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Correlation and Regression Analysis of Crop Growth and Yield Attributing Characters of Soybean [*Glycine max* (L.) Merrill] on Weed Interference

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ABSTRACT

Background: A significant source of leguminous oilseeds in the nation, soybean [*Glycine max* (L.) Merrill] provides more than 30% of the nation's vegetable oil supply and more than 50% of oilseeds. Through biological nitrogen fixation, soybean crop has the unique ability to increase soil fertility in a cropping system. Tropical and subtropical climates are ideal for the crop growth.

Methods: The experiments were carried out in Randomized Block Design (RBD), with eleven treatments of with and without combinations of Diclosulam 0.9% + Pendimethalin PPI herbicides at different doses and it's compared with hand weeding and weedy check treatments. The treatments was replicated three time.

Result: As a results, *Phyllanthus urinaria*, *Cyperus iria* and *Mollugo pentaphylla* showed the strongest positive association with the dry weight of the weeds, according to the correlation analysis, on the other hand, *Echinochloa colona* exhibited the lowest association coefficient with dry weight of weeds. Regression analysis showed that when one *Phyllanthus urinaria* was added, the yield decreased to a certain degree. Seeds pod^{-1} exhibited the largest positive association among the different yield attributing parameters, followed by pods plant^{-1}, plant population, Leaf area index, nodules plant^{-1}, branches plant^{-1} and plant height, according to the various crop growth and yield attributing parameters with grain production.

Key words: Correlation coefficient, Correlation, Regression, Weeds dry weight, Yield reduction.

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] provide more than 30 per cent of the nation's vegetable oil supply and more than 50 per cent of oilseeds (Tiwari, 2006). Through biological nitrogen fixation, the crop has the unique ability to increase soil fertility in a cropping system. Tropical and subtropical climates are ideal for the crop growth. The 21st century's "Miracle Crop," "Wonder Crop" or "Golden Bean" is the soybean. It originated in China and was brought to India from the United States in 1968. In many nations, it has become one of the most significant commercial crops. Twenty percent oil, forty percent protein, thirty percent carbohydrate, four percent saponins, five percent fiber and no cholesterol were present in soybean seeds. It is frequently used as soy milk, oilseed, pulse and in vegetarian dishes. The United States accounts for 34 percent of global soybean production, followed by Brazil (30 per cent), Argentina (18 per cent), China (4 per cent) and India (3.95 per cent) (Anonymous, 2018a). In India, soybeans were produced on 10.84 million hectares of land, yielding 11.48 million tons. Madhya Pradesh is one of the leading states in India for soybean production, with 5.4 million hectares area and 5.9 million tonnes production. Consequently, Madhya Pradesh is referred to as "soya state" of India. However, soybeans only produce 1094 kg ha^{-1}, which is significantly less than their potential yield of 2500 kg ha^{-1} (Anonymous, 2018b). High rainfall during the *kharif* (rainy) season makes it impossible to do timely hand weeding, which can result in a yield loss of up to 30 to 80 per cent (Yaduraju, 2002). All weed control treatments reduced weed dry matter at harvest during both the years. Pendimethalin followed by hoeing and weeding at 30 DAS was significantly superior in reducing weed dry matter of broad-leaved, narrow-leaved and total weeds at harvest over rest of the treatments (Meena *et al.,* 2017). According to estimates ranging from 31 to 84 per cent weed interference during the early phases of crop establishment

