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Economic Evaluation of Summer Legumes Incorporation on Succeeding *Kharif* Rice

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ABSTRACT: At the College Farm, Navsari Agricultural University, Navsari (Gujarat), a field experiment was carried out in the summer and *kharif* of 2021 and 2022. The study included four main plot treatments, namely, T_1: Green gram, T_2: Cowpea, T_3: Dhaincha and T_4: Fallow which were sown in summer season, replicated thrice in a randomized block design. Summer legume residues, namely green gram (T_1) and cowpea (T_2), were incorporated after final crop harvest, while dhaincha (T_3) was incorporated at 50% flowering in corresponding plots. Each main plot treatment was carried out throughout the kharif season was divided into six sub-plot treatments as levels of recommended dose of fertilizer to *kharif* rice, which include W_1: 100% RDF, W_2: 75% RDF, W_3: 50% RDF, W_4: 75% RDF + 25% N from FYM, W_5: 50% RDF + 50% N from FYM, and W6: No-fertilizer application; resulting in twenty-four treatment combinations replicated thrice in a split plot design. Results posed that the higher (₹/ha 95332, 108322, 101744), net returns ((₹/ha 33478, 46044, 39678) was also recorded higher in rice grown in dhaincha incorporated plots with BCR of 1.54, 1.74, 1.64 in 2021, 2022 and in pooled study respectively. With the application of 100% RDF, maximum gross and net returns (/ha 111152, 51341; 125096, 64761; 118050, 57977) and BCR (1.86, 2.07, 1.97) were greater, while the lowest BCR (1.05, 1.21, 1.13) was in 2021, 2022, and on a pooled basis. Higher gross and net returns were observed in the green gram-rice cropping sequence during the pooled study, with a BCR of 2.22 in the treatment green gram-100% RDF (T_1W_1) and the lowest being in treatment T4W6 (1.03). Based on the findings of the two-year experiment, it was observed that introducing dhaincha with 100% RDF (Recommended Dose of Fertilizer) yielded positive financial outcomes. Additionally, considering the cropping sequence, it was determined that green gram during the summer season followed by rice cultivation with 100% RDF resulted in greater financial advantages.

Keywords: Summer legumes, Net reruns, Gross returns, Benefit cost ratio, Rice.

INTRODUCTION

The Rig Veda and Mahabharata both make references to rice (Prasad *et al.*, 2016), which highlights its significance as a staple food for nearly half of the world's population. This crop holds great importance, accounting for approximately 40% of the nation's total production of food grains. Since rice consumption constitutes 90% of the global food intake, it becomes crucial to ensure global food security. To maintain the current per capita availability of rice (69 kg/year) and keep land productivity constant, the demand for rice is projected to increase by 70% in the next 30 years. This information underscores the importance of addressing the growing demand for rice while sustaining agricultural productivity (Patra and Haque 2011). Legume crop wastes are a valuable source of plant nutrients and essential for the stability of agricultural ecosystems. The yearly in situ burning of over 23 Mt of rice residues in northwest states resulted in a loss of 9.2 Mt C equivalent to CO_2 load (NAAS, 2017). Rice productivity and rice-based systems' sustainability are at risk due to (1) dwindling resources (land, water, labour, and machinery), (2) inefficient input use (fertiliser, water, herbicides, insecticides, etc.), and (3) rising cultivation costs (Bhagirath *et al.*, 2017). The degradation of soil health is accelerating due to improper management practices, excessive use of fertilizers, and various other factors. Adopting the approach of residue integration can effectively reduce the burning of agricultural waste and mitigate the negative impact of modernization, all while enhancing soil fertility. To restore the soil's productivity and promote sustainable agriculture, it is crucial to incorporate legumes into the crop rotation, ensuring proper soil coverage. In order to address the rising demand for fertilizers and improve crop yield, it is essential to consider an alternative approach that involves reducing fertilizer usage while increasing productivity. One potential solution is to optimize the use of crop wastes, which could potentially lead to higher rice output and lower cultivation expenses. To better understand the economic implications, further research is required to assess the feasibility of integrating crop residue and different levels of nutrient dosages in *kharif* rice cultivation.

