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Assessment of Genetic Variability based on Morphological and Biochemical Markers in Red Chilli (*Capsicum annuum* L.)

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ABSTRACT: Chilli (*Capsicum annuum* L.) with enormous industrial, therapeutic and export potential is an imperative vegetable and condiment crop of the world. The country is still lagging behind to attain the optimum productivity in dry chilli owing to the use of local unimproved cultivars. Therefore, much-concentrated efforts are necessary to improve its dry fruit yield, quality and host plant resistance against viral diseases. Hence, evaluation of the indigenous germplasm is essential because the promise for further improvement programmes. To examine the variability in red chilli, 30 chilli genotypes were evaluated for 13 morphological and six biochemical traits. Based on mean performance, the highest dry fruit yielding genotype ACS-08-09 was significantly superior to all others, followed by ACS-18-02 and ACS-18-08. The genotype Anand Tej (48.23%) followed by GP-93 (43.68%) and GAVC 112 (42.42%) exhibited higher powder recovery and thereby promising for red chilli powder. For the majority of the traits, the genotypes exhibited abundant diversity with enormous heritability (>60.20%). Fruits per plant, fruit length, dry fruit weight, dry fruit yield per plant, number of seeds per fruit, ascorbic acid content, capsaicin content, total phenol, total antioxidant activity and colour value demonstrated a high PCV than GCV, where estimates of PCV and GCV for days to 50% flowering and days to red ripe fruit maturity were found to be low. Both Genetic advance as per cent of mean and heritability were high for most of the traits except for days to red ripe fruit maturity, primary and secondary branches per plant, number of seeds per fruit and 1000 seed weight, indicating that most of the characters studied were mainly controlled by additive gene effect and thus selection may be effective.

Keywords: Chilli, Variability, Phenotypic coefficient of variation, Heritability, Genetic advance.

INTRODUCTION

Chilli (*Capsicum annuum* L. 2n = 2x = 24) is one of the most significant vegetable and spice crops having considerable commercial and therapeutic value with great international competitiveness. A member of the Solanaceae family, chilli is also known as bird pepper, cayenne, paprika, hot pepper, and sweet pepper. There are twenty-five different species in this genus. The five domesticated species are *C. annuum*, *C. frutescens*, *C. chinense*, *C. baccatum*, and *C. pubescens* (Pickersgill, 1997).

They are grown in different parts of the world. The most extensively cultivated of these is *Capsicum annuum*. It is an annual or short-lived perennial herb with a variety of cultivated forms that differ in terms of fruit size, shape, colour, and degree of pungency. Although chillies are considered to be self-pollinated plants, pollination occurs at the time of opening of the flowers thus, there is a possibility for natural cross-pollination. Out crossing takes place up to 7 to 60 per cent in some species.

India is one of the top chilli-growing nations in the world; it produces over one-fourth of the world's production and is extensively grown therein under both rainfed and irrigated conditions in almost all the states.

Chilli is an important commercial spice crop in global commerce and is probably the second most important vegetable after tomato. Chilli is traded internationally right after black pepper (*Piper nigrum* L.) from India. Vitamins A, E, C, and P are plentiful in fruit of chilli. The placenta and pericarp of chilli contain an alkaloid called capsaicin, which is crystalline, bitter, and volatile. Oleoresin is an extract made of resin that is semi-solid. It is a crucial fatty oil that is obtained from chilli fruits and is utilised in the processed food and beverage sectors. It also has significant export potential. Especially in developed countries, the colour extracted from chillies is a major source to replace the artificial colours used in culinary products.

Due to the usage of locally unimproved cultivars and widespread infestations of insect pests and diseases, particularly viral diseases, the nation is still lagging behind in achieving the required production of dry chilli. Therefore, it requires intense efforts to increase the dry fruit yield, quality, and host plant resistance to viral infections. Hence, evaluation of the potentialities of the indigenous germplasm is essential because the promise for further improvement programmes depends on the genetic diversity of the crop.

One of the most crucial factors in creating an effective breeding programme is recognising the type and extent of genetic variability. Understanding the phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) can help one predict how much variation will be present in a particular assemblage of genotypes. In genetic studies, characters having high GCV show the potential for an effective selection. However, the heritable variation cannot be quantified using GCV alone (Singh and Nandpuri 1974). Genetic variability with heritable portion should be considered for assessing the maximum and accurate effect of selection (Burton, 1952).

