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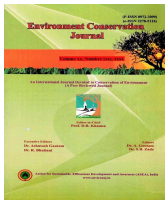

Comparing the economics of hemp (*Cannabis sativa* ssp. *sativa*) cultivation for fiber and seed yield as influenced by spacing and nutrition

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ABSTRACT

Hemp is dual purpose crop, where fibers and seeds have found its place in textile and food industry due to its strong fiber and nutrition content in seed. The cultivation of hemp is a new venture in India where farmers get dual income by both fibers and seeds hence, optimizing spacing and nutrient management to harness maximum yield of fiber and seed can double the income of farmers. The present investigation on economics of hemp cultivation revealed that the, maximum gross returns (Rs. 5,74,000/ ha) were obtained from plants grown at 10 cm × 5 cm spacing and supplied with 125 per cent RDF plus PGPR consortia but highest B:C ratio of 4.68 was observed in plants grown at spacing of 20 cm × 10 cm and nourished with 100 per cent of RDF plus PGPR consortia for fiber purposes. Upon considering seed economics maximum gross returns (Rs. 12,58,200/ ha) was recorded in the treatment combination of 10 cm × 10 cm spacing and supplied with 125 per cent RDF plus PGPR consortia while, maximum B:C ratio of 13.17 was noted from plots where plants were spaced at 15 cm × 10 cm and supplied with nutrition of 100 per cent RDF plus PGPR consortia for seed purposes.

Introduction

Hemp (*Cannabis sativa* ssp. *sativa*), a member of Cannabaceae family and native to Western and Central Asia (Zatta *et al*., 2012). The crop is under cultivation worldwide for fiber, seeds and medicinal importance hence it is considered as incredibly versatile plant with thousands of documented uses and has the capability to produce more than 25,000 crucial products, so it is often praised as trillion-dollar crop (Papastylianou *et al*., 2017). Hemp fibers served mankind for thousands of years and always been valued for its strength and durability. Fibers is used to manufacture countless products such as fibers, textiles, paper, construction materials, automobile parts, bricks, particle board, duck, wall insulator panels, fiber glasses, concrete, car parts, bricks, bio fuel, bioplastic preparations and pharmaceutical industries (Aubin *et al*., 2015). Hemp seed considered as powerhouse of good health due to its amazing nutrition profile, unsaturated fats and protein, while containing little to no cholesterol (Carus *et al*., 2013). Seeds are reputed as vegetarian meat, as it contains nine

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essential amino acid that human body can't produce naturally but which are necessary for vegetarians (https://iihaindia.org/). In India, agriculture is the major source of livelihood for over 85% of the rural population but small land holdings, low soil productivity, lack of assured irrigation, scientific knowledge, cultivation of only traditional crops, low return, price fluctuation, pest and diseases problems are the prime reason for less income to Indian farmers. Hemp is one such crop which can address all above problem as it is short duration (90 days), lower cultivation costs coupled with less water demand, largely untouched by pests, diseases, animals and high returns are the primary reasons for its acceptance among Indian farmers. Since it is a new crop and renders income to farmers from both fiber and seed but the information on agronomic practices is meager and the technologies with less use of fertilizers are much needed since the demand is more for the fibers are escalating in international market (Prasanna *et al*., 2021). Among agronomic practices, spacing plays important role in determining the yield per unit area as it facilitate aeration and light penetration into canopy for optimum plant growth (Campiglia *et al.*, 2017). Unscientific use of chemical fertilizer in crop production not only caused low yield and waste of fertilizer but also lead to increased production costs apart from contaminating the soil and water. In order to promote environment-friendly and sustainable agricultural systems, the concept of ecofriendly agriculture through application of PGPR consortia is a new field of interest without compromising the yield and quality of crop (Pagnania *et al*., 2018). Hence, study was framed with the intention to assess the influence of spacing and nutrients plus PGPR consortia on economics of cultivation of hemp for both fiber and seed purposes.

