Ton ha ⁻¹)
Inbred Rice:			
Inpari 11	105	6.5	8.8
Inpari 13	99	6.6	8.0
Inpari 18	102	6.7	9.5
Inpari 19	104	6.7	9.5
Inpari Sidenuk	103	6.9	9.1
Padjajaran Agritan	105	7.8	11.0
Cakrabuana Agritan	104	7.5	10.2
Hybrid rice:			
Hipa 10	114	8.1	9.4
Hipa 11	114	8.4	10.6
Hipa 12 SBU	105	7.7	10.5
Hipa 13	105	7.7	10.5
Hipa 14	112	8.4	12.1
Hipa 18	113	7.8	10.3
Hipa 19	111	7.8	10.1

Source: Sastro *et al.* [11].

Table 2 shows that the production of hybrid rice is higher than inbred rice. The hybrids in Indonesia have a potentially high production rate and shorter harvest age. The hybrid rice of Hipa 10, Hipa 11, and Hipa 14 can be used as the parent rice. These superior varieties, as parent rice, are expected to reduce high-producing genetic traits. Lardi *et al.* [8] stated that under natural conditions, plant growth is largely determined by the plants' genetic factors, especially the condition of growth regulators (hormones). According to Liu *et al.* [12], SR growth is influenced by the growth of parent rice, so it can be evaluated by determining parent rice-growing conditions.

The yield of grain in SR plants is a complement to the parent rice [13]. The high yield of hybrid rice is due to the increased harvest index. The hybrids significantly exhibit higher productivity than those cultivated in the dry season, but the difference is not significant in the wet season. Hybrids produce spikelet panicle⁻¹ and 1000 grain dry weight higher than inbred rice [14]. The ratoon yield of the hybrids is better than inbred. The average result is 75.2% of the parent rice [15]. Short-lived varieties are more profitable [16]. Ratoon yields are higher using hybrid than inbred rice [17]. Utilization of the hybrid ratoon rice in androgenetic conditions will save cultivation time and costs [18].

Rice production is influenced by some factors, such as varieties, management, and environments. Among the environmental factors are agronomic traits and climate [19]. Land-use efficiency forms must be developed continuously [20]. Land is a key factor in production agriculture [21]. Rice as a perennial crop produces a stable and sustainable grain yield over successive seasons across years [22]. Hybrid rice involve higher productivity and profitability [23]. Besides, agricultural technology innovation is an important factor in supporting increased rice production [24]. The efforts of SR cultivation are made to increase land productivity in order to meet food needs through SR cultivation. Rice crops can be cultivated many times a year by SR cultivation, thereby increasing land productivity. Agronomic factors play a big role in increasing SR production.

3. AGRONOMIC FACTORS

3.1. Availability of Soil Water

SR allows rice harvests to be carried out 3.5–4 times a year with yields equivalent to the parent rice [7]. The increasing harvest index depends on the water availability conditions. According to Negalur *et al.* [2], SR has a short growing duration, suitable in rainfed areas with residual soil moisture. Rainfed rice fields can be planted once or twice in harvests, making planning difficult depending on the unpredictable rainwater. Harvesting can be done 3–4 times a year on semi-technical rice fields and fields involving technical irrigation. The cropping system patterns of TS (1st stage), SR (2nd stage), and SR (3rd stage) are more profitable than TS (1st stage) and TS (2nd stage) in one year.

The selection of rice varieties is better determined by water conditions in the field [25]. Increasing land productivity is a determining factor for rainfed rice farming [26]. Rice breeders regard ratooning as an important practice for sustainable rice

production in tropical agricultural systems to maximize profits [27]. Rainfed land has important benefits in increasing food production. TS is better than the seed-direct system as it takes advantage of residual soil moisture [16]. Rice cultivation in rainfed lowland can increase from one to two harvests using the TS (1st stage) and SR (2nd stage) in a year.

The soil moisture content influences the main crop harvest [28]. The inundation height of 5 cm from the soil surface results in taller plants and more tillers than the saturated condition treatment with a 0.5 cm water layer [29]. Saturated conditions up to 1 cm in height can be applied in rice cultivation by farmers, which will not affect rice production and soil characteristics [30]. Ratoon rice yields show that inundation (full flooding) provides the highest yield than inundation intervals of 2, 4, and 6 days [31].

In contrast to the findings presented by Elkheir *et al.* [32], each soil type essentially conserves water due to which yields show better rice production under aerobic conditions. According to Bleoussi *et al.* [33], the protein content of each rice variety increases with increasing drought intensity. The groundwater deficit has significant implications for grain quality. Momolu [34] stated that grain yields for all rice cultivars decrease with the formation of tillers due to the extended stress period.

