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Intercropping of Faba Bean and Bread Wheat at Kulumsa, South-Eastern Ethiopia

Debela Bekele

Kulumsa Agricultural Research Center, Ethiopian Institute of Agricultural Research, Asella, Ethiopia

Email address:
debelabeke@gmail.com

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Abstract: The increasing price of inputs increased cost of production of wheat in Arsi zone which leads to minimum net income. This forced few farmers to use crop rotation in the area. They do this to minimize the amount of fertilizer required and break pest cycle (disease, weed and insect) for cereal especially wheat. However most farmers do not use this rotation as required because of land shortage. They do not want to loss wheat every year. Because of this, alternative cropping system is needed to solve this problem. Therefore, the objective of this study was to assess the compatibility of faba bean/wheat inter cropping, to select suitable variety of faba bean under different spatial patterns of intercropping, and to assess the economic feasibility of intercropping faba bean with bread wheat in the area. A field experiment was conducted in 2019 main cropping season at Kulumsa Agricultural Research Center, Southeastern Ethiopia to select suitable varieties of faba bean in intercropping and to assess the economic profitability of intercropping faba bean with bread wheat in the area. The treatments were three faba bean varieties (Ashebeka, Hachalu and Tumsa) intercropped with bread wheat (variety Hulluka) in three different planting ratios (1W:1FB, 1W:2FB, 2W:1FB) and sole planting of the three faba bean varieties and wheat. Randomized complete block design with three replications was used. Planting ratio of 1W:2FB, sole cropped faba bean and planting ratio of 1W:1FB with variety Hachalu gave highest grain yield (3426.3 $kgha^{-1}$), above ground biomass (11257.3 $kgha^{-1}$) and harvest index of faba bean (36%), respectively. Planting ratio of 2W:1FB gave the highest wheat yield (1896.6 $kgha^{-1}$). The highest (8057.13 $kgha^{-1}$) above ground biomass yield of wheat was recorded at 2W:1FB. Highest gross monetary value of 100,591ETB/ha was obtained with planting ratio of 1W:2FB with variety Tumsa. Sole wheat gave the lowest gross monetary value of 59,752 ETB/ha. This could be due to high price and better competition ability of faba bean with good rainfall distribution in the growing season.

Keywords: Grain Yield, Gross Monetary Value, Land Equivalent Ratio, Planting Ratios, System Productivity

1. Introduction

Faba bean (*Viciafaba* L.) is an important legume crop that contains high protein [10]. In addition to its great nutrition content, it has the ability to fix nitrogen, and provide a significant level of nitrogen from the soil air using a symbiotic relationship with Rhizobium bacteria [30]. Faba bean takes the largest share of the area under pulses production in Ethiopia [7]. The annual area coverage of the crop in Ethiopia is 492,271.60 ha with the total production and productivity of 1.04 million tons and 2.1 tons/ha, respectively [7]. It is mostly grown as a sole crop but in some countries intercropping with cereals is a common practice [9].

Wheat (*Triticum spp.*) is one of the most important cereal crops in terms of area and production in the world. Global wheat production in 2017 was 744.5 million tons [12]. It is one of the major staple crops in Ethiopia in terms of both production and consumption [11]. Increase in input costs, reduction in farm size and soil quality, and increasing problem with pests, diseases and weeds have threatened the ecological and economic sustainability of wheat production in Ethiopian highlands [13]. Despite this, a resource use study in northern Ethiopia has shown that farmers have changed their cropping system from growing a pure crop of improved varieties of semi-dwarf wheat to mixed intercropping with a small proportion of faba bean and field pea [14].

Intercropping is the agricultural practice of cultivating two or more crops in the same land at the same time [28]. It is relatively common in tropical and temperate areas because of the effective utilization of water [28], nutrients [27, 31] and solar energy [29].

Sullivan P [23] reported that staggered maturity dates as well as development periods in intercrops take advantage of variations in peak resource demands for nutrients, water and light. Intercropping legumes with cereals contributes some nitrogen to the cereal component through residual nitrogen [3]. A three years study of sorghum/groundnut and sorghum/soybean intercropping in Asosa (Ethiopia) showed that sorghum/groundnut intercrop had the highest sorghum yield at all growing seasons [8]. The gross income and land equivalent ratio indicate greater economic benefit with intercropping of groundnut in 1:1 proportion and simultaneous planting than sole planting [8].