Material and Methods

The study was carried out in factorial randomized complete block design with twenty-four treatment combination and replicated thrice by considering spacing as factor one and nutrition along with PGPR consortia as factor two at Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, University of Horticultural Sciences campus, Gandhi Krishi Vignana Kendra, Bengaluru during *kharif* season of 2019-2020. One week old, healthy and uniform seedlings of NHEMPCO Vijaya -I fiber strain has been transplanted in plot having dimension of one square meter and were separated by a distance of two meter from each other. Seedlings were transplanted at six different spacings such as, S_1: 10 cm × 5 cm (200 plants/ m^2), S_2: 10 cm × 10 cm (100 plants/ m^2), S_3: 15 cm × 5 cm (133 plants/ m^2), S_4: 15 cm × 10 cm (66 plants/ m^2), S_5: 20 cm × 5 cm (100 plants/ m^2) and S_6: 20 cm × 10 cm (50 plants/ m^2) and applied with four different levels of nutrition *viz*., N_1: 10 t FYM/ ha + 150:75:150 kg N, P_2O_5, K_2O/ ha (75% RDF) + PGPR consortia, N_2: 10 t FYM/ ha + 200:100:200 kg N, P_2O_5, K_2O /ha (100% RDF) + PGPR consortia, N_3: 10 t FYM/ ha + 250:125:250 kg N, P_2O_5, K_2O/ ha (125% RDF) + PGPR consortia and N_4: FYM 10 t/ ha + 200:100:200 kg N, P_2O_5, K_2O/ ha (100% RDF) without PGPR consortia (Control). Fifty per cent of nitrogen and full dose of phosphorous and potassium were applied 15 days after transplanting and the remaining fifty per cent of nitrogen was applied 30 days after transplanting. After 10 days of transplanting PGPR consortia of *Azospirillum brasilense*, *Bacillus megaterium* and *Pseudomonas fluorescens* were applied by mixing at the rate of five kilo gram each. As the crop was dioicous in nature plants were harvested separately for male and female (after shedding of pollens and after harvesting seed respectively) stalks according to treatment by cutting above the soil surface and shade dried stalks were used for fiber extraction by decortication process (Jankauskiene *et al*., 2017). Seeds are harvested from female plants when seeds turns to brown from green, which coincide from 70 days after transplanting and extended up to 90 days. Later, female stems were uprooted, tied and dried under shade for fiber extraction.The cost incurred towards inputs and farm labours charges that were prevailed during the study period in Bengaluru region are considered and computed per hectare cultivation cost are presented in Table 1. The total cost of cultivation (in Rs./ha) incurred towards cultivation hemp for fiber and seed purposes are presented separately in Table 2 and Table 3 respectively. Gross income was calculated based on the market price prevailed for fiber and seed at the time of harvest according to hemp foundation.

Market price for extracted hemp fiber was Rs. 200 kg^{-1} and hemp seeds was Rs. 150/kg. The net income per hectare was calculated by subtracting total costs in the gross income. The benefit cost ratio was worked out using the following formula.

$$\textbf{Benefit : Cost ratio} = \frac{\textbf{Net returns (Rs./ ha)}}{\textbf{Total costs (Rs./ ha)}}$$

Table 1: Cost of inputs and labour used for raising hemp crop per hectare

Particulars	Quantity	Unit cost	Total cost (Rs.)
Land preparation (Tractor)	8 hours	Rs. 600/hour	4,800
FYM	10 t/ ha	Rs.1750/ t	17,500
Seedlings	S_1-20,00,000 S_2-10,00,000 S_3-13,30,000 S_4-6,60,000 S_5-10,00,000 S_6-5,00,000	Rs.10 200/ seedlings	1,00,000 50,000 66,500 33,000 50,000 25,000
Fertilizers (200:100:200 kg NPK ha^{-1}) Urea SSP MOP	 434.78 kg 625 kg 333.33 kg	 Rs. 6.5/ kg Rs. 7.2/ kg Rs. 16.04/ kg	 2,826.07 4,500.00 5,346.61
Transplanting	10 labours	Rs.250/ labour	2,500
Weeding	5 labours	Rs. 250/ labour	1,250
Plant protection chemicals: Chlorpyriphos Ridomil- gold	 1liter 100 g	 Rs. 600/ liter Rs. 1,350/ kg	 600 135
Harvesting and processing	30 labours	Rs. 250 /labour	7,500
Fiber extraction			5,000/ ha
PGPR consortia	5 kg	360/ kg	1,800
Miscellaneous	Transportation and others	1,500	1,500
Total			11,53,613.4

