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Evaluation of yield potential of maize-soybean intercropping in drought-prone areas of Bangladesh

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ABSTRACT

North-western parts of Bangladesh especially Barind Tract, is affected by water scarcity problems in agriculture and secured livelihood. Improved agricultural techniques are needed to increase agricultural production in this region. An experiment was conducted at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, during the period from November, 2015 to April 2016 to assess the yield potentials and profitability of maize + soybean intercrop. The experiment was carried out with three cropping systems (sole maize, SM; sole soybean, SB and maize + soybean intercrop, MB) and two row orientations (north-South, NS and east west, EW). Hybrid maize variety ACI-3110 and Binasoybean-3 were used as planting materials. Most of the growth parameters, yield contributing characters as well as yields in both crops were the highest when grown as sole cropping (maize or soybean alone). In Maize, maximum grain yield was found in sole maize (5.66 t ha^{-1}) with north–south orientation and minimum yield was found in maize + soybean intercrop with east-west orientation (4.99 t ha^{-1}). On the other hand the maximum seed yield (1.39 t ha^{-1}) was found in sole soybean and the minimum seed yield (0.81 t ha^{-1}) was found in maize + soybean intercrop. Although both crop shows better growth and yield when cultivated alone but intercrop gives higher economic return compared to sole soybean or sole maize. So it can be concluded that maize + soybean intercrop might be the best practice for north-western parts of Bangladesh rather than sole soybean or sole maize.

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INTRODUCTION

High population pressure and scarcity of arable land have compelled planting of two or more crops at the same pieces of land at the same time. Intercropping is considered as an advanced agricultural technique in past decades which increases crop productivity per unit of land via better utilization of resources, minimizes the risks, reduces weed competition and stabilizes the yield (Morgado and Willey 2008). Several factors are correlated with the success of intercropping such as maturity periods, selection of compatible crops, planting density, time of planting as well as socio economic status of farmers and the region.

The intercropping of maize and legumes is widespread among smallholder farmers due to the ability of the legume to cope with soil erosion and with declining levels of soil fertility (Addo-Quaye et al. 2011). The principal reasons for smallholder farmers to intercrop are flexibility, profit maximization, risk minimization against total crop failure, soil conservation and improvement of soil fertility, weed control and balanced nutrition. Other advantages of intercropping include potential for increased profitability and low fixed costs for land as a result of a second crop in the same field (Javanmard et al. 2009). Furthermore, intercrop can give greater yield stability, more efficient use of nutrients, better weed control and above all higher economic return (Clark and Francis 1985). Thus cereal-legume intercropping would be the beneficial practice for agricultural production in Bangladesh.

Last few decades Bangladesh is facing water related difficulties like river bed siltation, low water flow and a big dam made by neighboring country India. On the other hand Barind Tract has a different geographic character than other parts of Bangladesh. Its soil formation is also different. This northern part is 37 meter above the sea level. Peoples in this area used to cultivate rice once a year, but now produce various crops round the year including maize. Recently, farmers are switching to maize cultivation in *rabi* season because of high water demand of *boro* rice and higher demand of maize by feed and flour mills.

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Therefore, improved agricultural techniques are needed to promote this crop (maize).

Intercropping is regarded as an important agricultural practice to improve crop production and environmental quality in the regions with intensive agricultural production. Compared to conventional monoculture of maize, maize + soybean had significant advantage in yield, economy, land utilization ratio as well as better residual effect on the subsequent other crop. Intercropping system reduces use of N fertilizer per unit land area and increased relative biomass of intercropped maize, due to promoted photosynthetic efficiency of border rows and N utilization during symbiotic period. Intercropping advantage began to emerge at teaseling stage after N topdressing for maize. The most important advantage of intercropping is to increase biomass of intercropped maize and soybean, which further led to the increase of total N accumulation by crops as well as economic benefit.