The rice field ecosystem is divided into lowlands, highlands, and water. Rice ratooning is more suitable for lowland rice fields [35]. The SR cultivation can be done on rainfed land, although it can be done in two stages, TS (1st stage) and SR (2nd stage), due to the limited availability of soil water. Barnaby *et al.* [36] stated that rice plants have a variety of physiological and metabolic strategies in producing tolerance to water stress. It is necessary for rice varieties selection that is adaptable to deficit irrigation production systems or less water. The model of SR cultivation pattern is presented in Table 3.

Table 3. The model of SR cultivation in rice fields.

Rice Fields Types	Generation of the Rice Plant			
	TS (1 st Generation)	SR (2 nd Generation)	SR (3 rd Generation)	SR (4 th Generation)
Rainfed land	Ø	√	-	-
Semi-technical irrigated land	Ø	√	√	-
Technical irrigated land	Ø	√	√	√

Remarks: TS = Transplanting system, SR = Salibu rice, Ø = TS cultivation, √ = SR cultivation, and - = No cultivation.

Table 3 shows that soil water availability for one year will determine the number of SR cultivation stages. In semi-technical irrigated land, it can be increased to 3 harvests per year with the patterns, TS (1st stage), SR (2nd stage), and SR (3rd stage). In comparison, on technical irrigated land, it can be increased to 4 rice harvests a year with the patterns, the TS (1st stage), SR (2nd stage), SR (3rd stage), and SR (4th stage). The SR can be cultivated more than four times from one planting of parent rice.

3.2. Time and Height of Stem Cuttings

The SR cultivation is better implemented in a land that is not always inundated [37]. During two weeks before and after harvest, soil water content should be maintained according to field capacity. Initial shoots growth of SR is better if the field capacity conditions are maintained rather than inundated. Rice varieties' ability to produce the number of shoots or tillers after cutting the stem of main rice depends on genetic and environmental characteristics, including soil water content availability. Shiraki *et al.* [38] stated that soil moisture conditions two weeks before and after the harvest significantly affect grain yield. Ratoon plants in dry soil moisture conditions can increase yields by 69% than humid or flood conditions. According to Oda *et al.* [39], late irrigation is recommended in ratoon rice management practices.

Cutting of the stem at physiological maturity provides the best ratoon yield [40]. Rice yields are proportional to the number of ratoon tillers produced. The late stem cuttings have the most effect on the ratoon tillers number [39]. The shorter stem cutting causes the ratoon growth to be longer at the vegetative stage of growth, and delays the maturity stage of the grain [41]. Cutting height significantly influences plant height, the number of grains per panicle, and filled grains. Fitri *et al.* [7] showed that the optimal results for the number of productive tillers, the number of seeds per panicle, and rice productivity are obtained when the remaining stems are cut at the height of 3-5 cm above the soil surface, and carried out at the age of 7-8 days after harvest (DAH).

The main crop's first harvest is done at 5 cm of cutting height [42]. Carbohydrates are needed to maintain metabolic activity during the initial growth stages. The remaining stems provide the energy requirements for new tillers' growth after cutting, and then the tillers immediately become autotrophic [8]. The highest yield of ratoon rice (Ciherang variety) is achieved when stems are cut at harvest with a height of 3 cm above the soil surface with a grain yield of 3.54 tons ha⁻¹ [43]. The effect of cutting height on rice yields depends on the photosynthetic conditions and the number of internodes remaining in the main stem as a place for ratoon shoots to appear [44].

There are differences in the dynamics of shoot growth at the stem nodes. The morphology of vegetative organs shows that hormones regulate shoot growth on the main stem nodes. There are several proteins involved in brassinosteroid biosynthesis. Brassinosteroid signaling plays a role in the germination of axillary buds of ratoon rice [45]. The ability of rice crops to produce ratoon is strongly influenced by the carbohydrate and phytohormone content left in the stem meristem tissue after harvest [46]. If the stems' cutting is done 2-3 cm from the soil surface, the new germin shoots could be reproduced to form the next new rice tiller. The difference in the emergence of new shoots on the parent stem can be seen in Fig. (1).

In higher cutting (Fig. 1a), new lateral shoots emerge from the upper stem node. Taller stem cuttings produce more new shoots, and soon, new leaves form. Shoots have a short vegetative growth so the leaves number is small and the leaf

area size is narrow, and they immediately move into the reproductive phase. In lower stem cutting (Fig. 1b), new shoots grow from the basal stem. The shorter stem cuttings cause new shoots to grow in the soil surface that immediately form new roots, producing new tillers. Rice tillers have a more extended vegetative growth phase and produce more leaves extending to a broader area. The leaf area affects the photosynthesis process, producing carbohydrates.