Results and Discussion

The perusal of data in Table 4 for fiber production indicates that, cost of cultivation was maximum (Rs. 1,58,426/ ha) with the spacing of 10 cm × 5 cm and application of 125 per cent RDF plus PGPR consortia. Whereas, plants spaced at 20 cm × 10 cm and nourished with 75 per cent RDF plus PGPR consortia registered least cost of cultivation (Rs. 77,090/ ha). The maximum gross return of Rs. 5,74,000/ ha was obtained from plants grown at 10 cm × 5 cm spacing and supplied with 125 per cent RDF plus PGPR consortia but highest net returns of Rs. 4,65,910/ ha was obtained from plots where plants were placed 20 cm × 5 cm spacing and supplied with 75 per cent RDF plus PGPR consortia. However, highest B:C ratio of 4.68 was obtained from plants grown at 20 cm × 10 cm and nourished with 100 per cent RDF plus PGPR consortia.The data on economics of hemp cultivation for seed yield documented in Table 5 indicated that, spacing of 10 cm × 5 cm supplied with 125 per cent RDF plus PGPR consortia resulted in maximum cost of cultivation (Rs. 1,51,926/ ha). The maximum gross returns (Rs. 12,58,200/ ha) and net returns (Rs. 11,56,274/ ha) were obtained in the treatment combination of 10 cm × 10 cm spacing and application of 125 per cent RDF with PGPR consortia. While, highest B:C ratio (13.17) was realized from plots where plants were spaced at 15 cm × 10 cm and supplied with nutrition of 100 per cent RDF and PGPR consortia. The least gross returns (Rs. 5,43,000/ ha), net returns (Rs. 3,96,062/ ha) as well as B:C ratio (2.70) were obtained in the treatment combination of 10 cm × 5 cm spacing along with 100 per cent RDF.The probable reason for maximum cost involved for cultivating hemp for fiber production due to high cost incurred towards the purchase of a greater number of seedlings per unit area and also cost incurred towards purchase of higher doses of chemical fertilizer and PGPR consortia in treatment comprise of higher density with maximum level of nutrition along with PGPR consortia. Whereas, least cost of cultivation was found at widely spaced plants coupled with low dose of fertilizers without PGPR consortia as there was reduction in number of seedlings coupled with reduced dose of fertilizer devoid of PGPR consortia. Kubsad, (2009) also reported increased production cost for ashwagandha production in closer spacing and highest dose of fertilizers. Increased benefit cost ratio for fiber purpose in widely spaced plants (20 cm × 10 cm) with 100 per cent RDF plus PGPR consortia may be attributed to lower cost of planting material, optimum usage of nutrition and good yield. Though maximum yield and gross returns was noticed in other treatment but due to increases cost of

Table 2: Cost of cultivation (Rs./ ha) as influenced by different spacing and nutrition for fiber yield of hemp