Therefore, it is crucial to organise and carry out a breeding programme for the improvement of quantitative traits by estimating heritable variation and its genetic components, such as GCV and genetic advance. The simplest way to express genetic variability for the concerned character in the population under study is range in magnitude.

MATERIALS AND METHOD

A. Phenotyping of germplasm

The current experiment was carried out at Main Vegetable Research Station, Anand Agricultural University, Anand during *kharif-rabi* 2021-22. The soil of the research farm was sandy loam and sufficient amount of organic matter. For field testing, a group of 30 diverse chilli genotypes were selected and raised in a Randomized Complete Block Design (RCBD) through transplanting of seedlings in three replications. Each genotype was transplanted in a single line of 6 m length with inter- and intra-row spacing of 60×60 cm, respectively. For maintaining vigorous plant stand adopted Recommended agronomic and plant protection measures were follow to grow vigorous plant stand of crop. For morphological trait studies, phenotyping in each replication was carried out on five randomly selected competitive plants of each accession. Phenotyping for 19 quantitative traits *viz*., plant height (cm), primary branches per plant, secondary branches per plant, fruits per plant, fruit length (cm), fruit width (cm), dry fruit weight (g), dry fruit yield per plant (g), powder recovery (%), number of seeds per fruit, 1000 seed weight (g), moisture content (%), ascorbic acid content (mg/100g), capsaicin content (mg/g), total phenol (mg/100g), total antioxidant activity (mg/100g) and colour value (ASTA) was carried out based on the individual plant. However, in case of days to 50% flowering and days to red ripe fruit maturity, data were taken on the population basis.

Few or more dry fruits were collected from selected plant of each genotype in each replication and powder prepared from them. Using this powder different biochemical parameters *viz*., moisture content (%), ascorbic acid content (mg/100g), capsaicin content (mg/g), total phenol (mg/100g), total antioxidant activity (mg/100g) and colour value (ASTA) were estimated. The moisture content, ascorbic acid content, capsaicin content, total phenol, total antioxidant activity and colour were assessed using the protocol given by Association of Official Analytical Chemists (Anon., 1980); Sadasivam and Manickam (1992); Quagliotti and Ottaviano (1971); Cliffe *et al*. (1994); Sadasivam and Manickam (1992); Rosebrook *et al.* (1968) respectively.

B. Data analysis

Analysis of variance and least significant different test on phenotypic data of 13 morphological and six biochemical characters were executed to identify the diverse genotypes. The genotypic and phenotypic components of variance, variability coefficients, heritability (in the broad sense), genetic advance, and genetic advance as a percentage of mean were examined. According to Sivasubramanian and Menon (1973), phenotypic (PCV) and genotypic coefficients of variation (GCV) were classified [<10% = low, 10-20% = moderate and >20% = high]. Similarly, heritability (broad sense) [<30% = low, 30-60% = moderate and >60% = high] and genetic advance as per cent of mean [<10% = low, 10-20% = moderate and >20% = high] were classified according to Robinson *et al.* (1949); Johnson *et al.* (1955) respectively.

RESULT AND DISCUSSION

A. Mean and range

Mean is a relatively simple measure used in plant breeding to assess phenotypic variability and it serves as the basis for screening desirable genotypes. The mean values of 30 genotypes of chilli for all the 19 quantitative characters along with standard error of mean (S.Em ±), critical difference (C.D) and coefficient of variation (C.V %) are given in Table 2. Earliness in chilli helps to escape from various biotic and abiotic stresses occurring during the crop period and hence days to 50% flowering and days to red ripe fruit maturity is appropriate selection standard to identify early maturing genotypes. In current study, ACS-13-07 (82.33 days) followed by ACS-18-02(82.67 days) and ACS-10-02 (83 days) were matured early while, ACS-13-03 and GP-89 (94.33 days) followed by GP-87 and P-10-16 (91.67 days) was detected as late-maturing genotype (Table 1).

