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Growth, Yield Attributes and Yield of *Kharif* Rice (*Oryza sativa* L.) as Influenced by Establishment Techniques and Weed Management Practices

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An experiment on establishment techniques and weed management practices in *kharif* rice was conducted at Agronomy Farm of College of Agriculture, Konkan Krishi Vidyapeeth,Dapoli, Maharashtra during *kharif* 2017. The field experiment was laid out in a strip plot design with 15 treatment combinations, each replicated three times. The main plot treatments comprised of five crop establishment techniques (T_1: Seed sowing on flat bed with drum seeder, T_2: Transplanting by hand-operated transplanter, T_3: Transplanting by mechanical transplanter, T_4: Dibbling on broad bed and furrow (BBF) with polymulch and T_5: Recommended manual transplanting with puddling) and the subplot treatments consisted of three weed management practices (W_1: Weedy check, W_2: Weed free check [hand weeding at 20, 40 and 60 days after sowing (DAS)/days after transplanting (DAT)] and W_3: Pre-emergence herbicide application (Oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding at 30 DAS/DAT). From the results of the investigation, it can be inferred that for obtaining higher growth and yield attributes, grain and straw yield of *kharif* rice, the rice crop should be established by seed sowing on flat bed by drum seeder along with preemergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding at 30 DAS.

(***Key words:*** *Establishment techniques, Growth attributes, Kharif rice, Weed management, Yield attributes and yield)*

Rice (*Oryza sativa* L.) is the most important staple food grain crop of the world which constitutes the principal food for about 60% of the world's population. India is the world's second largest rice producer and consumer next to China. In India, rice is cultivated on an area of 43.77 million hectares with an annual production of 112.76 million tonnes and productivity of about 2.58 t ha^{-1} (Directorate of Economics and Statistics, 2020a). In Maharashtra, rice is cultivated over an area of 1417 thousand hectares with a production of 3144 thousand metric tonnes (Directorate of Economics and Statistics, 2020b).

Rice in the *Konkan* region of Maharashtra is being grown mostly as puddled transplanted crop. This method of cultivation involves labour intensive practices like traditional '*Rab*', raising seedlings, uprooting and transplanting them in puddled fields. Continuous adoption of puddling and transplanting for rice cultivation has been reported to cause a decline in soil and crop productivity (Nambiar and Abrol, 1989).

In recent years, rural labour had migrated towards the industrial sector which had led to the non-availability of labour.It results in delayed transplantation of rice and consequent yield reductions. Transplanting of paddy seedlings is a common method in the irrigated rice systems of Asia but transplanting is labour intensive (30 persons ha^{-1} day^{-1}). Dry direct-seeded rice differs from transplanted rice in terms of crop establishment as well as subsequent crop management practices,which offers many advantages such as more efficient water use, high tolerance to water deficit, less methane gas emission, reduced cultivation cost (Sarangi *et al*., 2020), prevents the formation of hardpan in sub-soil and minimizes labour input (Balasubramanian and Hill, 2002).

The mechanical transplanting of rice has been considered the most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that contributes to high productivity. Hence, in the present study power operated four-row paddy transplanter suitable for root wash seedlings was evaluated for its performance on a field scale. Plastic mulches can offer a barrier against weeds, moisture loss, nutrient loss, erosion, insect and disease injury, while it encourages plant establishment and subsequent development and thus results in better yield. Weed competition is one of the major factors responsible for

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the low yield of rice. The competition offered by weeds is most important and it reduces the grain yield up to the extent of 32% (Singh *et al*. 2007). Therefore, keeping all these points in view, a field experiment was conducted to study the growth and yield attributes and yield of kharif rice (*Oryza sativa* L.) under various establishment techniques and weed management practices.

