Comparing the influence of natural farming on cotton (Gossypium hirsutum) yield and economics with integrated and organic farming

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INTRODUCTION
Cotton is a global cash crop, contributing significantly to the agricultural and industrial economy. It is the backbone of the textile industry in India, accounting for 75% of fiber consumption and 38% of exports, generating ₹ 50,000 crores annually (Muthukrishnan et al., 2017). India cultivates the largest cotton area globally, covering 10.15 million hectares, equivalent to 25% of the world's cotton area and approximately 2.4% of arable

Abstract
Cotton, a vital global cash crop, influences the economy and sustainability. Natural farming is a cost-effective, eco-friendly method. This study examines Natural Farming's effects on cotton yield and the economics of cotton compared to Integrated and organic farming. Field experiments were conducted during 2021-22 and 2022-23 at Tamil Nadu Agricultural College, Coimbatore. The experiment consisted of eight treatments, laid out in Randomized Block Design and replicated thrice. The treatments consist of control (T1), various Indian Natural farming practices including Beejamirit as a seed treatment, Ghanajeevamirit as basal, Jeevamirit with irrigation water, crop residue mulch, intercropping with pulses (T2 to T5), Organic farming practices (T6), Integrated crop management (ICM) practices with organic pest control (T7) and ICM with chemical pest (T8). The results indicated a significant increase in yield components: sympodial branches plant−1 (12.85 and 13.40), number of squares (29.28 and 31.28), bolls plant−1 (10.74 and 11.32), and boll weight (4.30 and 4.38 g) under Integrated Crop Management practices in 2021-22 and 2022-23, respectively. However, organic farming practices, followed by natural farming practices, were at par with integrated crop management. Integrated crop management practices resulted in significantly higher seed cotton yields (2178 and 2232 kg/ha in 2021-22 and 2022-23, respectively) than organic and natural farming practices with a higher cost of cultivation and a gross return. Complete natural farming outperformed organic and integrated farming in cotton, yielding higher net returns and B: C ratios. This approach holds promise for enhancing yield, economic viability and environmental sustainability in cotton cultivation.

Keywords: Beejamirit, Economics, Ghanajeevamirit, Jeevamirit, Organic Cotton, Natural Farming and Yield

How to Cite
land (Barotova et al., 2023). In 2022-23, India produced 337 lakh bales (170 kg each) from 130.49 lakh hectares, with a productivity of 439 kg ha⁻¹ (Indiastat, 2023). Green revolution technologies in the 1960s improved crop production, but the excessive use of agrochemicals led to soil fertility depletion, nutrient deficiencies, reduced crop productivity and diminished farmer returns (Ramesh et al., 2005).

Agrarian distress arises from low returns, high input costs and natural disasters. Low-input practices offer reduced costs, higher yields, chemical-free food and improved soil fertility (Tripathi et al., 2018). Input costs have outpaced the increase in output per hectare for most crops, resulting in reduced farm income (Naik et al., 2020).

Natural farming, influenced by Fukuoka's philosophy (Fukuoka, 1987) and championed by Palekar, gained popularity in India (Khadse et al., 2018). Farmers avoid chemical inputs in natural farming and instead opt for homemade alternatives. These alternatives include Indian natural farming inputs crafted from cow dung and urine, such as Jeevamirit, Beejamirit and Neemastra. Additionally, they embrace practices like intercropping and mulching to promote ecological balance and sustainability. (Palekar, 2005). However, amid these practices, critics inquire about the scientific basis and underlying beliefs supporting these alternative approaches (Kumar et al., 2019; Shottonkirk, 2018). Many studies lack field-level evidence. The present study was taken up to analyze cotton farming’s impact on costs, yield and income, providing insights into organic, natural and integrated approaches.