Spatial arrangement of faba bean with barley around DebreBirhan revealed that significantly greater land equivalent ratio (LER) was obtained in intercropping than both crops when planted as sole. The 2B:1FB (one row of faba bean intercropped in two rows of barley) was more productive than other planting patterns (1B:1FB and 1B:2FB). All spatial arrangements had the LER values of more than one (LER> 1) [15].

2. Materials and Methods

2.1. Description of the Study Area

Field experiment was conducted in 2019 main cropping season at Kulumsa Agricultural Research Center (KARC). It is located in Gora silingokebele, Tiyo district of Arsi Zone, Oromia Regional State, Southeastern Ethiopia. The experimental site is located at 8°01'N latitude and 39°09'E longitude, at altitude of 2200m above sea level. It receives average annual rainfall of 809.2mm and has a uni- modal pattern rainfall. The peak season of the rainfall is from July to August. The average annual minimum and maximum temperatures are 9.9 and 23.1°C, respectively [1]. The soil type is luvisol/eutricnitosols with a good drainage system. It contains 5.5% organic matter, 0.25% nitrogen and its pH is 5.5-6.0 [18].

2.2. Treatments and Experimental Design

The treatments consisted of three faba bean varieties (Ashebeka, Hachalu and Tumsa) intercropped with bread wheat (variety Hulluka) and three different planting ratios (1W:1FB, one row of wheat and one row of faba bean; 1W:2FB, one row of wheat and two rows of faba bean; 2W:1FB, two rows of wheat and one row of faba bean) and sole planting of the three faba bean varieties and wheat. Randomized complete block design (RCBD) with three replications was used for the experiment.

2.3. Experimental Procedures

The crops were planted in row in which the inter row spacing for faba bean and wheat was 40 cm and 20 cm respectively where wheat was planted between faba bean rows. In 1:1 ratio, wheat was planted between every two faba bean rows, so it was 20 cm far from faba bean. In 1:2 ratio, wheat was planted between alternate faba bean rows and there was 40 cm between faba bean rows and 20 cm between faba bean and wheat rows. In 2:1 ratio, faba bean was planted after two wheat rows and there was 20 cm between wheat rows and 20 cm between faba bean and wheat rows. Blended NPS fertilizer (19% Nitrogen, 38% P_2O_5 and 7% Sulfur) at recommended rate of 120 kgha^{-1} for faba bean was applied to all treatments during planting except sole wheat which received both blended NPS during planting at the rate of 180 kgha^{-1} and urea (46% nitrogen) half at planting and half at tillering at the rate of 100 kgha^{-1} according to recommendation for wheat.

The experimental plot size was 2.5 m × 4 m (10 m^2) for all inter-cropped treatments and 2.4 m × 4.17 m (10 m^2) for both sole cropped crops. Plots receiving different treatments had different number of rows with equal row length (4 m), except sole cropping which was 4.17 m. The gross plot size for all treatments was 10 m^2 with net plot area of 3.8 m^2 for all treatments.

2.4. Data Collection

2.4.1. Three Faba Bean Component

(i). Biological Yield (kg/ha) of Faba Bean Component

Above ground dry biomass was harvested from the net plot area and weighted after sun drying to a constant weight before threshing and converted to kg per hectare.

(ii). Grain Yield (kg/ha) of Faba Bean Component

This was obtained from each net plot to estimate grain yield kg/ha. It was weighed and adjusted to 10% moisture content.

$$\text{Grain yield (kg/ha) at 10\% moisture base} = \text{yield obtained (kgha}^{-1}) \times \frac{(100-\%mc)}{(100-\%MC)}$$

where, mc=Measured grainmoisture content (%) and MC=the standard moisture content (10%) [17].

Grain moisture content was determined by using seed moisture tester instrument (Model PL- 10-860 Olszyn, Owocowa 17).