Higher values for fruits per plant are desirable because they are directly associated with high fruit yield per plant. Twelve genotypes were significantly deviated toward the higher side of the mean. So, they were considered superior compare to other genotypes. The highest number of fruits per plant was expressed by genotype ACS-08-09 (151.47) which was at par with Kashi Anmol (142.83). The highest dry fruit yielding genotype ACS-08-09 (106.76g) was significantly superior to all others, followed by ACS-18-02 (88.93 g) and ACS-18-08 (84.38 g). The genotype Anand Tej (48.23%) followed by GP-93 (43.68%) and GAVC 112 (42.42%) exhibited higher powder recovery and thereby promising for red chilli powder (Table 1 and Fig. 1).

Table 1: List of top three genotypes identified for dry fruit yield and its component traits in chilli.

Sr. No.	Characters	Name of the genotypes		
1.	Days to 50% flowering	Gujarat chilli 2	Kashi Anmol	ACS-18-02
2.	Days to red ripe fruit maturity	ACS-13-07	ACS-18-02	ACS-10-02
3.	Fruits per plant	ACS-08-09	Kashi Anmol	Gujarat chilli 2
4.	Fruit length (cm)	GP-90	ACS-18-08	JCS-740
5.	Dry fruit yield per plant (g)	ACS-08-09	ACS-18-02	ACS-18-08
6.	Powder recovery (%)	Anand Tej	GP-93	GAVC 112
7.	Capsaicin content (mg/g)	ACS-13-07	JCS-740	ACS-18-02
8.	Colour value (ASTA)	GP-88	Anand Tej	JCS-740

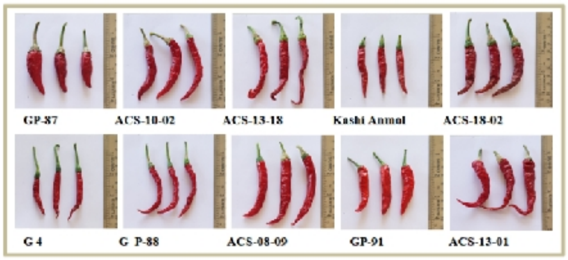

Fig. 1. Variability present among chilli genotype for fruit morphology.

In quality point of view, the genotype GAVC 112 (0.63 mg/g) possessed less capsaicin content followed by Ujwala (0.83 mg/g) and ACS-18-08 (0.86 mg/g) hence, these genotypes are least pungent than others. While genotype ACS-13-07 (2.41 mg/g) was highly pungent due to presence of high amount of capsaicin content. The genotype GVC 121 (198.00 mg/100g) followed by JCS-740 (180.00 mg/100g), GP-92 and GP-94 (144.33 mg/100g) exhibited higher ascorbic acid content. Colour value is useful trait for selection of genotype for red chilli powder. The genotype GP-88(225.21 ASTA) followed by Anand Tej (206.84 ASTA) and JCS-740 (205.52 ASTA) showed higher colour value.

The Analysis of variance for studied quantitative traits depicted highly significant (P <0.01) differences among the genotypes (Table 2) in the overall result of F tests which indicated the existence of ample variability in genotypes which can be exploited for chilli improvement.

Table 2: Mean performance, analysis of variance (ANOVA) and estimation of genetic variables for 19 characters of chilli.