**MATERIALS AND METHODS**

A field experiment was conducted in the Eastern block farm of Tamil Nadu Agricultural University, Coimbatore, which is located at 11°N latitude and 77°E longitude at an altitude of 426.7 m above mean sea level. The soil of the experimental field was sandy clay loam in texture which is located at 11°N latitude and 77°E longitude at an altitude of 426.7 m above mean sea level. The soil of the experimental field was sandy clay loam in texture with low available nitrogen (213 kg ha⁻¹), medium available phosphorus (16 kg ha⁻¹) and high available potassium (886 kg ha⁻¹). The experiment was laid out in a randomized complete block design with 8 treatments and replicated thrice. The treatments were as follows.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>Control (No input additions, only labor for weeding operations)</td>
</tr>
<tr>
<td>T₂</td>
<td>Complete Indian Natural Farming (NF) practices (Beejamirit + Ghanajeevamirit + Jeevamirit + crop residue mulching + intercropping)</td>
</tr>
<tr>
<td>T₃</td>
<td>Natural Farming Practices 1 (without Beejamirit + Ghanajeevamirit + Jeevamirit)</td>
</tr>
<tr>
<td>T₄</td>
<td>Natural Farming Practices 2 (without crop residue mulching)</td>
</tr>
<tr>
<td>T₅</td>
<td>NF 3 (without intercropping)</td>
</tr>
<tr>
<td>T₆</td>
<td>Organic Farming (OF) practices (5 t ha⁻¹ FYM + 2.5 t ha⁻¹ Vermicompost)</td>
</tr>
<tr>
<td>T₇</td>
<td>Integrated Crop Management (ICM) (50% organic +50 % inorganic with bio-pesticide)</td>
</tr>
<tr>
<td>T₈</td>
<td>ICM (50% organic + 50% inorganic with chemical pesticide)</td>
</tr>
</tbody>
</table>

The treatments T₇ and T₈ were maintained separately with a plot size of 12 m x 8.4 m adjacent to the organic & natural farming area.

**Indian Natural farming inputs preparation**

**Beejamirit**

500 g of fresh cow dung was taken in a cloth, bound by tape, and hanged in it for 2 litres of water. One litre of water was taken and 5 g of lime was added in it. Kept these two separately for 12 hours. Then this cow dung bundle was squeezed thoroughly in water to extract material. A pinch of undisturbed soil from bunds or under tree and then 500 ml of cow urine was added. Finally, the lime water was added and stirred well. Beejamirit was ready to treat the seeds.

**Ghanajeevamirit**

To prepare the mixture, 100 kg of fresh cow dung was taken and 1 kg of jaggery along with 1 kg of pulse flour were added. The mixture was then kept in shade and 250 g of soil from an undisturbed bund or under a tree was added. After adding all the materials, the mixture was shaped into cakes and stored. After 10 days of its preparation, it could be and was applied in the experiment as per the treatment details.

**Jeevamirit**

In a plastic drum, 10 kg of fresh cow dung was added, 2 kg of jaggery and 2 kg of pulse flour, and 150 grams of soil from undisturbed bunds or under trees. The mixture was thoroughly mixed using a wooden stick. Subsequently, 10 litres of cow urine were added, followed by 200 litres of water. Finally, Jeevamrit was prepared for application starting from the 3rd day onwards. It could be used for irrigation water for 7 days following its preparation.

**Crop cultivation practices**

**Natural farming:** According to Palekar (2006), cow-based organic formulations Beejamirit, Ghanajeevamirit and Jeevamirit were used in natural farming plots. Ghanajeevamirit was incorporated before sowing at a rate of 250 kg ha⁻¹. Jeevamirit was applied twice a month at a rate of 500 l ha⁻¹ through irrigation water. Beejamirit (1 liter per kg of seed) was used for seed treatment. Green gram (DGGV 2) intercrop was between cotton rows. No weeding in natural farming plots. Crop residue mulch @ 5 t ha⁻¹ with millet straw was spread immediately after sowing. Ecological engineering method used for plant protection, including cowpea as border/trap crop. Organic pesticide (3 G) was ap-
Organic farming and Integrated crop management: Seeds treated with Trichoderma viride (5 g kg\(^{-1}\)) and Bacillus subtilis (5 g kg\(^{-1}\)). Cotton seeds were dibbled with specific spacing (90 x 15 cm) and seed rate (15 kg ha\(^{-1}\)). Pre-emergence herbicide of pendimethalin @ 1.0 kg ha\(^{-1}\) was applied in an integrated plot followed by hand weeding at 40 DAS. Two hand weeding on 20 and 40 DAS was performed for control, organic farming plot and integrated plot. Irrigation was given at intervals with a withholding period of 15 days. Cowpea was used as a trap crop for \(T_7\) and \(T_8\). Pest repellent (3G extract spray) was used for \(T_8\). Yellow sticky traps and pheromone traps (12 Nos ha\(^{-1}\)) were kept to trap pests. Neem oil (3%) was sprayed to control pests. Panne traps (12 Nos ha\(^{-1}\)) were kept to trap pests. Pest repellent (3G extract spray) was used as a growth regulator in organic farming plots. These practices were followed for two years (2021-22 and 2022-23).