Intercrop can efficiently suppress weeds which otherwise would become major production constraint. Moreover, such a system also helps in efficient utilization of natural resources (space, moisture and light) to gain maximum productivity. Further, to avoid adverse effect on main crop by addition of intercrop, suitable adjustment in plant population and crop geometry has to be worked out. Hence in this research, an effort has been made to evaluate the profitability of maize+ soybean intercropping system in drought affected north-western areas of Bangladesh.

MATERIALS AND METHODS

The experiment was carried out at the Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi, Rajshahi, Rajshahi-6205, Bangladesh during the *rabi* season from November 2015 to April 2016. Geographically the experimental field was located at 24˚17′-24˚31′N latitude and 88˚28′ to 88˚43′E longitude with a height of 20m above the sea level, belonging to the Agro Ecological Zone-11.

Treatments included three cropping systems (sole maize, SM; sole soybean, SB and maize + soybean intercrop, MB), and two row orientations (NS: north-south, EW: east-west). A randomized complete block design was used with three replications. Row spacing was 0.75 m for sole maize and 0.30 m for sole soybeans. In intercropping, one row of bean was inserted into the maize (alternative intercropping) (Figure 1). Plot size was 4m × 4m.

The variety of maize and soybean used in the experiment was ACI-3110 and Binasoybean-3, respectively. In case of maize,urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and boric acid were used as source of nitrogen, phosphorus, potassium, sulphur and boron @ 540, 240, 240, 240, 15 and 5 kg ha^{-1} respectively. Half urea along, with all other fertilizers was applied at the time of final land preparation. The remaining urea was divided in two equal splits and applied at 30 and 60 days after sowing (DAS). In case of soybean, urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum was applied @ 40, 120, 80 and 40 kg ha^{-1}, respectively. Total amount of urea, TSP, MoP and gypsum were applied at basal doses during final land preparation.

At maturity, the experimental crops were harvested plot-wise at 15 April, 2016. Prior to harvesting $1m^2$ plant samples were selected randomly and uprooted from each plant for data recording. The harvested crops from each plot were bundled separately, tagged and brought to clean threshing floor. The same procedure was followed for sample plant (10 plants from each plot).

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) technique and the mean differences were adjudged by Duncan's Multiple Range Test (Gomez and Gomez 1984) with the help of computer based statistical package program, MSTAT-C. The mean differences among the treatments were compared by least significant difference test at 5% and 1% level of significance.

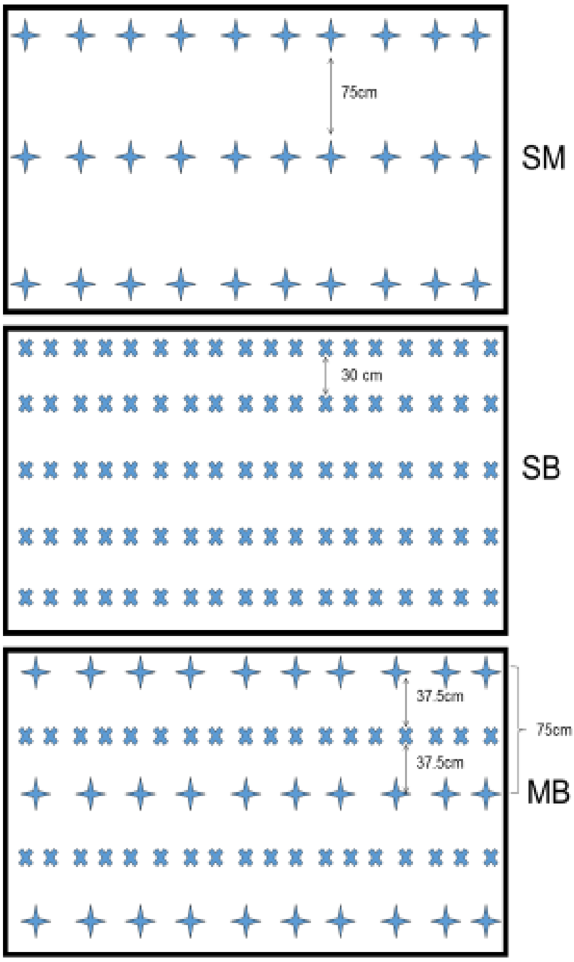

Figure 1: Diagram showing row spacing of sole maize (SM), sole soybean (SB) and intercrop (Maize + soybean, MB)