Trait	Mean performance					Source of variation and mean squares (ANOVA)		
	Mean	Range	S. Em.	C.D. at 5%	CV%	Replication (DF = 02)	Genotypes (DF = 29)	Error (DF = 58)
Days to 50% flowering	39.27	32.67-46.67	0.81	2.29	3.57	5.23	37.06**	1.96
Days to red ripe fruit maturity	88.38	82.33-94.33	1.25	3.53	2.45	10.41	34.43**	4.68
Plant height (cm)	58.22	40.80-75.73	2.92	8.27	8.69	84.33*	215.41**	25.61
Primary branches per plant	2.98	2.13-4.07	0.24	0.68	13.92	0.30	0.61**	0.17
Secondary branches per plant	5.93	4.27-7.67	0.43	1.22	12.58	0.15	2.21**	0.56
Fruits per plant	76.84	27.00-151.47	7.33	20.77	16.53	403.50	3048.80**	161.40
Fruit length (cm)	6.65	3.56-8.64	0.25	0.71	6.56	0.58	6.15**	0.19
Fruit width (cm)	1.15	0.88-1.76	0.062	0.21	9.46	0.024	0.10**	0.011
Dry fruit weight (g)	0.81	0.46-1.54	0.073	0.21	15.61	0.030	0.17**	0.016
Dry fruit yield per plant (g)	50.78	15.92-106.76	5.60	15.86	19.10	544.49*	1391.72**	94.15
Powder recovery (%)	34.98	24.72-48.23	0.54	1.53	2.68	0.90	90.17**	0.87
Number of seeds per fruit	62.25	39.27-98.40	6.00	17.00	16.71	4.91	591.84**	108.19
1000 seed weight (g)	5.23	3.94-7.10	0.35	0.98	11.52	0.53	1.63**	0.36
Moisture content (%)	8.27	6.39-13-38	0.12	0.34	2.54	0.015	6.75**	0.044
Ascorbic acid content (mg/100g)	115.83	72.00-198.00	0.82	2.33	1.23	0.63	2514.89**	2.02
Capsaicin content (mg/g)	1.49	0.63-2.41	0.013	0.038	1.55	0.00075	0.68**	0.00054
Total phenol (mg/100g)	32.88	20.30-49.93	0.65	1.85	3.44	0.14	181.17**	1.28
Total antioxidant activity (mg/100g)	45.69	34.14-67.30	0.34	0.97	1.30	1.53*	270.57**	0.35
Colour value (ASTA)	155.03	55.90-225.21	0.96	2.70	1.067	4.40	5696.50**	2.70

B. Genetic variability, heritability and genetic advance

In chilli, being often-cross pollinating and inbreeding species, genetic variation is required for improvement of quantitative traits. Analysis of variance (ANOVA) may not divulge the absolute variability present in the population and this could be evaluated by standardizing the phenotypic and genotypic variances by obtaining the coefficient of variability.

Similar to earlier studies, higher values of PCV than GCV was observed for all studied characters (Sharma and Sood 2018; Ain *et al.*, 2019). However, difference between GCV and PCV estimates was very small (Table 3 and Fig. 2) for all characters under investigation, except primary and secondary branches per plant, number of seeds per fruit and 1000 seed weight. Higher estimates of GCV (>20%) was demonstrated for fruits per plant, fruit length, dry fruit weight, dry fruit yield per plant, number of seeds per fruit, ascorbic acid content, capsaicin content, total phenol, total antioxidant activity and colour value. Higher GCV for fruits per plant (>35%), fruit length (>25%) and dry fruit yield per plant has also reported by Pandit and Adhikary (2014); Nagaraju *et al.* (2018). Greater estimates for yield-related economically important traits and GCV values that were closer to their corresponding PCV values suggested that the environment had little effect on the expression of the trait and that there was also a lot of variability. The findings revealed that phenotypic based selection for investigated traits mentioned above may be rewarding for the chilli improvement programme. However, Low GCV and PCV (<10%) was recorded for days to 50 % flowering and days to red ripe fruit maturity indicating less variability for these traits in the genotypes studied and thereby less chances of improvement through selection. The similar result was reported by Bundela *et al.* (2017); Janaki *et al.* (2017); Nagaraju *et al.* (2018) who also reported low PCV and GCV for days to 50% flowering and days to red ripe fruit maturity.

Table 3: Variability parameters for 19 characters of chilli.

Characters	σ^2_g	σ^2_p	GCV (%)	PCV (%)	H^2_b (%)	GA % Mean
Days to 50% flowering	11.70	13.67	8.71	9.42	85.59	16.60
Days to red ripe fruit maturity	9.91	14.60	3.56	4.32	67.90	6.05
Plant height (cm)	63.26	88.88	13.66	16.19	71.18	23.74
Primary branches per plant	0.15	0.32	12.89	18.97	46.18	18.04
Secondary branches per plant	0.55	1.10	12.52	17.75	49.75	18.19
Fruits per plant	962.46	1123.86	40.37	43.63	85.64	76.96
Fruit length (cm)	1.99	2.18	21.19	22.18	91.25	41.70
Fruit width (cm)	0.03	0.04	15.22	17.93	72.04	26.60
Dry fruit weight (g)	0.05	0.06	28.08	32.14	76.37	50.56
Dry fruit yield per plant (g)	432.52	526.68	40.95	45.19	82.12	76.45
Powder recovery (%)	29.76	30.64	15.60	15.82	97.14	31.66
Number of seeds per fruit	161.22	269.41	20.40	26.37	59.84	32.50
1000 seed weight (g)	0.42	0.79	12.42	16.94	53.73	18.75
Moisture content (%)	2.23	2.28	18.06	18.24	98.06	36.85
Ascorbic acid content (mg/100g)	837.62	839.65	24.99	25.01	99.76	51.40
Capsaicin content (mg/g)	0.225	0.226	31.80	31.84	99.78	65.44
Total phenol (mg/100g)	59.97	61.25	23.55	23.80	97.91	48.00
Total antioxidant activity (mg/100g)	90.07	90.42	20.77	20.81	99.61	42.70
Colour value (ASTA)	1897.93	1900.67	28.10	28.12	99.86	57.85