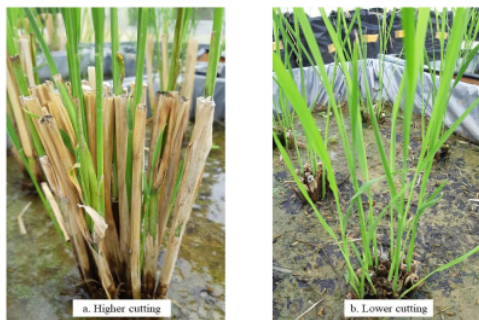


Fig. (1). The emergence of new shoots on the remaining stems with different cutting heights in 14 DASC.

The ratoon tillers are related to the level of stem carbohydrates at harvest time [28]. Higher stem cuttings cause the plant to grow and flower quickly because the shoots take advantage of the remaining carbohydrate reserves in the stem of the parent plant. In contrast to shorter stem cuttings, new shoots are formed to produce new roots. Furthermore, new shoots arise from the next new tillers so the vegetative life is longer. Mareza *et al.* [44] indicated that the lower stem cuttings cause the tiller number per clump to be lower and more productive. The number and leaves area per tiller is more wider, but the leaf area per clump is lower. Also, stem cutting results in longer flowering age and harvesting, higher dry weight of the tillers, and the same seed carbohydrate content as the parent plant, but plant dry weight per clump is lower.

3.3. Dose and Time of Fertilization

The regrowth of tillers depends on the carbohydrate reserves in the plant stems or roots remaining after pruning. The carbohydrates are needed to maintain metabolic activity during the initial stages of regrowth. The energy is required to supply new tillers that immediately become autotrophic [47]. Furthermore, after the shoots grow, it takes a sufficient supply of nutrients from the environment to support normal growth like the previous parent rice. Nutrients in the soil during the harvest of the main crop greatly affect the performance of the shoots.

The growth and yields of SR are primarily influenced by the balanced nutrients [8]. Better yields of ratooned crops are possible by increasing fertilization, mainly the supply of nitrogen [46]. SR age is shorter than the parent rice, so a balanced fertilization system is needed to strengthen its vegetative growth. Nitrogen (N), phosphorus (P₂O₅), and potassium (K₂O) are the primary nutrients for increasing and

sustaining SR productivity.

The urea fertilizer application can increase the N element in the soil. The N availability can cause plant leaves to look greener, the number of tillers to be more, accelerate the growth of shoots, roots, photosynthesis, and stimulate rice plants' growth. According to Ambarita *et al.* [48], the excessive N application can be inhibited by other elements, which may lead to decreased growth and yield and increased amount of empty grain. Mamun *et al.* [49] showed that using an additional 25% nitrogen of the recommended dose for ratoon crops after harvesting the main crop can yield economic yields for hybrid rice.

In a study, fertilizer application was done in 3 stages. The first fertilization was applied at 10 DAH (20% of urea dose), the second at 21 DAH (40% of urea dose), and the third at 35 DAH (40% of urea dose). The dose of 375 kg ha⁻¹ urea application significantly affected the increase in the number of tillers (32.06 tillers clump⁻¹), the number of panicles (18.86 units clump⁻¹), and grain dry weight (0.63 kg m⁻²) in SR cultivation of Ciherang variety [50]. The dose of 50 kg ha⁻¹ urea and 50 kg ha⁻¹ NPK Phonska fertilizer did not significantly affect rice production between the three zones of high, medium, and lowland on the Salibu system [7]. NPK Phonska is an inorganic fertilizer with the name NPK compound fertilizer consisting of several macronutrients, such as nitrogen (N), phosphorus (P), potassium (K), and sulfur (S). The content of NPK Phonska 15-15-15 is N (15%), P₂O₅ (15%), K (15%), and S (10%). Rice farmers widely use this fertilizer because it can increase the yield and grain quality.

An increase in nitrogen dose within a certain range is followed by an increase in leaf area index, plant height, number of tillers, net photosynthesis rate, transpiration rate, and grain yield. In addition, the effect of increasing nitrogen dose on grain yield index and nitrogen contribution rate are parabolic [51]. The dosage of nitrogen fertilizer has a different effect on the number of tillers per clump, the percentage of filled grains per panicle, and the weight of 1000 grains [52]. The vegetative age of SR is shorter than the parent plant. A delay in fertilization can lead to fewer tillers and decreased grain yields. Rice plants must absorb sufficient N, P, and K during the growth stage to obtain optimal growth characteristics and yields [53]. Fertilization of SR is carried out according to site-specific recommendations. According to Kristantini *et al.* [4], the dose of fertilizer application should comply with recommendations from paddy soil test equipment and be given in two times. The first fertilization **1** could be done at 40% of the recommended dose at 15-20 days after stem cuttings (DASC). **The second** fertilization should be as much as 60% of the recommended dose at 30-35 DASC. Suparwoto and Waluyo [54] reported, in their study, the first fertilization at 14 DASC by applying **2** 50 kg ha⁻¹ urea fertilizer and the second at 40 DASC with 25 kg ha⁻¹ SP-36 and 25 kg ha⁻¹ KCl fertilizers.