RESULTS AND DISCUSSION

Evaluation of maize as sole and intercropping

The plant height was significantly influenced by intercropping but was not significant for row orientation (Table1& 2).The tallest plant was found in sole maize (221.70cm) cropping system. Considering row orientations, the tallest plant (220.53 cm) was found in east-west orientation. Plant height of maize was not influenced by the interaction between cropping system and row orientation (Table 3). Numerically, the tallest plant was found in sole maize in north- south orientation (222.23 cm). Cob lengths of maize were not significantly affected by intercropping and row orientation (Table1&2).The highest cob length was found (20.22cm) in sole maize among the cropping systems. Considering row orientations, cob length of maize was the highest (20.11cm) in north-south orientation. Due to interaction between cropping system and row orientation, cob length of maize was not influenced significantly but numerically, the highest value (21.00cm) was found in sole maize in north-south orientation (Table 3).

Grain cob^{-1} was significantly influenced by intercropping system (Table 1). The highest grain cob^{-1} was found in sole maize (500.48) cropping system. Grain per cob varied significantly with different row orientation where the maximum grain per cob (473.03) was found in north-south orientation (Table 2). The number of grain per cob was also influenced remarkably by interaction between intercropping and row orientation. The highest number of grain (520.20) was found in combination of sole maize and north-south orientation (Table 3).

Row cob^{-1} was not significantly affected by intercropping as well as row orientation (Table 1&2). Considering cropping systems, the highest row cob^{-1} was found (11.95) in sole maize on the other hands the value was the highest (12.11) in north-south row orientation. Combination of sole maize and north-south orientation system achieved the condition for the highest (12.22) row cob^{-1}(Table 3).

Significant differences in 1000 grain weight were noted within cropping patterns, row orientation as well as their interaction (Table 1, 2 and 3). Within the cropping patterns, the highest 1000 grain weight (342.83g) was found in sole maize. In case of row orientation trials, the highest 1000-grain weight (344.67g) was found in north-south (N-S) orientation. Interaction of sole maize in north-south orientation resulted the highest 1000-grain (348.33g).

Grain yield was not significantly affected by the cropping system. Apparently, the highest grain yield (5.52 t ha^{-1}) was found in sole maize cropping system (Table 1). However, grain yield significantly affected by row orientation where the highest yield (5.66) was found in north-south orientation (Table 2). Interaction of sole maize with north-south orientation (Table 3) produced significantly the highest grain yield (7.25 t ha^{-1}).

Stover yield was not significantly affected by the cropping system used in this study (Table1). Numerically, the maximum stover yield (6.700 t ha^{-1}) was found in sole maize cropping system. Stover yield varied significantly (Table-2) due to row orientation and the highest value (7.22 t ha^{-1}) was obtained in north-south (N-S) orientation. Due to interaction the stover yield was not influenced significantly (Table 3) and the highest value (7.24 t ha^{-1}) was found in sole maize with north-south orientation.

Biological yield of maize was not significantly affected by the cropping system, numerically the maximum biological yield (12.2 t ha^{-1}) was found in sole maize (Table 1). A remarkable effect in biological yield was noted for row orientation (Table 2) where the highest value (12.88 t ha^{-1}) was noted in north-south orientation. Biological yield of maize was not influenced by interaction within the treatments.

Harvest index was not significantly affected by the cropping systems but, apparently, the highest value (45.30%) was found in sole maize (Table-1). No significant variation in harvest index was also observed for row orientation (Table 2). The highest harvest index was found (45.19 %) in east-west orientation. There was not significant effect in harvest index was observed for interaction between cropping system and row orientation (Table 3). Numerically the maximum value (45.55%) was obtained from sole maize in north-south orientation.