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dramatically reduced crop yield (Kachroo *et al.,* 2003; Kewat and Pandey 2001 and Kurchania *et al.,* 2001). Although, weed free recorded higher seed yield and showed significant superiority over rest of the weed management treatments, but it was statistically at par with W12 and W11 (Yadav *et al.,* 2019). In contrast, Gidesa and Kebede (2018) found that weed competition reduced soybean seed yield by a maximum of 78.50 per cent. Among the different doses and time of application of imazethapyr, application of imazethapyr 30 g/ha at 10 DAG resulted in 57.9% higher grain yield (1098 kg/ha), lower weed dry matter (6.88 g/0.5 m^2) and higher WCE (75.33%) over unweeded control and other treatments (Rathod *et al.,* 2017). According to Kundu *et al.* (2011), weeds caused a 43 per cent reduction in soybean output, demonstrating the need to eliminate weeds in order to maximize soybean yield potential. The aim of this research is to shed insight on the correlation between soybean yield and the factors that influence it. The effect of herbicide applied as pre-emergence was subdued at this belated stage, which may possibly be on account of longer period after application and restricted effective residual period (Devi *et al*., 2016). However, *Echinochloa colona* (41.56%) and *Trianthema portulacastrum* (33.16%) were predominant in soybean but, other weeds (*Cyperus rotundus, Cynodon dactylon, Commelina benghalensis, Digera arvensis, Amaranthus viridis, Physalis minima, Corchorus spp*.) were also present at 60 DAS (Bhimwal *et al.,* 2019). The significance of correlations in understanding the intricate links between different plant characteristics especially with regard to seed output cannot be overstated. Understanding the correlations between traits is very helpful in breeding projects because it makes it simple for the breeder to decide which features should be used as selection indicators (Prathima *et al.,* 2022). A more thorough comprehension of these relationships can open the door to novel approaches to crop management, agronomic interventions and breeding that maximize soybean yield (Hyten *et al.,* 2010). Seed yield was found to have a positive association in respect to crop growth and a negative association with weed growth (Bhan *et al.,* 1972). According to Jain *et al*. (1985), the yield of soybean showed a significantly positive association with crop biomass (r=0.6860) when correlated with biomass, sink characteristics and photosynthetic efficiency (biomass production). Seed yield and yield-attributing traits like test weight, yield plant^{-1} and pods plant^{-1} also showed a positive link, albeit this relationship was not statistically significant. The soybean yield was negatively correlated with weed dry matter particularly with grassy as well as total weed dry matter while plant dry matter accumulation was strongly correlated with soybean yield (Barla *et al.*,2025).

MATERIALS AND METHODS

The current study, "Correlation and Regression Analysis of Crop Growth and Yield Attributing Characters of Soybean [*Glycine max* (L.) Merrill] on Weed Interference'' was conducted during *kharif* season 2019, a field study was conducted at BSP unit, Agronomy, Jabalpur (M.P.). The field area used for the experiment had a consistent terrain and was overrun with weeds that were unique to the area.

Climate

The climate of Jabalpur region is typically sub humid, featured by hot dry summer and cool dry winter. Jabalpur is situated at 23°09′ North latitude and 79°58′ East longitudes with an altitude of 411.78 meters above the mean sea level. It is classified under "Kymore Plateau and Satpura Hills" agro- climatic zone as per norms of National Agriculture Research Project (NARP), New Delhi. Recently, it has been identified as agro-ecological region number 10, named as Central Highlands (Malwa and Bundhelkhand), Sub region number 10.1, named as hot sub-humid eco-region (Malwa Plateau and Narmada Valley). The results of the meteorological data during crop season are given in Table 1.

The mean annual rainfall of Jabalpur is 1350 mm, mostly received between mid-June to end of September with a little and occasional rains in remaining parts of the year. The mean monthly temperature goes down to the extent of 4°C during winter, while the maximum temperature reaches as high as 45°C during the summer. Generally, relative humidity remains very low during summer (15 to 30%), moderate during winter (60 to 75%) and attains higher values (80 to 95%) during rainy season.

Soil

As per norms of United State classification of soil, the soil of Jabalpur region is classified as Vertisols. The soil is medium to deep in depth and black in colour. The soil swells when wetting and shrinks when dries. Due to these properties the soil develops wide cracks on the surface during summer season. The soil of the experimental field offers infestation of several weeds depending on the season and crop growth as well as management practices followed during the course of study. In order to evaluate the physio-chemical properties of the soil, ten soil samples were taken randomly from different spots at the depth of 0-20 cm with the help of screw type soil auger. After this, soil samples were thoroughly mixed to make a composite sample. The composite sample was dried and powdered finally with the help of pistal and morter and then subjected to various analysis in the laboratory, Department of Agronomy, JNKVV, Jabalpur. The results of the analysis are given in Table 2. It is clear from the data that the soil of the experimental field was sandy clay loam in texture, neutral in reaction (7.10), medium in organic carbon (0.65%), nitrogen (360.30 kg/ha), phosphorus (15.83 kg/ha) and Potassium (310.80 kg/ha) contents.