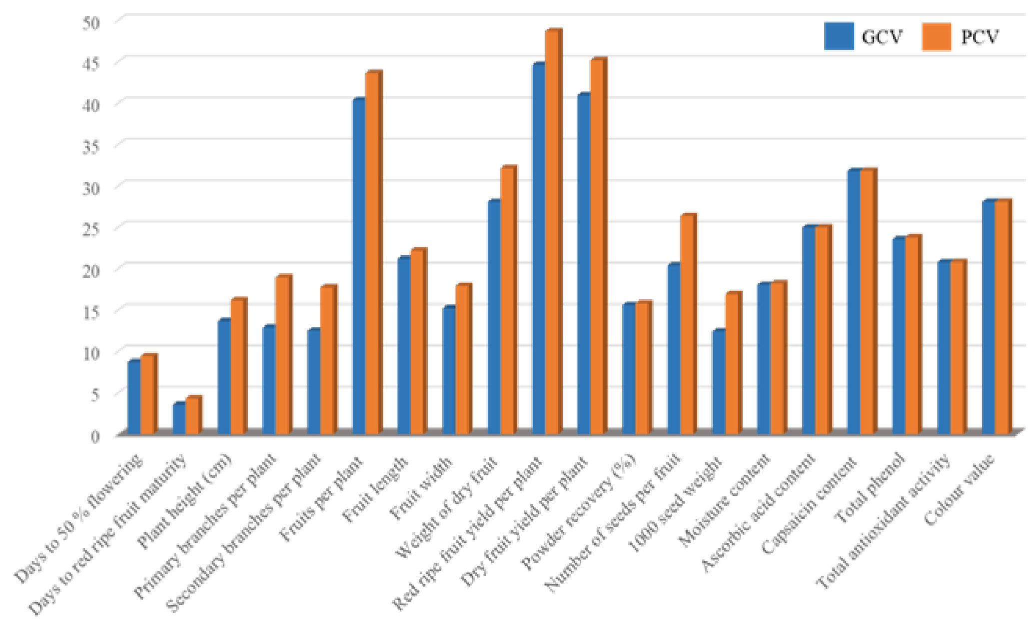

Fig. 2. Graphical representation of genotypic and phenotypic coefficient of variation.