Treatments	FYM	Land Preparation	Seedlings	Transplanting	Fertilizers	PGPR consortia	Weeding	Plant Protection	Harvesting and processing	Fiber extraction & Miscellaneous	Total Cost
S_1N_1	17,500	4,800	1,00,000	2,500	9,505	1,800	1,250	735	7,500	6,500	1,52,090
S_1N_2	17,500	4,800	1,00,000	2,500	12,653	1,800	1,250	735	7,500	6,500	1,55,238
S_1N_3	17,500	4,800	1,00,000	2,500	15,841	1,800	1,250	735	7,500	6,500	1,58,426
S_1N_4	17,500	4,800	1,00,000	2,500	12,653	-	1,250	735	7,500	6,500	1,53,438
S_2N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	6,500	1,02,090
S_2N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	6,500	1,05,238
S_2N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	6,500	1,08,426
S_2N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	6,500	1,03,438
S_3N_1	17,500	4,800	66,500	2,500	9,505	1,800	1,250	735	7,500	6,500	1,18,590
S_3N_2	17,500	4,800	66,500	2,500	12,653	1,800	1,250	735	7,500	6,500	1,21,738
S_3N_3	17,500	4,800	66,500	2,500	15,841	1,800	1,250	735	7,500	6,500	1,24,926
S_3N_4	17,500	4,800	66,500	2,500	12,653	-	1,250	735	7,500	6,500	1,19,938
S_4N_1	17,500	4,800	33,000	2,500	9,505	1,800	1,250	735	7,500	6,500	85,090
S_4N_2	17,500	4,800	33,000	2,500	12,653	1,800	1,250	735	7,500	6,500	88,238
S_4N_3	17,500	4,800	33,000	2,500	15,841	1,800	1,250	735	7,500	6,500	91,426
S_4N_4	17,500	4,800	33,000	2,500	12,653	-	1,250	735	7,500	6,500	86,438
S_5N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	6,500	1,02,090
S_5N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	6,500	1,05,238
S_5N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	6,500	1,08,426
S_5N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	6,500	1,03,438
S_6N_1	17,500	4,800	25,000	2,500	9,505	1,800	1,250	735	7,500	6,500	77,090
S_6N_2	17,500	4,800	25,000	2,500	12,653	1,800	1,250	735	7,500	6,500	80,238
S_6N_3	17,500	4,800	25,000	2,500	15,841	1,800	1,250	735	7,500	6,500	83,426
S_6N_4	17,500	4,800	25,000	2,500	12,653	-	1,250	735	7,500	6,500	78,438

Table 3: Cost of cultivation (Rs./ ha) as influenced by different spacing and nutrition for seed yield of hemp

Treatments	FYM	Land Preparation	Seedlings	Transplanting	Fertilizers	PGPR consortia	Weeding	Plant Protection	Harvesting and processing	Total Cost
S_1N_1	17,500	4,800	1,00,000	2,500	9,505	1,800	1,250	735	7,500	1,45,590
S_1N_2	17,500	4,800	1,00,000	2,500	12,653	1,800	1,250	735	7,500	1,48,738
S_1N_3	17,500	4,800	1,00,000	2,500	15,841	1,800	1,250	735	7,500	1,51,926
S_1N_4	17,500	4,800	1,00,000	2,500	12,653	-	1,250	735	7,500	1,46,938
S_2N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	95,590
S_2N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	98,738
S_2N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	1,01,926
S_2N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	96,938
S_3N_1	17,500	4,800	66,500	2,500	9,505	1,800	1,250	735	7,500	1,12,090
S_3N_2	17,500	4,800	66,500	2,500	12,653	1,800	1,250	735	7,500	1,15,238
S_3N_3	17,500	4,800	66,500	2,500	15,841	1,800	1,250	735	7,500	1,18,426
S_3N_4	17,500	4,800	66,500	2,500	12,653	-	1,250	735	7,500	1,13,438
S_4N_1	17,500	4,800	33,000	2,500	9,505	1,800	1,250	735	7,500	78,590
S_4N_2	17,500	4,800	33,000	2,500	12,653	1,800	1,250	735	7,500	81,738
S_4N_3	17,500	4,800	33,000	2,500	15,841	1,800	1,250	735	7,500	84,926
S_4N_4	17,500	4,800	33,000	2,500	12,653	-	1,250	735	7,500	79,938
S_5N_1	17,500	4,800	50,000	2,500	9,505	1,800	1,250	735	7,500	95,590
S_5N_2	17,500	4,800	50,000	2,500	12,653	1,800	1,250	735	7,500	98,738
S_5N_3	17,500	4,800	50,000	2,500	15,841	1,800	1,250	735	7,500	1,01,926
S_5N_4	17,500	4,800	50,000	2,500	12,653	-	1,250	735	7,500	96,938
S_6N_1	17,500	4,800	25,000	2,500	9,505	1,800	1,250	735	7,500	70,590
S_6N_2	17,500	4,800	25,000	2,500	12,653	1,800	1,250	735	7,500	73,738
S_6N_3	17,500	4,800	25,000	2,500	15,841	1,800	1,250	735	7,500	76,926
S_6N_4	17,500	4,800	25,000	2,500	12,653	-	1,250	735	7,500	71,938