Data collection and analysis
Five plants per plot were randomly chosen and tagged for biometric observations. The count of reproductive branches originating from extra-auxiliary buds represented branches per plant. Bolls retained per plant were counted at 120 DAS. The total number of squares produced per plant was recorded. Five matured bolls from marked plants in each plot were weighed for average boll weight (g). The boll setting percentage was calculated as the ratio of bolls to fruiting points using the formula below:

\[
\text{Boll setting percentage} = \frac{\text{Total no. of bolls on 120 DAS}}{\text{Total no. of fruiting points on 120 DAS} \times 100}
\]

Kapas from net plots were carefully collected, ensuring no bracts or trash adherence. The khas were dried, cleaned and weighed, yielding seed cotton in kg ha\(^{-1}\).

Samples of 100 seed cotton from each plot were weighed. After ginning, the weight of lint and seed was recorded (kg ha\(^{-1}\)). The fresh weight of cotton plants at harvest was measured as stalk yield and expressed in kg ha\(^{-1}\). Using local prices, standard procedure was followed to determine cultivation cost, gross returns, net returns, and B: C ratio. Expenses from sowing to harvest, including field preparation, were calculated at current TNAU input prices. Income from seed cotton was computed. Net returns were obtained by subtracting cultivation cost from gross return. Benefit Cost Ratio (BCR) was calculated as follows.

\[
\text{BCR} = \frac{\text{Gross return}}{\text{Cost of Cultivation}}
\]

**RESULTS AND DISCUSSION**

**Yield parameters**

**Symposidal branches**

Significant differences were observed in the number of sympodial branches and presented in Table 1 among the different farming practices, including natural, organic, and integrated farming. Significantly higher sympodia plant\(^{-1}\) 12.85 and 13.40 in 2021-22 and 2022-23, respectively was recorded in ICM with organic pest management followed by ICM with chemical pest management (12.33 and 12.63) and organic farming practices (11.73 and 12.96) during both the years 2021-22 and 2022-23, respectively. The control plot produced lesser sympodia plant\(^{-1}\) (9.38 and 9.71 in 2021-22 and 2022-23, respectively), which was at par with natural farming practices. The seed cotton yield is influenced by Natural farming practices, Organic Farming practices and Integrated crop management method.