Evaluation of soybean as sole and intercropping

Plant height varied significantly due to cropping system at1% level of probability and the tallest plant (79.00 cm) was found in soybean intercropping system (Table 4). Plant height was not significantly influenced by the row orientation (Table 5) where numerically the highest value (70.50 cm) was recorded in north-south orientation. Due to interaction between cropping system and row orientation, plant height of soybean influenced significantly and the highest value (83.33cm) was recorded in maize - soybean intercropping with north-south orientation (Table 6).

Number of branches in soybean plants significantly influenced by cropping system, where the highest value (4.50) was found in sole soybean (Table 4). Number of branches plant-^{1} was not influenced by the row orientation. In that case, numerically the highest value (4.50) was obtained from north-south orientation (Table 5). Branch per plant was not significantly influenced by the interaction effect of cropping system and row orientation (Table 6).

Table 1. Effect of intercrop on yield and yield component of maize

Treatment	Plant height (cm)	Cob length (cm)	Grain cob^{-1}	1000grain weight (g)	row cob^{-1}	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Sole Maize	221.70	20.223	500.488	342.833	11.945	5.518	6.700	12.218	45.297
Maize intercrop	218.95	19.78	435.957	339.333	11.888	5.135	6.597	11.735	43.872
Level of Significance	*	NS	**	*	NS	NS	NS	NS	NS
CV (%)	0.64	6.72	0.73	0.66	5.28	6.69	6.69	8.45	4.94

Mean values in a column with similar letter (s) do not differ significantly (as per DMRT); ** = Significant at 1% level of probability; * = Significant at 5% level of probability; NS = Non significant; CV = Coefficient of variation

Table 2. Effect of row orientation on yield and yield component of maize

Treatment	Row orientation	Plant height (cm)	Cob length (cm)	Grain cob^{-1}	1000grain weight (g)	row cob^{-1}	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Sole Maize	North south	220.117	20.112	473.033	344.667	12.110	5.66	7.220	12.887	43.975
Maize intercrop	East west	220.533	19.892	463.412	337.500	11.733	4.99	6.077	11.067	45.193
Level of Significance		NS	NS	**	**	NS	*	*	*	NS
CV (%)		0.64	6.72	0.73	0.66	5.28	6.69	11.07	8.45	4.94

Other details are same as Table 1.

Table 3. Interaction effect of intercrop and row orientation on yield and yield component of maize

Treatment	Row orientation	Plant height (cm)	Cob length (cm)	Grain cob^{-1}	1000grain weight (g)	row cob^{-1}	Seed yield	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Sole Maize	North south	222.233	21.00	520.200a	348.333a	12.223	7.25	7.247	13.283	45.553
Maize intercrop	North south	221.167	19.447	480.777b	337.333b	11.667	6.15	6.153	11.153	45.040
Sole Maize	East west	218.000	19.223	425.867d	341.000b	11.997	7.19	7.193	12.490	42.397
Maize intercrop	East west	219.900	20.337	446.047c	337.667b	11.780	6.00	6.000	10.980	45.347
Level of Significance		NS	NS	**	*	NS	*	NS	NS	NS
CV (%)		0.64	6.72	0.73	0.66	5.28	13.84	11.07	8.45	4.94

Other details are same as Table 1.

Number of pods $plant^{-1}$ differed significantly due to cropping systems at 1% level of probability where the highest number of pods plant-1 (41.00) was found in sole soybean cultivation system (Table 4). Number of pods plant-^{1} was also significantly influenced by the row orientation and the maximum value (37.83) was obtained from north-south orientation (Table5). Number of pods plant-^{1} was significantly influenced due to interaction effect of cropping system and row orientation and in that case the highest value (41.67) was recorded in sole soybean with north-south orientation (Table 6).

Number of seeds pod^{-1} was not influenced by intercropping system. Apparently, the highest number (2.67) of seeds pod-^{1} was found in sole soybean cropping system (Table 4). Number of seeds pod-^{1} was not influenced by row orientation (Table 5). Interaction effect of cropping system and row orientation was not significant for the number of seeds pod^{-1}

Pod length of soybean was not influenced by the cropping pattern, row orientation as well as their interaction (Table 4, 5 and 6).