METHODOLOGY

In the summer and *kharif* seasons of the years 2021 and 2022, a field experiment was carried out at the College Farm, Navsari Agricultural University, Navsari (Gujarat). The experimental field's soil had a clayey texture, a medium level of organic carbon, low levels of readily available nitrogen and P_2O_5, and a high level of readily available K_2O. The soil was slightly alkaline in reaction. The experiment conducted included four main plot treatments, namely, T_1: Green gram, T_2: Cowpea, T_3: Dhaincha and T_4: Fallow which were sown in summer season, replicated thrice in a randomized block design. Summer legume residues, namely green gram (T_1) and cowpea (T2), were incorporated after final crop harvest, while dhaincha (T_3) was incorporated at 50% flowering in corresponding plots. Each main plot treatment during the *kharif* season was divided into six sub-plot treatments as levels of the prescribed fertiliser dose for *kharif* rice, which include W_1: 100% RDF, W_2: 75% RDF, W_3: 50% RDF, W_4: 75% RDF + 25% N from FYM, W_5: 50% RDF + 50% N from FYM, and W_6: No-fertilizer application; resulting in twenty-four treatment combinations replicated thrice in a split plot design. The economics of summer legumes (green gram, cowpea, dhaincha) and rice was worked out by considering the prevailing market rates for different inputs and produces. The cost involved and the returns obtained under different treatments is very important aspect for determining the overall advantages. It was worked out in terms of net returns and benefit cost ratio (B:C ratio) to ascertain the economic viability of the treatments. The treatment wise cost of cultivation (₹/ha) was calculated by considering the item wise prices/rates for respective years. Selling price of each kilogram of summer legumes and rice was taken from minimum support price. The gross realization (₹/ha) was worked out based on pod and stover yields of summer legumes (green gram, cowpea, dhaincha) and rice for each treatment considering prevailing market prices. The net realization (₹/ha) for individual treatment was worked out by deducting the total cost of cultivation of each treatment from gross realization of respective treatment.

Net returns (₹/ha) = Gross returns (₹/ha) – Cost of cultivation (₹/ha)

Benefit-cost ratio which gives an indication of the monetary gain over every rupee invested under a particular treatment. The ratio of each treatment was calculated by dividing the net realization by the cost of cultivation of respective treatment.

B : C ratio = Gross return (₹/ha)/Cost of cultivation (₹/ha)

Rice equivalent yield (kg/ha)

The conversion of summer legume yield and rice grain yield into rice equivalent yield (kg/ha) was determined based on the prevailing market prices for both crops. The following equation was used to determine the rice yield for the two different treatments.

$$\text{REY (kg/ha)} = \frac{\text{Ya} \times \text{Pa}}{\text{Pb}} + \frac{\text{Yb} \times \text{Pb}}{\text{Pb}}$$

Ya - Yield of summer legumes (kg/ha)

Yb - Yield of rice (kg/ha)

Pa - Price of summer legumes (₹/kg)

Pb - Price of rice (₹/kg)

RESULTS AND DISCUSSION

The gross return, net return, and BCR were remarkably influenced by preceding summer legumes and their residue incorporation and nutrient doses in *kharif* rice (Table 1-3). The highest net returns were obtained with dhaincha (T_3, Rs. 33478, 46044 and 39678 in 2021, 2022 and pooled respectively). The BCR was 1.54, 1.74 and 1.64 during 2021, 2022 and pooled respectively. Even though extra cost was included for residue incorporated plots, the higher grain yield might have compensated the net returns. The lower returns were recorded in fallow plots (T_4) with BCR of 1.25, 1.41 and 1.33 in 2021, 2022, and pooled respectively. The reason behind this could be attributed to the fact that rice grown in dhaincha-integrated plots yielded higher quantities of both grain and straw compared to rice cultivated in green gram, cowpea, and fallow treatments, as documented by Anitha and Mathew (2011). Among the various factors influencing the increased grain output, enhanced nutrient availability and reduced cultivation expenses played a significant role, as stated by Premalatha (2017).