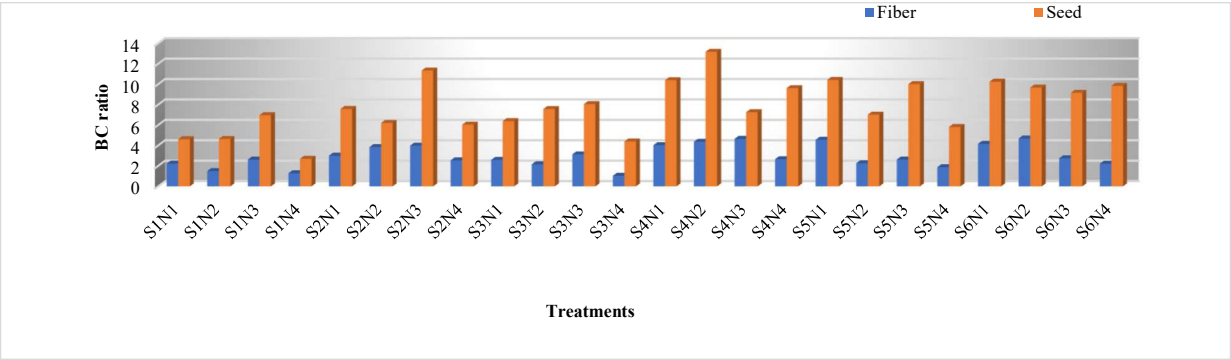

Figure 1: Comparing the BC ratio for fiber and seed yield purpose as affected by spacing and nutrition

Table 4: Economics of hemp as influenced by spacing and nutrition on fiber yield basis

Treatments	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)	Net returns (Rs./ ha)	B:C ratio
S_1N_1	1,52,090	4,92,000	3,39,910	2.23
S_1N_2	1,55,238	3,88,000	2,32,762	1.50
S_1N_3	1,58,426	5,74,000	4,15,574	2.62
S_1N_4	1,53,438	3,50,000	1,96,562	1.28
S_2N_1	1,02,090	4,08,000	3,05,910	3.00
S_2N_2	1,05,238	5,10,000	4,04,762	3.85
S_2N_3	1,08,426	5,40,000	4,31,574	3.98
S_2N_4	1,03,438	3,66,000	2,62,562	2.54
S_3N_1	1,18,590	4,26,000	3,07,410	2.59
S_3N_2	1,21,738	3,85,000	2,63,262	2.16
S_3N_3	1,24,926	5,16,000	3,91,074	3.13
S_3N_4	1,19,938	2,44,000	1,24,062	1.03
S_4N_1	85,090	4,28,000	3,42,910	4.03
S_4N_2	88,238	4,74,000	3,85,762	4.37
S_4N_3	91,426	5,17,000	4,25,574	4.65
S_4N_4	86,438	3,16,000	2,29,562	2.66
S_5N_1	1,02,090	5,68,000	4,65,910	4.56
S_5N_2	1,05,238	3,43,000	2,37,762	2.26
S_5N_3	1,08,426	3,92,000	2,83,574	2.62
S_5N_4	1,03,438	2,98,000	1,94,562	1.88
S_6N_1	77,090	3,98,000	3,20,910	4.16
S_6N_2	80,238	4,56,120	3,75,882	4.68
S_6N_3	83,426	3,13,000	2,29,574	2.75
S_6N_4	78,438	2,52,000	1,73,562	2.21