MATERIAL AND METHODS

The investigation was conducted during *kharif* 2017 at the Agronomy Farm (17.10° N latitude and 73.10° E longitude), College of Agriculture, Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli located at Ratnagiri district of Maharashtra. The field experiment was laid out in a strip plot design. The main plot treatments comprised of five crop establishment techniques *viz*., T_1: Seed sowingon a flat bed with drum seeder, T_2: Transplanting by hand-operated transplanter, T_3: Transplanting by mechanical transplanter, T_4: Dibbling on broad bed and furrow (BBF)with polymulch and T_5: Recommended manual transplanting with puddling and the subplot treatments consisted of three weed management practices, namely, W_1: Weedy check, W_2: Weed free check (hand weeding at 20, 40 and 60 DAS/DAT) and W_3: Pre-emergence application of herbicide (Oxadiargyl @ 0.12 kg ha^{-1}) + one hand weeding at 30 DAS/DAT. There were 15 treatment combinations each being replicated thrice.The seed of rice variety Karjat-3 was used for sowing.

Raising of seedlings on nursery bed for transplanting

For nursery bed preparation, the soil was ploughed twice by a tractor and subsequently brought under fine tilth. The raised beds of 10 m length, 1 m breadth and 15 cm height were prepared. Good quality farmyard manure was spread and mixed well with soil over the beds. Urea and single super phosphate were applied @ 1 kg and 3 kg 100 m^{-2}, respectively at the time of sowing. The seed of rice variety Karjat-3 which was treated with thiram @ 3 g kg^{-1} seed was sown in lines 10 cm apart at 2-3 cm depth. Germination started from the third day and was completed by the fifth day. Topdressing with urea @ 1 kg 100 m^{-2} was done 15 days after sowing. The need-based plant protection and weed control measures were carried out in the nursery.

Dry sowing

Here, the sowing of seeds was carried out by using a manually operated four coulter drum seeder at about 3-5 cm depth with row spacing of 22.5 cm on 10th June 2017. After sowing, the seeds were covered with soil.

Dibbling of seeds on polymulch

The silver black polythene mulch of 25-micron thickness was used for polymulch treatment. After applying polymulch, seeds of rice were dibbled on the raised bed on 10th June 2017 at a spacing of 20 cm × 15 cm as per the treatment.

Transplanting of seedlings

Twenty-one days old seedlings were transplanted on 1st July, 2017 with the recommended spacing of 20 cm × 15 cm. While in the treatments of mechanical and hand-operated transplanting the healthy and vigorous seedlings of 21 days old age were used for transplanting. While uprooting the seedlings, care was taken that roots remained attached to the seedlings and the same was used for transplanting after washing the roots. Two to three seedlings were transplanted per hill. Transplanting was carried out on 1st July 2017. Transplanting was done in lines at a distance of 20 cm, 22.5 cm and 23.5 cm between two rows in treatments T_5, T_2 and T_3 respectively. In recommended manual transplanting 15 cm distance was kept between two hills.

FYM was applied in experimental plots @ 5 t ha^{-1} at the time of land preparation before layout. The crop was fertilized with 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. At the time of sowing and transplanting, 40 kg N ha^{-1} was applied with the full dose of P_2O_5 and K_2O as a basal dose. The remaining 40 kg N ha^{-1} was applied at 30 DAS/DAT as per treatments and 20 kg at the panicle initiation stage (75 DAS). Nitrogen was supplied through urea having (46% N) while phosphorous and potash was supplied through single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O). In case of treatment dibbling on broad bed furrow (BBF) with polymulch, the remaining urea was applied through the deep placement method at the centre of four hills.

Application of herbicides

The herbicide oxadiargyl was applied as pre emergenceand one hand weeding at 30 DAS/DAT as per treatments. Three hand weedings were undertaken at 20, 40 and 60 DAS/DAT as per treatments to keep the experimental crop plot free of weeds wherever necessary.

Plant protection measures

Since the seeds were treated with thiram before sowing, the crop was free from disease during the early growth stages, but crab attack was observed at the early growth stage which was controlled by the application of phorate 10 G granules.

Growth and yield attributes

The observations on growth and yield attributes, such as dry matter accumulation, number of effective tillers, panicle number, spikelet number, grain and straw yields were recorded following standard procedures.