(iii). Harvest Index (HI) of Faba Bean Component

It was calculated on a plot basis, as the ratio ofdried grain weight adjusted to 10% moisture content to the dried total above ground biomass weight and multiplied by 100. Seed moisture content was determined using seed moisture tester instrument. Then, the grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield using the following formula [5]. Adjusted yield=C.F × Plot yield. Conversion factor

$$(\text{C.F}) = \frac{100-Y}{100-X}$$

where Y is actual moisture content and X is thestandard moisture content to which the yield is to be adjusted (for legumes the standard moisture content is 10).

2.4.2. Five Wheat Component

(i). Biological Yield (kg/ha) of Wheat Component

Above ground biomass per net plot was determined before threshing and converted to hectare.

(ii). Grain Yield (kg ha^{-1}) of Wheat Component

This was obtained from each net plot to estimate grain yield in kg ha^{-1}. It was weighed and adjusted to 12.5% moisture content.

$$\text{Grain Yield (kg ha}^{-1}\text{) at 12.5\% moisture base} = \text{yield obtained (kg ha}^{-1}\text{) x}\frac{(100-\%mc)}{(100-\%MC)}$$

where, mc=Measured grain moisture content (%) and MC=the standard moisture content (12.5%) [17].

(iii). Harvest Index (HI%) of Wheat Component

It was calculated on a plot basis, as the ratio of dried grain weight adjusted to 12.5% moisture content to the dried total above ground biomass weight and multiplied by 100. Seed moisture content was determined using seed moisture tester instrument. Then, the grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield using the following formula [5]:

$$\text{Conversion factor (C.F)} = \frac{100-Y}{100-X}$$

where Y is actual moisture content and X is the standard moisture content to which the yield is to be adjusted (for cereals the standard moisture content is (12.5%).

$$\text{Adjusted yield} = \text{C.F} \times \text{Plot yield}$$

(iv). Land Equivalent Ratio of Wheat Component

To evaluate productivity and profitability of land, land equivalent ratio (LER) of the crops was estimated as:

$$LER = L_a + L_b = Y_a/S_a + Y_b/S_b$$

where L_a and L_b= the LERs for individual crops in the mixture and Y_a and Y_b = the individual crop yields in an intercropping situations, S_a and S_b= the yield of species a and b as sole crops [26].

(v). Gross Monetary Value (GMV) of Wheat Component

This was calculated to estimate the economic advantage of inter cropping as compared to sole cropping. It was calculated from the yield of faba bean and wheat by multiplying yields of the component crops by their respective market price. During harvesting period, the price of faba bean was 25 Ethiopian birr per kilogram and the price of wheat was 14 Ethiopian birr per kilogram at Asella town.

2.5. Data Analysis

The collected data was subjected to analysis of variance (ANOVA) using SAS software version 9.0 [22]. Significant difference among treatment means were assessed using the least significant difference (LSD) at 5% level of probability [16].

3. Results and Discussion

3.1. Faba Bean Component

3.1.1. Faba Bean Component 1: Grain Yield

The results of analysis showed that there was no significant effect of varieties and interaction effects on grain yield of faba bean, but planting ratio showed highly ($P<0.05$) significant effect on faba bean yield. Similarly, Merkine M. and Teshome M. [20] reported that faba bean did not show significant difference for grain yield among varieties. On the contrary, Ashenafi M. and Mekuria W. [4] reported that there was a variation between varieties for most yield and yield components including grain yield. Planting ratio of 1W:2FB gave the highest grain yield (3426.0 kg ha^{-1}) of faba bean followed by sole planting of faba bean (3393.8 kg ha^{-1}). The lowest grain yield (2487.8 kg ha^{-1}) was obtained when faba bean was intercropped with 2W:1FB planting ratio (Table 1). This could be due to efficient utilization of growth resources (nutrients, moisture and space) under higher plating ratio of inter cropped faba bean. This might suggest that with increasing rows of faba bean under intercropping condition with wheat, better yield was obtained whenever the growing conditions are satisfied. Likewise, Klimek-Kopyra A. *et al.* [19] reported that faba bean yield was significantly affected by seeding rate of naked oat and the highest yield of faba bean was recorded when faba bean was intercropped with least seed rate of naked oat. Increasing wheat rows in faba bean decreased its grain yield. Getachew G. *et al.* [14] stated that growing of faba bean as a companion crop with wheat reduced the productivity of wheat and vice-versa.