Based on the results of previous studies, a summary of the dose of fertilizer and time of fertilization in the cultivation of SR can be made. For more details, this summary is shown in Table 4.

Table 4 shows that the dose of fertilizer and the time of

fertilization vary. Therefore, it is necessary to research on the type and dose of fertilizer and the right time of application. Even though there is no recommendation for site-specific fertilization, SR cultivation is still profitable compared to TS from the farming aspect.

Table 4. The dose and time of fertilization in salibu rice cultivation.

Dose of fertilizer	Time of fertilization	References
Recommendations from paddy soil test equipment	The first fertilization was applied as much as 40% of the recommended dose at 15-20 DASC, and the second involved 60% of the recommended dose at 30-35 DASC.	Kristantini <i>et al.</i> [4].
375 kg ha ⁻¹ urea	The first fertilization was applied at 10 DAH (20% of urea dose), the second at 21 DAH (40% of urea dose), and the third at 35 DAH (40% of urea dose).	Safrudin [50].
2 150 kg ha ⁻¹ urea, 150 kg ha ⁻¹ SP-36, and 25 kg ha ⁻¹ KCl	The first fertilization was applied at 14 DASC (150 kg ha ⁻¹ urea), and 2 second at 40 DASC (150 kg ha ⁻¹ SP-36, and 25 kg ha ⁻¹ KCl).	Suparwoto and Waluyo [54].

The SR has been found to be more profitable than TS. The farmers save the costs of the production process in the second planting season. Production activities, such as plowing, harrowing, nursery, seedlings removal, planting, and purchasing seeds, are not carried out. According to Surdianto *et al.* [1], the comparison of costs between SR and TS is shown in Table 5.

Table 5. The comparison of costs between SR and TS.

No.	Cost description	Total (Rp. ha ⁻¹)		Cost difference (Rp. ha ⁻¹)
		SR	TS	
1.	Labor cost	(6,083,333)	(7,790,000)	1,706,667
	Nursery	-	330,000	
	Soil tillage	-	1,300,000	
	Planting	-	1,200,000	
	Stem cuttings	660,000	-	
	Maintenance (stitching, weeding, fertilization, and spraying)	3,440,000	2,720,000	
	Harvest and thresh	1,983,333	2,240,000	
	Cost of production facilities	(4,455,000)	(4,623,000)	168,000
2.	Seeds	-	480,000	
	Anorganik fertilizer	1,145,000	1,505,000	
	Manure fertilizer	1,680,000	900,000	
	Pesticide	1,630,000	1,738,000	
1 + 2	Total	10,338,333	11,483,000	1,874,667

Remarks: - = No activity, SR = Salibu rice, and TS = Transplanting system. Source: Surdianto *et al.* [1].

Table 5 shows that the cost difference between the SR and TS is Rp. 1,874,667 ha⁻¹ for each growing season. It means that

the SR cultivation system can increase farmers' income and production costs can be eliminated.

CONCLUSION AND RECOMMENDATION

The literature reviewed above shows that the development of SR cultivation in Indonesia is slow, but it can be improved again. Farmers need to apply the agronomic factors that affect the success of SR cultivation. The soil water availability for one year can determine the number of stages of SR cultivation. Two weeks before and after harvesting paddy rice, soil water content should be maintained according to field capacity. Stem cuttings as high as 3-5 cm from the soil surface at 7-8 DAH are the right method for SR cultivation. Fertilizer dose needs to be determined according to site-specific recommendations. The first fertilization should involve 40% of the recommended dose at 14-21 DAP, and the second as much as 60% at 30-40 DASC. The soil water availability, time and height of the stem cuttings, and dose and time of fertilization affect the SR cultivation. Three agronomic factors need to be applied by farmers in SR cultivation.

LIST OF ABBREVIATIONS

DAH	= Days After Harvest
DAP	= Days After Planting
DASC	= Days After Stem Cuttings
N, P, K, S	= Nitrogen, Phosphorus, Potassium (K), and Sulfur
SR	= Salibu Rice
TS	= Transplanting System

CONSENT FOR PUBLICATION

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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