1000 seed weight was significantly influenced by cropping system where the highest value (81.80) was found in sole soybean cropping system (Table 4). Seed weight was also significantly influenced by the row orientation where the maximum value (77.94g) was found in north-south orientation (Table 5). Interaction effect of cropping system and row orientation was also significant and the maximum value (82.15g) was obtained from sole soybean with north-south orientation (Table 6).

The seed yield varied significantly between sole soybean and maize - soybean intercropping system (Table 4). The highest seed yield (1.39 t/ha) was found in sole soybean cropping system. Due to row orientation trials seed yield of soybean influenced significantly and the highest value (1.31) was recorded in north-south orientation (Table-5). Considering interaction effect, seed yield of soybean was significantly the highest (1.37) in sole soybean with east-west orientation (Table 6).

Stover yield varied significantly within the cropping system and the highest value (1.79) was found in sole soybean cropping system (Table 4). Stover yield of soybean was not influenced by row orientation (Table5) but the stover yield of soybean significantly influenced by the interaction effect of cropping system and row orientation where the highest value (1.72) was found in sole soybean in north-south orientation (Table-6).

Biological yield of soybean was significantly influenced by cropping system and the highest value (3.18) was found in sole soybean cropping system (Table 4).. Considering row orientation, the effect was not significant for stover yield (Table 5).

Harvest index of soybean was not influenced by the cropping system, row orientation as well as their interaction (Table 4, 5 &6).

Yield evaluation of maize + soybean intercrop:

During our observation, it was found that sole maize produced the maximum grain yield but when maize intercropped with soybean the yield of maize reduces slightly but it can produce some extra soybean without receiving any additional input. Thus total economic return was the highest in maize bean intercrop compared with sole maize or sole soybean (Table 7). Cultivation of sole maize (yield 5.51 t ha^{-1}) gave economic return of 110360 taka/ha and maize yield in intercrop was 5.135 t ha^{-1} can gave 102700 taka/ha which indicated that maize yield in intercrop reduces slightly (Table 7). In case of sole soybean, the maximum yield was 1.31 t ha^{-1} and economic return was 52400 taka /ha and soybean with intercrop yield was (1.06) and economic return was 42400 taka /ha. In case of maize-bean intercrop additional one-third soybean can be produced with maize yield thus total economic return would be 116833 taka/ha (Table 7) which was higher than sole maize or sole soybean. Therefore it can be concluded that intercrop practice would be preferable to the farmer.

One of the most important reasons for intercropping is to increase productivity per unit of area compared to sole cropping (Gebru 2015). Prasad and Brook (2005) reported that land equivalent ratios of maize-soybean intercrops were greater than sole crops. Despite the economic benefits, cereal-legumes intercropping systems improve and maintain soil fertility under different environmental conditions (Kumwenda et al. 1998; Giller et al. 2001; Mugendi et al. 2011; Bationo et al. 2011).

From our observations, it is clear that both crop shows better growth and yield when cultivated alone but intercrop gives higher economic return compared to sole soybean or sole maize. Clark and Francis (1985) also found a similar result and they reported that maize –bean intercrop had similar energy yield to sole maize but yielded more energy than sole bean. Mukhala et al (1999) however reported that maize-bean intercrop yielded 11 and 32% more energy than sole maize and bean respectively.

Table 4. Effect of intercrop on yield components and yield of soybean

Treatment	Plant height (cm)	No. of branch plant^{-1}	No. of pod plant^{-1}	No. of seed pod^{-1}	Pod length (cm)	1000-grain weight	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Sole Soybean	59.00	4.50	41.00	2.67	3.08	81.80	1.39	1.79	3.18	43.71
Soybean intercrop	79.00	3.33	30.83	2.33	2.81	71.32	0.98	1.49	2.48	39.67
Level of Significance	**	*	**	NS	NS	**	**	*	**	NS
CV (%)	3.25	16.48	5.27	26.67	8.37	1.89	10.71	16.05	8.99	10.17

Other details are same as Table 1.