The nutrient doses favourably influenced the net returns in both the years. Application of 100% RDF (W_1) recorded maximum gross and net returns (₹/ha 111152, 51341; 125096, 64761; and 118050, 57977) in 2021, 2022 and pooled study respectively. The BCR noticed was 1.86, 2.07 and 1.97 respectively in 2021, 2022 and pooled study in 100% RDF (W_1). The lower returns were recorded in No-fertilizer treatment (W_6) with BCR of 1.05, 1.21 and 1.13 in 2021, 2022 and pooled study respectively (Table 1,2,3). Similar results were found by Jat *et al*. (2011). In contrast to W_4, W_5, where cultivation expenses increased as a result of using FYM combined with fertiliser, W_1 treatment had reduced cultivation costs and improved grain and straw yields (Bora *et al*., 2014). In comparison, the yields in W_2, W_3, and W_6 were low. Surprisingly, the summer fallow-No fertiliser treatment (T_4W_6) showed positive net returns in 2022 (Table 2) and in pooled study (Table 3), but it had negative net returns in 2021 (Table 1). This implies that not utilising fertiliser resulted in decreased yield and economic benefits for the farmer (Moolaram *et al*., 2011; Saisravan *et al.*, 2016).

Table 1: Economics of *kharif* rice as influenced by different treatment combinations (2021).

Treatments	Fixed cost (₹/ha)	Variable cost (₹/ha)	Total cost of cultivation (₹/ha)	Grain yield (kg/ha)	Straw yield (kg/ha)	Returns from grain yield (₹/ha)	Returns from straw yield (₹/ha)	Goss returns (₹/ha)	Net returns (₹/ha)	BCR
T_1W_1	56992	2819	59811	4389	6463	85146	29083	114229	54418	1.91
T_1W_2	56992	2249	59241	3239	4773	62837	21479	84316	25075	1.42
T_1W_3	56992	1678	58670	2742	4035	53187	18157	71344	12674	1.22
T_1W_4	56992	8595	65587	4034	5943	78263	26744	105006	39419	1.60
T_1W_5	56992	13834	70826	3474	5116	67396	23021	90417	19591	1.28
T_1W_6	56992	0	56992	2280	3358	44234	15112	59346	2354	1.04
T_2W_1	56992	2819	59811	4255	6271	82551	28219	110770	50959	1.85
T_2W_2	56992	2249	59241	3107	4585	60281	20634	80915	21674	1.37
T_2W_3	56992	1678	58670	2736	4033	53079	18147	71226	12556	1.21
T_2W_4	56992	8595	65587	3974	5846	77100	26305	103405	37818	1.58
T_2W_5	56992	13834	70826	3509	5167	68066	23250	91317	20491	1.29
T_2W_6	56992	0	56992	2273	3366	44096	15148	59245	2253	1.04
T_3W_1	56992	2819	59811	4638	6836	89971	30763	120734	60923	2.02
T_3W_2	56992	2249	59241	3649	5379	70790	24205	94995	35754	1.60
T_3W_3	56992	1678	58670	3004	4426	58281	19918	78199	19529	1.33
T_3W_4	56992	8595	65587	4239	6245	82243	28102	110344	44757	1.68
T_3W_5	56992	13834	70826	3873	5711	75134	25701	100834	30008	1.42
T_3W_6	56992	0	56992	2561	3815	49689	17166	66856	9864	1.17
T_4W_1	56992	2819	59811	3798	5599	73678	25194	98871	39060	1.65
T_4W_2	56992	2249	59241	2734	4031	53032	18139	71171	11930	1.20
T_4W_3	56992	1678	58670	2512	3700	48738	16649	65387	6717	1.11
T_4W_4	56992	8595	65587	3547	5229	68818	23531	92349	26762	1.41
T_4W_5	56992	13834	70826	3183	4691	61748	21108	82856	12030	1.17
T_4W_6	56992	0	56992	2117	3105	41073	13973	55046	**-1946**	**0.97**

Table 2: Economics of *kharif* rice as influenced by different treatment combinations (2022).