Statistical analysis

The data obtained were subjected to the analysis of variance as described by Panse and Sukhatme (1985) and the treatment means and their interaction effects were compared by computing the critical difference at the 5% level of significance.

RESULTS AND DISCUSSION

Effect of establishment techniques

The data pertaining to the mean number of functional leaves m^{-2} as influenced by different treatments at harvest are presented in Table 1. From the data it is evident that, treatment recommended manual transplanting with puddling was superior in case of the number of functional leaves, over the dibbling on BBF with polymulch transplanting by mechanical transplanter and transplanting by hand-operated transplanter during at harvest.

At harvest recommended manual transplanting with puddling recorded significantly higher number of effective tillers m^{-2} (358) over rest of the treatment except dibbling on BBF with polymulch which was at par with each other and lowest number of effective tillers were recorded in seed sowing on flat bed with drum seeder.

The different establishment techniques showed significant effect on the mean dry matter accumulation at harvest. The recommended manual transplanting with puddling was recorded significantly maximum dry matter accumulation (489 g m^{-2})over rest of the treatments.Jagtap and Mahadkar (2017) revealed that total dry matter production at harvest was similar undertransplanting, *Thomba* method and SRI technique and was significantly superior to pre-monsoon dibbling of seeds and dibbling of seeds with the onset of monsoon. However, in 2009 the SRI technique, was on par with pre-monsoon dibbling of seeds but was significantly superior to dibbling of seeds with the onset of monsoon.

The mean number of panicles m^{-2} showed significant effect due to different establishment techniques. However, significantly maximum mean number of panicles m^{-2} (357) were recorded by the recommended manual transplanting with puddling over rest of the treatments except dibbling on BBF with polymulch which was at par with each other. Similarly, dibbling on BBF with polymulch was significantly superior over transplanting by mechanical transplanter, transplanting by hand operated transplanter and seed sowing on flat bed with drum seeder during the investigation period.

The mean number of spikelets $panicle^{-1}$ of rice was affected significantly by the different establishment techniques, during the year of study. Significantly maximum number of spikelets $panicle^{-1}$ (123) of rice crop were recorded by the recommended manual transplanting with puddling over rest of the treatments except dibbling on BBF with polymulch which were at par with each other. Similarly, dibbling on BBF with polymulch was superior over the seed sowing on flat bed with drum seeder transplanting by hand operated transplanter, transplanting by mechanical transplanter during the study.

The mean number of filled grains $panicle^{-1}$ of rice varied significantly among the different establishment techniques. Significantly maximum number of filled grains $panicle^{-1}$ (112) in rice was recorded under the recommended manual transplanting with puddling over rest of the treatments except dibbling on BBF with polymulch which were at par with each other. Similarly, dibbling on BBF with polymulch was superior over the seed sowing on flat bed with drum seeder and at par with transplanting by hand operated transplanter and transplanting by mechanical transplanter during the study. Jagtap *et al.* (2012) and Jagtap *et al.* (2013) reported that transplanting was on par with *Thomba* method and SRI technique in respect of number of filled grains $panicle^{-1}$ and was significantly superior to pre-monsoon dibbling of seeds and dibbling of seeds on the onset of monsoon.

The mean 1000 grain weight (g) of rice was not

Table 1. *Growth and yield attributing characters, grain yield and straw yield of rice as influenced by different treatments*