Table 1. *Main effects of varieties and planting ratio on grain yield (GY (kg ha^{-1})) and above ground biomass (AGBM (kg ha^{-1})) of faba bean.*

Variety	GY (kg ha^{-1})	AGBM (kg ha^{-1})
Hachalu	3190.1	9342.0
Tumsa	3018.9	9364.1
Ashebeka	2969.5	9429.9
LSD (0.05)	NS	NS
Planting ratio		
Sole FB	3393.8a	11257.3a
1W:1FB	2930.3b	8596.6b
1W:2FB	3426.0a	10029.2a
2W:1FB	2487.8c	7631.6b
LSD (0.05)	419.85	1289.0
CV (%)	14.04	14.05

LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation; NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of significance.

3.1.2. Faba Bean Component 2: Above Ground Biomass

The analysis of variance indicated that there was no significant effect of varieties on above ground biomass (AGBM) of faba bean. In line with this, Tekle E. *et al.* [24] reported that there was no significant variation between faba bean varieties for biological yield. On the contrary, Ashenafi M. and Mekuria W. [2] reported that dry biomass varied among faba bean varieties. Above ground biomass was highly (P<0.05) significant for planting ratios. Unlike grain yield, sole planted faba bean gave significantly (P<0.05) highest AGBM (11257.3 kg ha^{-1}) followed by 1W:2FB ratio (10029.2 kg ha^{-1}). The lowest AGBM (7631.6kg ha^{-1}) was obtained when faba bean was intercropped with 2W:1FB planting ratio (Table 1). Generally, extended rainfall distribution increased the biomass obtained asfaba bean has indeterminate growth habit either in sole or in intercropped faba bean with wheat.

3.1.3. Faba Bean Component 3: Harvest Index

Harvest index (HI) was highly significantly (P<0.05) affected by main effects of varieties and planting ratios as well as interaction effects of varieties and planting ratios. The highest HI (36.0%) was recorded by variety Hachalu, and at 1W:1FB, planting ratio followed by Ashebeka at 1W:1FB planting ratio (34.6%). Lowest HI (26.8%) was recorded at Ashebeka when planted solely (Table 2).

Lowest HI (26.8%) was recorded at Ashebeka when planted solely (Table 2). This could be related to inherent characteristics of the varieties and rainfall distribution. Ashenafi M. and Mekuria W. [4] reported that harvest index of faba bean had been significantly affected by faba bean varieties. Better HI means better yield efficiency of the plant under the given management practices.

3.2. Wheat Component

3.2.1. Wheat Component 1: Grain Yield

The analysis result revealed that planting ratio showed highly (P<0.05) significant difference in grain yield, but main effects of varieties and their interaction effects did not. Planting ratio of 2W:1FB gave the highest wheat grain yield (1896.6 kg ha^{-1}). The lowest wheat grain yield (711.3 kg ha^{-1}) was recorded in 1W:2FB planting ratio. The mixture with a higher sharing of wheat (2W:1FB) achieved a highly significantly higher yield regardless ofthe type of variety (Table 3). This attributed to the highest population density of wheat at 2W:1FB planting ratio which allowed better resource use efficiency. The same bread wheat variety Hulluka was intercropped with different varieties of faba bean so that the same yield of 1343.5 kg ha^{-1} was obtained (Table 3). This indicates that faba bean varieties had no varietal effect on intercropped wheat grain yield. Practically, sole wheat outsmarted intercropped wheat as it has high solar absorption efficiency and low intercrop competition. When number of rows of intercropped wheat increased, grain yield of wheat was also increased. Klimek-Kopyra A. [19] reported that the highest grain yield of faba bean was obtained from highest seed rate of faba bean in faba bean naked oat intercropping. Klimek-Kopyra A. [19] further reported that the highest grain yield of faba bean 1.57 ton per hectare was recorded at 75:25 faba bean/naked oat cropping ratio. Similarly, Getachew G. *et al.* [14] gained significant difference of wheat grain yield in wheat and faba bean mixed intercropping. He described that the highest grain yield of wheat (3601 $kgha^{-1}$) was observed at the lowest seeding rate sharing of faba bean (100:12.5 wheat/faba bean).