S1: 10 cm × 5 cm, S2: 10 cm × 10 cm, S3: 15 cm × 5 cm, S4: 15 cm × 10 cm, S5: 20 cm × 5 cm, S6: 20 cm × 10 cm
N_1: 75 % RDF + PGPR consortia N_2: 100 % RDF + PGPR consortia
N_3: 125 % RDF + PGPR consortia N_4: 100 % RDF

cultivation, net returns shown slight decline, this finding were supported by Shivani and Gautam, (2019). With respect to seed yield, maximum gross returns and net returns were obtained from plots which received 125 per cent RDF plus PGPR consortia and spaced at 10 cm × 10 cm. However, greatest B:C ratio (13.75) was realized when hemp plants were spaced at 15 cm × 10 cm and nourished with 100 per cent RDF plus PGPR consortia might be due to optimum plant population coupled with maximum seed yield and minimum cost of inputs incurred towards purchase of seedlings and nutrients.

The findings are in line with Lothe *et al*. (2021). Upon comparing the benefit cost ratio between fiber and seed, highest net return and BC ratio was recorded with the intention of seed purpose compared to fiber purpose. This might be due to reduced fiber yield and less cost per unit weight of fiber compared to seed. Increased cost of cultivation when grown for fiber purpose is due to additional cost incurred for fiber extraction. However, hemp can be exploited for both purposes by utilizing the same stem after seed harvesting which ensures double income for farmers

Table 5: Economics of hemp as influenced by spacing and nutrition on seed yield basis

Treatments	Cost of cultivation (Rs./ ha)	Gross returns (Rs./ ha)	Net returns (Rs./ha)	B:C ratio
S_1N_1	1,45,590	8,17,950	6,72,360	4.62
S_1N_2	1,48,738	8,38,500	6,89,762	4.64
S_1N_3	1,51,926	12,10,500	10,58,574	6.97
S_1N_4	1,46,938	5,43,000	3,96,062	2.70
S_2N_1	95,590	8,20,200	7,24,610	7.58
S_2N_2	98,738	7,12,200	6,13,462	6.21
S_2N_3	1,01,926	12,58,200	11,56,274	11.34
S_2N_4	96,938	6,82,500	5,85,562	6.04
S_3N_1	1,12,090	8,28,750	7,16,660	6.39
S_3N_2	1,15,238	9,87,450	8,72,212	7.57
S_3N_3	1,18,426	10,71,750	9,53,324	8.05
S_3N_4	1,13,438	6,12,750	4,99,312	4.40
S_4N_1	78,590	8,94,750	8,16,160	10.39
S_4N_2	81,738	11,58,450	10,76,712	13.17
S_4N_3	84,926	7,01,250	6,16,324	7.26
S_4N_4	79,938	8,49,000	7,69,062	9.62
S_5N_1	95,590	10,91,700	9,96,110	10.42
S_5N_2	98,738	7,92,000	6,93,262	7.02
S_5N_3	1,01,926	11,22,450	10,20,524	10.01
S_5N_4	96,938	6,60,000	5,63,062	5.81
S_6N_1	70,590	7,93,950	7,23,360	10.25
S_6N_2	73,738	7,86,750	7,13,012	9.67
S_6N_3	76,926	7,81,200	7,04,274	9.16
S_6N_4	71,938	7,80,450	7,08,512	9.85

S1: 10 cm × 5 cm, S2: 10 cm × 10 cm, S3: 15 cm × 5 cm, S4: 15 cm × 10 cm, S5: 20 cm × 5 cm, S6: 20 cm × 10 cm
N_1: 75 % RDF + PGPR consortia N_2: 100 % RDF + PGPR consortia
N_3: 125 % RDF + PGPR consortia N_4: 100 % RDF

Conclusion

Hemp is a multipurpose crop where both seed and fiber are of economic importance hence, it gives dual advantage for the farmers. Results suggest cultivating hemp either at spacing of 20 cm × 10 cm or 15 cm × 10 cm and supplied with nutrition of 100 per cent RDF plus PGPR consortia in order to obtain dual income from both fiber and seed. After harvesting of seeds, same stems can be used to extract fiber without much comprising in yield is added advantage of cultivating hemp.

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Conflict of interest

The authors declare that they have no conflict of interest.

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