Treatments	No. of functional leaves (m^2)	No. of effective tillers (m^2)	Dry matter accumulation (g m^{-2})	No. of panicle (m^{-2})	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Establishment techniques									
T_1: Seed sowing on flat bed with drum seeder	1229	345	466	345	121	108	22.07	3.9	4.7
T_2: Transplanting by hand operated transplanter	1273	351	470	350	121	111	22.08	3.9	4.7
T_3: Transplanting by mechanical transplanter	1277	352	477	351	122	111	22.21	4.0	4.8
T_4: Dibbling on BBF with polymulch	1312	356	483	355	122	112	22.22	4.1	4.8
T_5: Recommended manual transplanting with puddling	1319	358	489	357	123	112	22.35	4.1	4.9
SE±	0.95	0.69	0.70	0.69	0.20	0.50	0.23	0.32	0.35
C.D. at 5%	3.11	2.26	2.27	2.26	0.65	1.62	N.S.	1.04	1.14
Weed management practices									
W_1: Weedy check	1242	350	457	350	121	110	21.70	3.9	4.6
W_2: Weed free check	1320	354	497	353	123	111	22.62	4.2	4.9
W_3: Pre-emergence (Oxadiargyl@ 0.12 kg ha^{-1}) + one hand weeding	1284	352	476	352	122	111	22.24	4.0	4.8
SE±	0.65	0.50	0.98	0.50	0.35	0.46	0.20	0.43	0.56
C.D. at 5%	2.55	1.98	3.84	1.98	N.S	N.S.	N.S.	1.69	2.21
Interaction									
SE±	0.98	0.67	1.27	0.67	0.50	0.67	0.24	0.67	0.71
C.D. at 5%	2.94	2.01	3.80	2.01	N.S.	N.S.	N.S.	2.00	N.S.
General mean	1282	352	477	352	122	111	22.18	4.0	4.8

significantly influenced due to different establishment techniques, during the year of study. However, numerically maximum 1000 grain weight (32.35 g) of rice was recorded in treatment of recommended manual transplanting with puddling, dibbling on BBF with polymulch, transplanting by mechanical transplanter, transplanting by hand operated transplanter and seed sowing on flat bed with drum seeder in descending order at harvest.

Establishment techniques *viz*., seed sowing on flat bed with drum seeder, transplanting by hand operated transplanter, transplanting by mechanical transplanter, dibbling on BBF with polymulch and recommended manual transplanting with puddling showed their varying effect on yield and yield contributing characters of rice. The recommended manual transplanting method was more prominent than remaining four methods in respect of yield attributing characters and yield of rice.

The maximum number of tillers m^{-2} were associated with the treatment recommended manual transplanting technique during all stages of crop growth. The higher tiller production in recommended manual transplanting might be due to better inducement of root growth for anchorage. It leads to better nutrient and water uptake and ultimately leads to higher number of tillers. These results are in agreement with the results reported by Singh *et al*.(2006) and Jagtap (2011).

The beneficial effect of recommended manual transplanting method in enhancing the growth through increased height, leaves, number of tillers and dry matter production ultimately reflected in higher yield attributing characters *viz*., length of panicle, number of panicles m^{-2}, number of filled grains m^{-2}, number of spikelets $panicle^{-1}$ and test weight. The grain yield of rice is a function of yield attributes of an individual plant *viz*., length of panicle, number of panicles m^{-2}, number of filled grains $panicle^{-1}$, number of spikelets $panicle^{-1}$ and test weight and ultimately the grain yield obtained from the plant.

Recommended manual transplanting was at par with dibbling on BBF with polymulch in respect of number of panicles m^{-2}, number of filled grains $panicle^{-1}$, number of spikelets $panicle^{-1}$ and test weight and which was significantly superior over the transplanting by mechanical transplanter, transplanting by hand operated transplanter and seed sowing on flat bed with drum seeder. Thus, recommended manual transplanting with puddling recorded significantly higher grain yield (4.1 t ha^{-1}) over rest of the establishment techniques except dibbling on BBF with polymulch. The increase in grain yield recorded under recommended manual transplanting with puddling over dibbling on BBF with polymulch, transplanting by mechanical transplanter, transplanting by hand operated transplanter and seed sowing on flat bed with drum seeder was to the tune of 1.91, 2.93, 5.44 and 6.80%, respectively. The increased yield attributes might be due to increased growth and development parameters which ultimately resulted in increased grain.