Treatments	Fixed cost (₹/ha)	Variable cost (₹/ha)	Total cost of cultivation (₹/ha)	Grain yield (kg/ha)	Straw yield (kg/ha)	Returns from grain yield (₹/ha)	Returns from straw yield (₹/ha)	Goss returns (₹/ha)	Net returns (₹/ha)	BCR
T_1W_1	57277	3058	60335	4499	6625	91779	36437	128216	**67881**	**2.13**
T_1W_2	57277	2427	59704	3349	4935	68320	27143	95464	35760	1.60
T_1W_3	57277	1797	59074	2852	4197	58173	23083	81256	22182	1.38
T_1W_4	57277	8774	66051	4144	6105	84541	33578	118119	52068	1.79
T_1W_5	57277	13953	71230	3584	5278	73114	29028	102142	30912	1.43
T_1W_6	57277	0	57277	2390	3520	48758	19362	68120	10843	1.19
T_2W_1	57277	3058	60335	4365	6466	89050	35562	124612	64277	2.07
T_2W_2	57277	2427	59704	3207	4733	65428	26030	91458	31754	1.53
T_2W_3	57277	1797	59074	2836	4180	57855	22990	80846	21772	1.37
T_2W_4	57277	8774	66051	4074	5993	83114	32961	116075	50024	1.76
T_2W_5	57277	13953	71230	3609	5314	73615	29227	102842	31612	1.44
T_2W_6	57277	0	57277	2373	3514	48409	19328	67737	10460	1.18
T_3W_1	57277	3058	60335	4738	6984	96648	38410	135058	**74723**	**2.24**
T_3W_2	57277	2427	59704	3799	5600	77499	30799	108298	48594	1.81
T_3W_3	57277	1797	59074	3154	4647	64345	25560	89905	30831	1.52
T_3W_4	57277	8774	66051	4389	6433	89542	35381	124923	58872	1.89
T_3W_5	57277	13953	71230	4023	5932	82067	32627	114694	43464	1.61
T_3W_6	57277	0	57277	2711	3963	55311	21798	77108	19831	1.35
T_4W_1	57277	3058	60335	3948	5820	80536	32008	112543	52208	1.87
T_4W_2	57277	2427	59704	2834	4178	57806	22980	80786	21082	1.35
T_4W_3	57277	1797	59074	2612	3847	53290	21159	74449	15375	1.26
T_4W_4	57277	8774	66051	3647	5377	74405	29571	103976	37925	1.57
T_4W_5	57277	13953	71230	3283	4838	66970	26609	93580	22350	1.31
T_4W_6	57277	0	57277	2217	3252	45230	17885	63115	**5838**	**1.10**

Table 3: Economics of *kharif* rice as influenced by different treatment combinations (Pooled).

Treatments	Fixed cost (₹/ha)	Variable cost (₹/ha)	Total cost of cultivation (₹/ha)	Grain yield (kg/ha)	Straw yield (kg/ha)	Returns from grain yield (₹/ha)	Returns from straw yield (₹/ha)	Goss returns (₹/ha)	Net returns (₹/ha)	BCR
T_1W_1	57135	2939	60074	4444	6544	88435	32719	121154	61081	**2.02**
T_1W_2	57135	2338	59473	3294	4854	65551	24271	89822	30349	1.51
T_1W_3	57135	1738	58873	2797	4116	55653	20580	76232	17360	1.29
T_1W_4	57135	8685	65820	4089	6024	81375	30120	111495	45675	1.69
T_1W_5	57135	13894	71029	3529	5197	70228	25984	96212	25183	1.35
T_1W_6	57135	0	57135	2335	3439	46468	17196	63665	6530	1.11
T_2W_1	57135	2939	60074	4310	6368	85773	31842	117615	57541	1.96
T_2W_2	57135	2338	59473	3157	4659	62829	23295	86124	26651	1.45
T_2W_3	57135	1738	58873	2786	4106	55442	20532	75974	17102	1.29
T_2W_4	57135	8685	65820	4024	5919	80082	29597	109678	43859	1.67
T_2W_5	57135	13894	71029	3559	5240	70816	26202	97018	25989	1.37
T_2W_6	57135	0	57135	2323	3440	46228	17201	63429	6294	1.11
T_3W_1	57135	2939	60074	4688	6910	93285	34550	127834	67761	**2.13**
T_3W_2	57135	2338	59473	3724	5489	74107	27447	101554	42081	1.71
T_3W_3	57135	1738	58873	3079	4537	61275	22684	83960	25087	1.43
T_3W_4	57135	8685	65820	4314	6339	85855	31694	117549	51730	1.79
T_3W_5	57135	13894	71029	3948	5822	78563	29109	107671	36643	1.52
T_3W_6	57135	0	57135	2636	3889	52462	19445	71907	14772	1.26
T_4W_1	57135	2939	60074	3873	5709	77069	28545	105615	45541	1.76
T_4W_2	57135	2338	59473	2784	4105	55394	20523	75917	16444	1.28
T_4W_3	57135	1738	58873	2562	3773	50989	18867	69856	10983	1.19
T_4W_4	57135	8685	65820	3597	5303	71587	26514	98101	32281	1.49
T_4W_5	57135	13894	71029	3233	4764	64334	23822	88156	17128	1.24
T_4W_6	57135	0	57135	2167	3179	43126	15893	59019	1884	**1.03**