3.2.2. Wheat Component 2: Above Ground Biomass

The results of analysis showed that above ground biomass (AGBM) yield was not significantly affected by main effects of varieties and interaction effect but was highly (P<0.05) significantly and significantly affected by main effects of inter-cropping ratio and cropping system respectively. The highest (8057.1 $kgha^{-1}$) and the lowest (3154.9 $kgha^{-1}$) AGBM yield of wheat was recorded in 2W:1FB and 1W:2FB plating ratios, respectively (Table 3). The higher seeding rate of wheat resulted in greater above ground biomass yield than the lower seeding rate of wheat. In addition to this, wheat was seriously affected by shading effect of faba bean which decreased wheat performance. The AGBM yield of sole planting was significantly higher than the intercropped (Table 3). Teshome G. *et al*. [25] reported that there was significant difference of AGBM yield of soybean in soybean maize intercropping and the higher seeding rate treatment gave the significantly greater AGBM yield of soybean. Likewise, Biruk T. [6] reported that biological yield ofbean increased as plant population increased under sorghum /bean intercropping.

Table 2. *Interaction effect of varieties and planting ratio on harvest index (HI) of faba bean.*

Planting ratio	FB varieties		
	Hachalu	Tumsa	Ashebeka
Sole FB	33.3ab^{cd}	30.5^{d}	26.8^{e}
1W:1FB	36.0^{a}	31.4^{bcd}	34.6^{a}
1W:2FB	34.1^{ab}	33.9^{ab}	34.4^{a}
2W:1FB	33.2abcd	33.4abc	30.9cd
LSD (0.05)	2.78		
CV (%)	5.02		

LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation; Means followed by the same letters are not significantly different at 5% level of Significance.

Table 3. *Main effects of varieties and planting ratio on grain yield (GY), above ground biomass (AGBM) and harvest index (HI) of wheat.*

Variety	GY (kg ha^{-1})	AGBM (kg ha^{-1})	HI (%)
Hachalu	1343.5	4852.2	30.2a
Tumsa	1343.5	6115.8	22.2b
Ashebeka	1343.5	4805.0	28.9a
LSD (0.05)	NS	NS	6.65
Planting ratio			
1W:1FB	1422.6b	4560.9b	32.7a
1W:2FB	711.3c	3154.9b	23.8b
2W:1FB	1896.6a	8057.1a	24.8b
LSD (0.05)	120.6	1535.7	6.65
CV (%)	8.98	29.22	24.53
Sole cropped versus intercropped			
Cropping system			
Sole cropped	4268.0a	10088a	42.1a
Intercropped	1343.5b	5258b	27.1b
LSD (0.05)	1693.4	3747.9	6.84
CV (%)	17.18	13.90	5.62

LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of Variation; NS= non-significant. Means in column followed by the same letters are not significantly different at 5% level of Significance.

3.2.3. Wheat Component 3: Harvest Index

Harvest index (HI) of wheat was significantly (P<0.05) affected by variety, planting ratio and cropping system, but not by their interaction effects. The highest HI (32.7%) was obtained from 1W:1FB and the lowest wheat harvest index (23.8%) was obtained from 1W:2FB (Table 3). This could be related to late maturing nature of the variety whereby it consumes more time to accumulate more dry matter. The highest HI recorded in 1W:1FB planting ratio might be due to the high grain yield to biomass as a result of high partitioning of dry matter to the grain.

Table 4. *Effect of varieties and planting ratio on partial land equivalent ratio of faba bean (PLERFB), partial land equivalent ratio of wheat (PLER W) and total land equivalent ratio (TLER).*

Variety	PLERFB	PLER W	TLER
Hachalu	0.85	0.31	1.09
Tumsa	0.99	0.31	1.22
Ashebeka	0.95	0.31	1.18
LSD (0.05)	NS	NS	NS
Planting ratio			
Sole FB	1.00ab	-	1.00b
1W:1FB	0.88bc	0.33b	1.21a
1W:2FB	1.11a	0.16c	1.27a
2W:1FB	0.73c	0.44a	1.18a
LSD (0.05)	0.19	0.0001	0.19
CV (%)	21.16	0.02	16.89
Sole cropped versus intercropped			
Cropping system			
Sole cropped Intercropped			1.00a 0.31b
LSD (0.05)			0.02
CV (%)			1.22

LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation; NS= non- significant. Means in column followed by the same letters are not significantly different at 5% level of Significance.