Higher straw yield (4.9 t ha^{-1}) (Table 2) recorded under recommended manual transplanting of rice was significantly superior over seed sowing on flat bed with drum seeder, transplanting by hand operated transplanter, transplanting by mechanical transplanter and which was

Table 2. *Interaction effect of establishment techniques and weed management practices on panicle number and grain yield as influenced by different treatments*

	Weed management practices					
	Number of panicles m^{-2}			Grain yield (t ha^{-1})		
Establishment techniques	W_1	W_2	W_3	W_1	W_2	W_3
T_1	346.95	356.39	359.09	3.87	3.91	3.86
T_2	356.84	361.40	358.29	3.62	4.19	3.98
T_3	357.39	360.66	359.33	4.00	4.13	3.98
T_4	360.09	363.22	359.95	3.85	4.25	4.09
T_5	359.61	365.43	362.76	3.98	4.29	4.16
S.Em.±	1.59			1.64		
C.D. at 5%	4.75			4.92		

on par with dibbling on BBF with polymulch. Increase in mean straw yield observed under recommended manual transplanting over dibbling on BBF with polymulch, transplanting by mechanical transplanter, transplanting by hand operated transplanter and seed sowing on flat bed with drum seeder was to the tune of 1.28, 2.47, 3.99 and 4.97%, respectively. This might be due to increased morphological characters *viz*., plant height, number of leaves m^{-2}, number of tillers and dry matter production m^{-2} observed under transplanting. Jagtap *et al*. (2011) revealed that, transplanting of rice recorded significantly higher grain, straw and biological yield per ha over the different treatments like, *thomba* method, SRI technique, pre monsoon dibbling of seeds and dibbling of seeds on the onset of monsoon. Mangat Ram *et al*. (2006) conducted a field trial at CCSH Agril. University, Haryana and concluded that the transplanting method of establishment recorded the highest plant height at maturity, panicles m^{-2}, grains $panicle^{-1}$ and 1000 grain weight followed by direct seeding in puddled soil. Manual transplanting of rice gave significantly higher grain yield of rice (7.1 t ha^{-1}), followed by direct seeding of rice in puddled soil (5.8 t ha^{-1}), whereas the lowest yield was obtained with dry seeding by seed drill (5.2 t ha^{-1}) or zero-till-drill (5.0 t ha^{-1}).

Establishment methods showed significant variation with respect to grain and straw yields. The establishment method normal transplanting as per recommendation was significantly superior over rest ofall the treatments. Early transplanting is significantly superior over *Thomba* method and drilling while least grain yield and straw yields were recorded in drilling method (Jagtap *et al*., 2016).

Thus, the results clearly showed that recommended manual transplanting with puddling method of establishment was superior and which was at par with dibbling on BBF with polymulch for obtaining higher grain and straw yield in rice.

Effect of weed management practices

All weed management practices recorded significantly more number of functional leaves m^{-2} as compared to weedy check at all growth stages. Significantly the highest number of functional leaves m^{-2} (1320) was recorded in the treatment weed free check which was followed by the treatment of pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding but it was observed significantly superior over the treatment weedy check at all the crop growth stages.

The treatment weed free check recorded significantly the highest number of tillers per m^2 (354) which was at par with pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding and significantly superior over treatment of weedy check at 30, 90 DAS and at harvest.

The treatment weed free check recorded significantly the highest mean dry matter accumulation m^{-2} (497 g) of rice which was followed by the treatment pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding and both were significantly superior over treatment of weedy check (W_1) at harvest.

The beneficial effect of weed management practices in enhancing the growth through increased height, number of leaves, number of tillers, and dry matter production ultimately reflected in higher yield attributing characters *viz*., length of panicle, number of panicles m^{-2}, number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and test weight. The grain yield of rice is a function of yield attributes of an individual plant *viz*., length of panicle, number of panicles, number of spikelets $panicle^{-1}$, number of filled grains $panicle^{-1}$ and test weight and ultimately the grain yield obtained from the plant.

The mean number of panicles m^{-2} of rice was significantly influenced due to different weed management practices. Significantly the highest number of panicles m^{-2} (353) were recorded by the treatment of weed free check which was at par with pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding and both were observed to be significantly superior over weedy check during the year of study. The different weed management practices did not show any significant effect with respect to the mean number of spikelets $panicle^{-1}$ of rice during the years of study. However, numerically maximum number of spikelets $panicle^{-1}$ (123) which were recorded in weed free check, pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding and weedy checkindescending order at harvest.