Economics of Summer Legumes-*Kharif* Rice Sequence. The gross return, net return, and BCR were remarkably influenced by preceding pulses, residue management and nitrogen levels (Table 4). The highest gross and net returns was obtained with green gram-rice sequence with application of 100% RDF (₹/ha 202077 and ₹/ha 111140 respectively) during pooled study. The BCR was 2.22.

The residue incorporated plots proved their significance in recording higher gross returns, net returns, and BCR. Though in rice economics (only *kharif*), dhaincha proved to be higher contributor for gaining more returns but in the case entire sequence green gram-rice (summer + *kharif*) proved to be better when compared to dhaincha-rice sequence with application of 100% RDF. This might be attributed to income earned through seed yield of green gram where there is no seed yield in dhaincha (Saisravan and Ramana 2014). Though the yield of rice recorded in dhaincha incorporated plots was higher, the economic returns for the entire sequence was higher in green gram-rice sequence and it was followed by cowpea – rice sequence. In these sequences the yield of green gram and cowpea were recorded along with the yield of rice whereas in dhaincha-rice sequence only yield of rice was considered. Hence, in this cropping sequence green gram incorporated followed by *kharif* rice was better (Ramalakshmi *et al*., 2015).

Rice Equivalent Yield. Significantly higher rice equivalent yield was recorded in green gram (T_1, 6949, 7542, 7246 kg/ha) followed by cowpea (T_2), dhaincha (T_3) and fallow plots (T_4, 2982, 3090, 3036 kg/ha) in descending order during 2021, 2022 and pooled study respectively. This could be attributed to the absence of seed yield in dhaincha, whereas seed yield in green gram and cowpea was recorded, resulting in an increase in rice equivalent yield.

Significantly higher rice equivalent yield (Table 5) was noticed in 100% RDF (W_1) with a yield 5997, 6284, and 6141 kg/ha in 2021, 2022 and pooled respectively and lowest was recorded in 4035, 4320 and 4177 kg/ha in No-fertilizer application (W_6). This is most likely attributable to higher grain yields in the 100% RDF (W_1) treatment when compared to the other treatments and there was lesser grain yield in the No-fertilizer application treatment (W_6) and better utilization of nutrients which were readily available through fertilizer when compared to FYM treatments (Barkha, 2020).

Table 4: Economics of summer legumes – *kharif* rice cropping sequence as influenced by different treatment combinations (Pooled 2021 & 2022).