**Table 1.** Sympodia, Squares, Bolls and Boll setting percentage of cotton as influenced by Natural farming practices, Organic Farming practices and Integrated crop management method.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total no. of Sympodia (Nos.)</th>
<th>Total no. of squares (Nos.)</th>
<th>Total no. of bolls (Nos.)</th>
<th>Boll setting%</th>
</tr>
</thead>
<tbody>
<tr>
<td>(T_1)- Control</td>
<td>9.38</td>
<td>9.71</td>
<td>18.43</td>
<td>20.43</td>
</tr>
<tr>
<td>(T_2)- Complete Natural Farming</td>
<td>11.00</td>
<td>10.99</td>
<td>26.17</td>
<td>28.17</td>
</tr>
<tr>
<td>(T_3)- NF (except GA, BA, JA)</td>
<td>9.93</td>
<td>10.23</td>
<td>23.07</td>
<td>25.07</td>
</tr>
<tr>
<td>(T_4)- NF (except mulching)</td>
<td>10.42</td>
<td>10.72</td>
<td>25.64</td>
<td>27.64</td>
</tr>
<tr>
<td>(T_5)- NF (except Intercropping)</td>
<td>10.78</td>
<td>10.91</td>
<td>26.37</td>
<td>28.37</td>
</tr>
<tr>
<td>(T_6)- Organic Farming</td>
<td>11.73</td>
<td>12.96</td>
<td>26.28</td>
<td>28.28</td>
</tr>
<tr>
<td>(T_7)- ICM (organic pest management)</td>
<td>12.85</td>
<td>13.40</td>
<td>29.28</td>
<td>31.28</td>
</tr>
<tr>
<td>(T_8)- ICM (Chemical pest management)</td>
<td>12.33</td>
<td>12.63</td>
<td>28.10</td>
<td>30.10</td>
</tr>
<tr>
<td>Sed</td>
<td>0.96</td>
<td>0.99</td>
<td>2.22</td>
<td>2.39</td>
</tr>
<tr>
<td>CD (p=0.05)</td>
<td>2.07</td>
<td>2.11</td>
<td>4.77</td>
<td>5.13</td>
</tr>
</tbody>
</table>
by yield-attributing characteristics, which contribute to variations in the yield. Muthukrishnan et al. (2017) also reported that integrated farming produced more sympodial branches. The basic structure responsible for bearing various reproductive organs of the crop is the sympodial branches. Different farming practices, such as the utilization of Beejamirit, Jeevamirit, and Ghanajeevamirit in natural farming, farm yard manure, vermicompost in organic farming and ICM practices, might have altered the development of these branches. The higher number of sympodial branches observed can be attributed to the enhanced concentration of accessible nutrients achieved through the combined utilization of chemical fertilizers and organic manures. This synergistic approach positively influenced the development of sympodial branches, leading to increased vertical growth of the plant and more nodes that serve as the points of origin for these branches (Vani et al., 2021). This variation could be attributed to factors such as better establishment and improved growth in cotton. This finding aligns with the research of Adeli et al. (2022). The combined application of organic manures and inorganic fertilizers, supplying nutrients consistently during the crop growth period, might have facilitated accelerated cell division and elongation, consequently leading to enhanced growth characteristics and increased sympodial branches in cotton. Similar results, with increased branches due to nutrient levels, were reported in cotton by Kalaichelvi (2009). The presence of additional nutrients in the organic natural farming treatments resulted in higher sympodial branches when compared to the control, which did not receive any manures or fertilizers.

Number of bolls and squares

The number of bolls per plant is a crucial factor that greatly affects seed cotton yield. Various farming practices significantly influenced the number of bolls per plant (Table 1). Among these practices, ICM with organic pest management (10.74 and 11.32), ICM with chemical pest management (10.06 and 10.87) demonstrated their superiority over other methods of organic farming practices (8.86 and 9.59) and complete natural farming (7.18 and 8.25) by achieving a higher count of bolls per plant in 2021-22 and 2022-23, respectively. Muthukrishnan et al. (2017) also proved that integrated farming practices attained more bolls from suraj variety than others. The number of squares plant\(^{-1}\) exhibited a similar trend to that observed in the number of bolls plant\(^{-1}\). The most widely adopted practice in natural
farming is Ghanajeevamirit, Jeevamirit and Beejamirit, allowing for innovation in natural farming practices (Pujeri et al., 2022). Malewar et al. (2000) and Sreenivasan (2004) found that higher levels of nitrogen and phosphorus influenced the number of bolls in cotton. Developing several squares and bolls in cotton is a multifaceted process influenced by a combination of factors, including nutrition, hormonal balance, field environment and weather conditions (Rathiya et al., 2010). Furthermore, the cotton crop that did not receive any nutrients, i.e., the control plot, exhibited the lowest count of bolls per plant (5.72 and 6.12) and a lesser number of squares (18.43 and 20.43) during 2021-22 and 2022-23, respectively, indicating the negative impact of nutrient deficiency.

**Boll setting percentage**

There were notable differences in the boll setting percentage observed across various farming practices (Table 1). The implementation of ICM with organic pest management showed a higher boll setting percentage (36.68% and 36.19%). The practice of ICM with chemical pest management (35.80% and 36.11%) and organic farming practices (33.71% and 33.91%) were comparable with ICM with organic pest management throughout both years. These results indicated that ICM practised treatments outperformed all other treatments regarding boll setting percentage. Cotton is an indeterminate crop, meaning that its vegetative and reproductive structures compete for available photosynthates throughout the growth period. The availability of sufficient nutrients during critical stages, particularly under ICM practices, significantly enhances the boll setting percentage and the overall number of bolls produced. Muthukrishnan et al. (2017) have recorded that integrated farming practices achieved a higher boll-setting percentage than organic farming practices and control. According to Forster et al. (2013), nitrogen had the most significant impact on the retention of bolls in cotton plants. The combined application of fertilizers and manures improves boll retention by enhancing the fertility coefficient. Using Jeevamirit, Ghanajeevamirit and Beejamirit in natural farming plots might be the reason behind their significance.