The different weed management practices did not show any significant effect with respect to the mean number of filled grains $panicle^{-1}$ of rice during the years of study. However, numerically maximum number of filled

grains panicle^{-1} (111) were recorded in weed free check, pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding and weedy check in descending order at harvest.

Different weed management practices did not show any significant effect with respect to the mean 1000 grain weight of rice during the study. However, numerically maximum number of 1000 grain weight (22.62 g) was recorded in weed free check, pre-emergence application of oxadiargyl@ 0.12 kg ha^{-1}+ one hand weeding and weedy check in descending order at harvest.

The data presented in Table 1 revealed that, different weed management practices significantly influenced the yield attributes. The number of panicle (m^2), number of filled grains panicle^{-1} was significantly higher under treatment weed free check followed by the treatment of pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding which were at par with each other but was found significantly superior over the treatment of weedy check during the year of investigation. This might be due to effective control of weeds and thereby reduced crop weed competition and ultimately resulted in better crop growth which might have helped in the synchronization of yield attributes. Shelar (2014) evaluated the effect of methods of weed control on the performance of direct seeded rice andreported that tillers m^{-2} and dry matter accumulation in plant was observed to be higher in the treatment of weed free check (hand weeding at 20, 40 and 60 DAS) followed by treatment of pre-emergence application of oxadiargyl @ 120 g ha^{-1} + post-emergence application of bispyribacsodium @ 25 g ha^{-1} which were at par with each other but significantly superior over rest of the weed control treatments. The minimum plant height, tillers m^{-2} and dry matter accumulation in plant was recorded in the treatment of unweeded check.

Weed free check *i.e*., hand weeding at 20, 40 and 60 DAS/DAT recorded highest grain and straw yield followed by treatment pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding which were at par with each other but found significantly superior over weedy check treatment during the study.

The weed free check treatment recorded significantly higher grain and straw yield of 4.2 t ha^{-1} and 4.9 t ha^{-1} respectively, which were followed by treatment pre-emergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding but which was at par with each other and found significantly superior over weedy check. The increase in grain and straw yield of rice might be due to significant improvement in growth and yield attributes, which finally resulted in increased grain and straw yield. Walia *et al*. (2012) in experiments conducted during kharif 2007 and 2008 at Punjab Agricultural University, Ludhiana on direct seeded rice under unpuddled (dry) conditions revealed that maximum grain yield was obtained with preemergence application of pendimethalin @ 0.75 kg ha^{-1} followed by bispribacsodium @ 25 g ha^{-1} which was closely followed by oxadiargyl (@ 90 g ha^{-1}) followed by bispribacsodium @ 25 g ha^{-1}. There were 152.4 and 142.9% increase in grain yield over unweeded control with these treatments, respectively.

Interaction effect of establishment techniques and weed management practices

Recommended manual transplanting with puddling recorded significantly maximum grain yield with weed free check over rest of the treatment combinations followed by dibbling on BBF with polymulch with weed free check treatment combinations during the course of study. Weed free condition under manual transplanting resulted in more number of spikelets per panicle ultimately there was increase in grain yield. Baloch *et al*. (2006) reported that the paddy yield and its components were significantly higher in the transplanted method than that in direct-seeded method, while the weed density and biomass were lower in the transplanted plots than the direct-seeded plots. Among weed management tools, the maximum rice yield was obtained in hand weeding, closely followed by herbicide application (Machete 60EC) during both cropping seasons.

From our investigation, it can be concluded that for obtaining higher growth and yield attributes, grain and straw yield of kharif rice, the crop should be established by seed sowing on flat bed by drum seeder along with preemergence application of oxadiargyl @ 0.12 kg ha^{-1} + one hand weeding at 30 DAS.

CONFLICTS OF INTEREST

The authors declare that there are no competing interests.

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