Table 5. Effect of row orientation on yield components and yield of soybean

Treatment	Row orientation	Plant height (cm)	No. of branch plant^{-1}	No. of pod plant^{-1}	No. of seed pod^{-1}	Pod length (cm)	1000-grain weight	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Sole Soybean	North south	70.50	4.00	37.83	2.50	3.00	77.94	1.31	1.67	2.98	43.95
Soybean intercrop	East west	68.33	3.83	34.00	2.50	2.88	75.17	1.06	1.63	2.69	39.40
Level of Significance		NS	NS	**	NS	NS	**	**	NS	NS	NS
CV (%)		3.25	16.48	5.27	26.67	8.37	1.89	10.71	16.05	8.99	10.17

Other details are same as Table 1.

Table 6. Interaction effect of intercrop and row orientation on yield components and yield of soybean

Treatment	Row orientation	Plant height (cm)	No. of branch plant^{-1}	No. of pod plant^{-1}	No. of seed pod^{-1}	Pod length (cm)	1000-grain weight	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Sole Soybean	North south	57.667c	4.67a	41.67a	2.67	3.20a	82.157a	1.31	1.72a	3.07a	42.67
Soybean intercrop	North south	83.33a	3.33b	26.33c	2.33	2.56b	68.180c	0.81	1.13b	1.94c	41.75
Sole Soybean	East west	60.33c	4.33ab	40.33a	2.67	2.95ab	81.43a	1.37	1.47ab	2.93ab	46.76
Soybean intercrop	East west	76.33b	3.33b	35.33b	2.33	3.05a	74.45b	1.25	1.47ab	2.62b	47.76
Level of Significance		**	NS	**	NS	*	**	*	*	*	NS
CV (%)		3.25	16.48	5.27	26.67	8.37	1.89	10.71	16.05	8.99	10.17

Other details are same as Table 1.

Table 7: Yield evaluation of maize bean intercrop

Treatment	Seed yield (t ha^{-1})	Price (BDT ha^{-1})*
Sole Soybean yield	1.31	52400
Soybean yield in intercrop	1.06	42400(14133*)
Sole Maize yield	5.518	110360
Maize yield in intercrop	5.135	102700
Maize–bean intercrop	–	(102700 +14133) = 116833

* 20000 BDT t^{-1} for maize and 40000 BDT t^{-1} for bean. Only one third additional soybeans can be produce in maize – bean intercrop.

Maize soybean intercrop would be a promising cropping system in drought effected North western areas of Bangladesh. Poor soil fertility and nutrient depletion is one of the major limitations for agricultural production in Bangladesh especially Barind tract. Integrated soil fertility management (ISFM) technologies are necessary for sustainable agricultural development in this area. Grain legumes help maintain and improve soil fertility due to their ability to biologically fix atmospheric nitrogen (Stern 1993; Jarenyama et al. 2000). Present investigation also suggested to cultivate soybean along with maize not only for economic return but also for soil fertility management.

CONCLUSIONS

An experiment was conducted to determine yield potentials and profitability of maize-bean intercrop. Three cropping systems (sole maize, SM; sole bean, SB and maize-bean intercrop, MB) and two row orientations (north-South, NS and east west, EW) were justified. From our observation it was found that most of the growth parameters, yield contributing characters as well as yields in both crops were the highest when they allowed growing as solo cropping system (maize or soybean alone). Cultivation of sole maize (yield 5.51 t ha^{-1}) gave economic return of 110360 taka/ha and maize yield in intercrop was 5.135 t ha^{-1} can gave 102700 taka/ha which indicated that maize yield in intercrop reduces slightly. In case of sole soybean, maximum yield was 1.31 t ha^{-1} and economic return was 52400 taka /ha and soybean with intercrop yield was (1.06) and economic return was 42400 taka /ha. In case of maize-bean intercrop additional one-third soybean can be produced with maize yield thus total economic return would be 116833 taka/ha (Table 7) which was higher than sole maize or sole soybean. Therefore it can be concluded that maize + soybean intercropping system practice would be preferable to the farmers of north- western part of Bangladesh

CONFLICTS OF INTEREST

The author declares that there is no conflict of interests regarding the publication of this paper.

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