Treatments	Total cost of cultivation (₹/ha) (Rice + summer legumes)	Grain yield of rice (kg/ha)	Straw yield of rice (kg/ha)	Seed yield of summer legumes (kg/ha)	Straw yield of summer legumes (kg/ha)	Returns from grain yield of rice (₹/ha)	Returns from straw yield of rice (₹/ha)	Returns from seed yield of summer legumes (₹/ha)	Returns from straw yield of summer legumes (₹/ha)	Total gross returns (₹/ha)	Total net returns (₹/ha)	Benefit cost ratio
T_1W_1	90937	4444	6544	1013	2474	88435	32719	75975	4948	202077	**111140**	**2.22**
T_1W_2	90337	3294	4854	1013	2474	65551	24271	75975	4948	170745	80408	1.89
T_1W_3	89736	2797	4116	1013	2474	55653	20580	75975	4948	157155	67419	1.75
T_1W_4	96683	4089	6024	1013	2474	81375	30120	75975	4948	192418	95735	1.99
T_1W_5	101892	3529	5197	1013	2474	70228	25984	75975	4948	177135	75243	1.74
T_1W_6	87999	2335	3439	1013	2474	46468	17196	75975	4948	144588	56589	1.64
T_2W_1	90171	4310	6368	904	2612	85773	31842	58760	5224	181599	91428	2.01
T_2W_2	89571	3157	4659	904	2612	62829	23295	58760	5224	150108	60537	1.68
T_2W_3	88970	2786	4106	904	2612	55442	20532	58760	5224	139958	50988	1.57
T_2W_4	95917	4024	5919	904	2612	80082	29597	58760	5224	173662	77745	1.81
T_2W_5	101126	3559	5240	904	2612	70816	26202	58760	5224	161002	59876	1.59
T_2W_6	87233	2323	3440	904	2612	46228	17201	58760	5224	127413	40180	1.46
T_3W_1	79905	4688	6910	0	5393	93285	34550	0	10786	138620	58715	1.73
T_3W_2	79305	3724	5489	0	5393	74107	27447	0	10786	112340	33035	1.42
T_3W_3	78704	3079	4537	0	5393	61275	22684	0	10786	94746	16042	1.20
T_3W_4	85651	4314	6339	0	5393	85855	31694	0	10786	128335	42684	1.50
T_3W_5	90860	3948	5822	0	5393	78563	29109	0	10786	118457	27597	1.30
T_3W_6	76967	2636	3889	0	5393	52462	19445	0	10786	82693	5726	1.07
T_4W_1	60073	3873	5709	0	0	77069	28545	0	0	105615	45542	1.76
T_4W_2	59473	2784	4105	0	0	55394	20523	0	0	75917	16444	1.28
T_4W_3	58872	2562	3773	0	0	50989	18867	0	0	69856	10984	1.19
T_4W_4	65819	3597	5303	0	0	71587	26514	0	0	98101	32282	1.49
T_4W_5	71028	3233	4764	0	0	64334	23822	0	0	88156	17128	1.24
T_4W_6	57135	2167	3179	0	0	43126	15893	0	0	59019	**1884**	**1.03**
Grain/seed	Rice = 19.9 ₹/kg	Green gram = 75 ₹/kg			Cowpea = 65 ₹/kg		Straw rate	Rice = 5 ₹/kg		Summer legumes = 2 ₹/kg		

(**Note**: There is no seed yield of dhaincha as it was incorporated in soil at 50% flowering and no returns from seed Straw yield is considered only for workout in economic calculation and yield returns was based on minimum support price)

Table 5: Rice equivalent yield as influenced by different treatments.

Treatments	2021	2022	Pooled
Main plots (summer legumes)			
T_1: Green gram	6949	7542	7246
T_2: Cowpea	6628	6925	6776
T_3: Dhaincha (GM)	3661	3802	3732
T_4: Fallow	2982	3090	3036
SEm±	72.16	74.51	73.33
CD ($P \leq 0.05$)	257	264	260
CV (%)	6.26	5.92	6.09
Sub plots (*kharif* rice)			
W_1: 100 % RDF	5997	6284	6141
W_2: 75 % RDF	4909	5194	5052
W_3: 50 % RDF	4476	4760	4618
W_4: 75 % RDF + 25 % N from FYM	5676	5960	5818
W_5: 50 % RDF + 50 % N from FYM	5237	5521	5379
W_6: No fertilizer application	4035	4320	4177
SEm±	70.01	66.22	66.83
CD ($P \leq 0.05$)	188	190	189
Interaction (T x W)			
SEm±	140.02	142.02	93.65
CD ($P \leq 0.05$)	NS	NS	NS
Significant interactions with Y	-	-	NS
CV (%)	4.54	4.30	4.41

CONCLUSIONS

Dhaincha incorporation considerably increased gross return, net return, and BCR over other summer legumes and fallow. With 100% RDF, the gross return, net return, and BCR all increased. Similarly, at 100% RDF, rice crops sown after dhaincha incorporation had a much higher net return and B:C ratio than crops sown following summer fallow with no fertilizer application.

Green gram had a higher rice equivalent with 100% RDF. When the summer legume-*kharif* rice sequence was assessed, the green gram-rice sequence had better economic returns and BCR.

FUTURE SCOPE

In legume-cereal rotations, the beneficial effects of legumes may not be immediate, 5-15 years long term experiments may be necessary to understand the nutrient levels of soil and yield which reflect in increasing returns and reducing cost of cultivation by decreasing cost of fertilizers as incorporation of legume residues provide nutrients.

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Conflict of Interest. None.

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