**Boll weight (g)**

Different farming practices did not significantly impact boll weight, as depicted in Table 2. However, among the treatments, the crop that received ICM practice with organic pest management exhibited higher boll weight (4.30 and 4.38 g) compared to ICM with chemical pest management (4.89 and 4.68 g) and organic farming practices (4.20 and 4.29 g) during the years 2021-22 and 2022-23, respectively. The crop without any nutrient application recorded the lowest boll weight (3.86 and 3.95 g) in both study years. The same trend was demonstrated by Muthukrishnan et al. (2017). The size and weight of cotton bolls were influenced by the presence of timely and sufficient nutrients provided to the cotton crop through both organic and inorganic sources.

**Yield**

Different farming practices significantly influenced seed cotton yield (Table 2). In both 2021-22 and 2022-23, ICM with organic pest management achieved the highest seed cotton yield of 2178 and 2232 kg ha⁻¹, respectively. The practice of ICM with chemical pest management (2104 and 2187 kg ha⁻¹) followed by organic farming practices (1695 and 1768 kg ha⁻¹) was comparable with ICM with organic pest management during both years (Table 2). Similar trends were observed for seed cotton yield.
yield, lint yield (Fig. 1), and stalk yield, with ICM practices outperforming organic and natural farming practices. The results of this research are consistent with the investigations carried out by Babalad et al. (2021) and Duddigan et al. (2022), where practicing Integrated crop management practices on cotton resulted in a higher seed cotton yield. Yield increase resulted from rapid nutrient release by inorganic fertilizer and nutrient supplementation with organic manures. Organic and natural farming with organic manure yielded less due to slow nutrient release. Organic manures contain nutrients but are less accessible to crops, causing nutrient deficiencies in early growth (Nagavani, 2010; Varsha et al., 2022). Organic inputs enhance crop yields through gradual nutrient release, aiding absorption and supplementing gibberellin, cytokinin, auxins, Indole Acetic Acid, and macro and micronutrients (Devakumar et al., 2014; Lalitha et al., 2000). Integrated nutrient management with 12.5 t ha⁻¹ FYM yielded the highest seed cotton yield of 2252 and 1752 kg ha⁻¹ during rabi 2012-13 and 2013-14, respectively, as evaluated by Muthukrishnan et al. (2017).

Natural farming practices achieved yield the same as organic farming practices due to using cow-based formulations like Beejamirit, Ghanajeevamirit, and Jeevamirit. Regularly applying liquid manures stimulate plant systems, enhancing the production of growth regulators and hormones. This sustains nutrient availability and uptake, improving crop growth and yield. The yield increase may be attributed to improved nutrient availability during crop growth, possibly resulting from enhanced soil microbial activity. These findings align with the studies conducted by Kaur et al. (2021) in wheat crop and Kasbe et al. (2009) in aerobic rice. Kumar et al. (2020) and Kumar et al. (2023) reported that several crops that received natural farming practices at different trials showed superior yield. According to Chandralekha et al. (2011), combining Beejamirit, Jeevamirit and Panchagavya resulted in increased yield and dry matter production in chili crops. Similarly, Gore & Sreenivas (2011) found that a mix of Beejamirit, Jeevamirit, and Panchagavya in a 1:1:2 ratio boosted tomato yield. This could be due to jeevamirit’s role, potentially aided by increased microbial activity. Improved soil moisture and nutrient accumulation might have also boosted yield. Kaur and Saini (2021) reported that using 20% jeevamirit resulted in significant increases in grain yield (3117 kg ha⁻¹) and straw yield (6193 kg ha⁻¹) in wheat crops.