3.3. System Productivity

3.3.1. Land Equivalent Ratio (LER)

Differences among faba bean varieties were not significant for all the three (partial LER of faba bean, partial LER of wheat and total LER) land equivalent ratios. Faba bean varieties did not show any influence on partial land equivalent ratio of wheat. Differences among planting ratios were highly (P<0.05) significant for both partial LER of faba bean and partial LER of wheat. The highest partial LER of faba bean (1.11) and partial LER wheat (0.44) was recorded at 1W:2FB and 2W:1FB, respectively (Table 4). As the ratio of intercropped wheat increased, PLERW and PLERFB increased and decreased, respectively. Total land equivalent ratio (TLER) was significantly affected by planting ratios. Statistically highest TLER was registered in 1W:1FB (1.21) and 1W:2FB (1.27) for efficient utilization of growthresources. Highest TLER (1.27) was obtained from 1W:2FB intercropping ratio and lowest TLER (1.00) were recorded in sole faba bean (Table 4). 21% and 27% additional yield advantage were respectively obtained at 1W:1FB and 1W:2FB planting ratios than planting sole crop, respectively. So it seems optimistic in resource poor and small land holding farmer. As the ratio of faba bean decreased, total land equivalent ratio decreased. In line with this, Nargis A. *et al.* [21] reported that total land equivalent ratio decreased from 1.17 to 1.12 when planting ratio was changed from 1W:1L to 1W:3L in wheat /lentil intercropping.

3.3.2. Gross Monetary Value

Gross monetary value (GMV) was significantly (P<0.05) affected by interaction effects of faba bean varieties and planting ratio. The highest gross monetary value (100591 ETB/ha) was obtained from planting ratio of 1W:2FB with variety Tumsa. Variety Hachalu when planted at 1W:2FB yielded 98,417 ETB/ha. GMV of 96,854 ETB/ha was gained when Ahebeka was planted at 1W:2FB planting ratio. Sole wheat gave the lowest gross monetary value which was 59,752 ETB/ha (Table 5). Thus, 18.5% and 40% additional income can be gained than planting solefaba bean and wheat, respectively. This could be due to high price and better competition ability of faba bean with good rainfall distribution in the growing season. Nevertheless, irrespective of faba bean varieties, 1W:2FB planting ratio could be tentatively recommended in the area. Also, further economic analysis might be necessary in calculating the actual yield benefit of intercropping from this trial.

Table 5. *Effect of varieties and planting ratio on gross monetary value (ETB/ha).*

Planting ratio	Hachalu	Tumsa	Ashebeka
Sole FB	93647ab	82694ab	78197b
1W:1FB	98417a	86793ab	94317ab
1W:2FB	89381ab	100591a	96854a
2W:1FB	93993ab	88241ab	84013ab
Sole wheat LSD (0.05)	59752c	18239	
CV (%)		12.27	

LSD (0.05) = Least significant difference at 5% level; CV = Coefficient of variation; NS= non-significant. Means in column followed by thesame letters are not significantly different at 5% level of Significance.

4. Conclusion

Grain yield and aboveground biomass of faba bean were highly significant for planting ratios. Harvest index was highly significantly affected by main effects of varieties, planting ratios as well as interaction effects. Grain yield and aboveground biomass yield of faba bean were highly significant for planting ratio, but not for main effects of varieties. The highest total land equivalent ratio (1.27) was obtained from 1W:2FB planting ratio. Gross monetary value was significantly affected by interaction effects of faba bean varieties and planting ratios. The highest gross monetary value, which was 100,591 ETB/ha was obtained with planting ratio of 1W:2FB with variety Ashebeka. Sole wheat gave the lowest GMV of 59, 752 ETB/ha. Irrespective of faba bean varieties, 1W:2FB planting ratio could be recommended in the area.

Conflict of Interests

The authors declare that they have no competing interests.

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