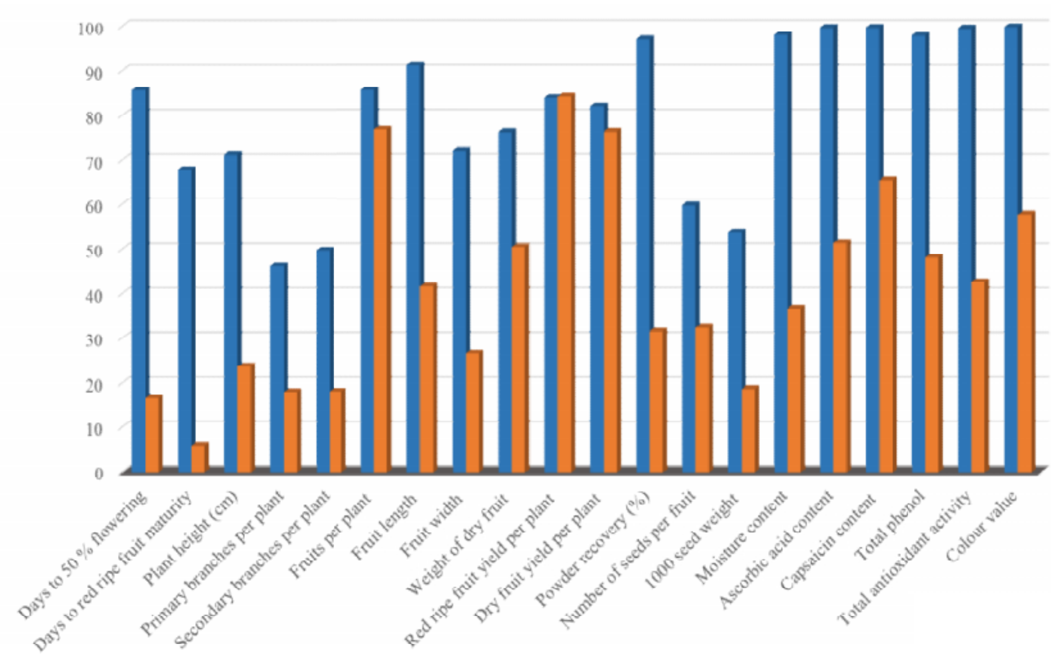

Fig. 3. Graphical representation of broad sense heritability (h^2_b %) and genetic advance as % mean.

Though, many advance genomic tools are available with breeder to deploy in chilli breeding programs. But without knowledge of heritability and genetic gain selection program is ineffective. Heritability evident the inheritance of traits to filials from parents (Falconer, 1960).

The knowledge of heritability and GA as per cent of mean help in prediction of gain under selection in any breeding programme. Based on Robinson *et al.* (1949) classification, all the quantitative traits in present investigation except primary branches per plant (46.18%), secondary branches per plant (49.75%), number of seeds per fruit (59.84%) and 1000 seed weight (53.73%) were highly heritable due to H^2 values >60% (Table 3 and Fig. 3).

High heritability for days to 50% flowering, days to red ripe fruit maturity, plant height, fruits per plant, fruit length, dry fruit weight, dry fruit yield per plant, capsaicin content and colour value has and been reported earlier by several researchers *viz.,* Nagaraju *et al.* (2018); Kumar (2020); Tirupathamma *et al.* (2021). Higher value of heritability suggested that the environment has little influence on characters expression.

From 6.05% for days to red ripe fruit maturity to 76.96% for fruits per plant, genetic advance as% mean (GAM) was observed. With the exception of days to red ripe fruit maturity, primary and secondary branches per plant, number of seeds per fruit, and 1000 seed weight, most traits had high GAM and heritability.

Earlier findings have also observed high heritability with high GAM for dry fruit yield per plant (Shirshat *et al.,* 2007; Srikanth *et al.,* 2016; Tirupathamma *et al.,* 2021) and fruits per plant (Pandit and Adhikary 2014; Zegeye *et al.,* 2018). The traits having high heritability and high Genetic advance as % mean may be improved by phenotypic selection due to the presence of additive gene action with less effort. Only one character, days to red ripe fruit maturity having high heritability and low GAM indicates the predominance of non-additive gene effect for development of trait and the may be boosted using population improvement approach. Earlier similar result was also observed by Nagaraju *et al.* (2018) for that trait.

CONCLUSIONS

Based on mean performance, genotypes ACS-08-09, ACS-18-02and ACS-18-08 are promising for dry fruit yield in chilli, whereas for powder recovery, Anand Tej followed by GP-93 and GAVC 112 were found superior genotypes and could be used in future breeding programme for improving yield and powder recovery per cent in red chilli, respectively. On the basis of the studies mentioned above, it can be inferred that the number of fruits per plant, fruit length, and dry fruit weight should all be given appropriate consideration when selection is imposed for genetic enhancement of dry fruit yield in chilli. Chilli is used as both green and dry hence for improvement in chilli germplasm especially for dry fruit, selection based on characters like days to red ripe fruit maturity, powder recovery percent and colour value is a prerequisite.

FUTURE SCOPE

The current investigation provided the information regarding the variability in terms of genotypic and phenotypic components, heritability and genetic advance as % of mean. In future selection of genotype based on these traits is useful to develop elite genotypes of chilli with higher production of red chilli. The selection for those particular traits identified with a high heritability and high genetic advance as percent of mean can directly be helpful in improving the yield of red chilli.

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Conflict of Interest. None.

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