### Harvest index

The Harvest index was influenced significantly by the farming practices and a significantly higher harvest index (0.27) was recorded from ICM with organic pest management. A lower harvest index (0.17) was obtained from the control during both years (Table 2). The ICM had a higher harvest index due to more seed cotton yield than other treatments. It was similar to the results found in cotton crop by Nagender et al. (2017).

### Economics

From an economic perspective, the Integrated Crop Management (ICM) practices registered the highest cost of cultivation at ₹94450, involving a blend of 50% organic manures and 50% inorganic nutrients with organic pest management (T₇). This can be attributed to the incorporation of urea, single super phosphate and muriate of potash, driving up production costs, followed by organic farming approaches. Generally, organic manure-applied plots tend to have higher production costs due to relatively elevated unit costs of organic inputs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost of Cultivation (₹ ha⁻¹)</th>
<th>Gross Return (₹ ha⁻¹)</th>
<th>Net return (₹ ha⁻¹)</th>
<th>B: C ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁- Control</td>
<td>49650</td>
<td>40858</td>
<td>41648</td>
<td>-8792</td>
</tr>
<tr>
<td>T₂- Complete Natural Farming</td>
<td>37296</td>
<td>120751</td>
<td>124037</td>
<td>83454</td>
</tr>
<tr>
<td>T₃- NF (except GA, BA, JA)</td>
<td>35800</td>
<td>89398</td>
<td>101000</td>
<td>53598</td>
</tr>
<tr>
<td>T₄-NF (except mulching)</td>
<td>35046</td>
<td>87702</td>
<td>97931</td>
<td>52656</td>
</tr>
<tr>
<td>T₅- NF (except Intercropping)</td>
<td>36296</td>
<td>72109</td>
<td>72899</td>
<td>35813</td>
</tr>
<tr>
<td>T₆- Organic Farming</td>
<td>89925</td>
<td>103056</td>
<td>107494</td>
<td>13131</td>
</tr>
<tr>
<td>T₇- ICM (organic pest management)</td>
<td>94450</td>
<td>132422</td>
<td>135706</td>
<td>37972</td>
</tr>
<tr>
<td>T₈- ICM (Chemical pest management)</td>
<td>90262</td>
<td>127923</td>
<td>132970</td>
<td>37661</td>
</tr>
</tbody>
</table>
Yet, within the ICM framework, amalgamating organic manure and inorganic fertilizer escalates cultivation expenses due to their combined application. Furthermore, ICM practices yielded elevated crop output, culminating in the highest gross returns (₹132422 and ₹135706 in 2021-22 and 2022-23, respectively) compared to alternative farming methods across both cotton cultivation years. This augmentation stems from superior yields achieved through ICM practices relative to other treatment combinations. Muthukrishnan et al. (2017) reported that combining RDF and 12.5 t ha⁻¹ of FYM led to increased gross returns, net returns, and B:C ratio, showing analogous results.

In the midst of this, cotton cultivation under natural farming practices yielded greater net returns (₹83454 and ₹86741 in 2021-22 and 2022-23, respectively) and a more favorable B:C ratio (3.24 and 3.33 in 2021-22 and 2022-23) compared to alternative approaches. While cotton growth under ICM practices generated higher gross returns due to augmented yields, the utmost net returns and B:C ratio were achieved through natural farming practices. Consistently positive net returns characterized both years within the natural farming system, consistent with the findings of Singh et al. (2023). These studies underscored that natural farming treatments yield higher net returns than conventional practices.

Conclusion

Two years of field experiments on various farming practices demonstrated that combining inorganic fertilizers and organic manures enhanced yield parameters and seed cotton yield, surpassing organic and natural farming alone. Complete Natural farming (Beejamritha 1 t/kg of seeds as seed treatment) + Ghanajeevamrit (250 kg ha⁻¹ as basal) + Jeevamrit (500 l ha⁻¹ along with irrigation water) + Crop residue mulch (5 t ha⁻¹) + intercropping showed the highest monetary gains, with greater net returns and B:C ratio than ICM (50% organic manure and 50% inorganic fertilizer) and organic practices (50% nutrient through FYM and 50% nutrient through vermicompost). This underscores the viability of adopting natural farming for sustainable cotton production in Tamil Nadu.

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Conflict of interest

The authors declare that they have no conflict of interest.

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