Experimental details

A total eleven weed control treatments were laid out in randomized block design with three replications. These treatments were randomized in each replication using

random table. Treatment details of the experiment represent by Table 3. The details of the treatments are given as under.

Regression and correlation studies on crop weeds

Using the formula proposed by Sendecor and Cochran (1967), the correlation matrix between various crop growth characteristics, weed population and crop production was computed.

$$r = \frac{\Sigma XY - \frac{\Sigma X \Sigma Y}{N}}{\sqrt{\Sigma X2 - \frac{(\Sigma X)2}{N} \times \Sigma Y2 - \frac{(\Sigma Y)2}{N}}}$$

The impact of weeds on soybean crop yield was predicted using regression models and the quantitative change in yield was understood by comparing the coefficients. The following regression equation was used.

$$\hat{Y} = a + bx$$

Whereas,

$\hat{Y}$= Soybean yield (Dependent variable).

X= Weed density (independent variable).

a and b= Regression constant and regression coefficient, respectively.

Analysis of statistics

The data pertaining to each crop attribute was combined and statistically evaluated using standard protocol.

Table 1: Meteorological data during crop season.

Date	Standard week	Temperature (°C)		RH (%)		Sun-shine hours	Rainfall (mm)	No. of rainy days
		Morning	Evening	Morning	Evening			
July 2019	27	23.10	29.90	94	87	1.3	178.8	3
	28	25.00	31.40	82	64	2.6	59.8	1
	29	25.00	34.90	82	59	8.7	24.4	2
	30	24.00	32.30	88	74	3.5	48.0	3
Aug 2019	31	23.90	29.60	93	81	1.5	47.6	4
	32	23.50	29.90	92	81	2.7	210.0	4
	33	22.90	28.60	91	83	2.9	302.1	4
	34	22.50	29.20	97	83	1.4	212.9	7
Sep 2019	35	23.40	30.90	93	75	3.3	57.2	4
	36	23.40	31.60	94	79	3.8	185.0	5
	37	23.40	28.50	93	83	1.2	101.4	5
	38	22.70	31.70	91	78	4.5	53.1	3
	39	22.10	29.50	93	78	2.5	77.6	4
Oct 2019	40	21.00	30.10	90	66	7.2	14.3	2
	41	18.00	30.30	91	56	8.4	0.0	0
	42	18.70	29.20	93	63	5.6	2.2	0
	43	19.10	27.10	92	60	0.9	1.0	0
Nov 2019	44	17.70	30.30	92	52	5.3	0.0	0
	45	14.00	29.60	92	52	6.5	0.0	0
	46	10.30	28.70	92	41	8.7	0.0	0
	47	10.50	28.20	91	48	6.8	0.0	0

Table 2: Physico-chemical properties of the experimental site.

Constituents	Data	Categories	Method used
A. Mechanical composition			
Sand (%)	32.22	Clay loamy	International Pipette method (Piper, 1967)
Silt (%)	27.28		
Clay (%)	40.50		
B. Chemical analysis			
OC (%)	0.65	Medium	Walkley and Black rapid titration method (Walkey and Black,1934)
Available nutrient (Kg ha^{-1})			
Nitrogen	360.30	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
Phosphorus	15.83	Medium	Calorimeter method (Olsen *et al.,* 1954)
Potassium	310.80	Medium	Flame Photometer method (Chapman and Pratt, 1961)
Soil pH 1:2.5 (Soil water ratio)	7.10	Neutral	Glass electric pH meter (Piper, 1967)
Electrical conductivity (dS/m)	0.32	Neutral	Solu-bridge method (Black, 1965)

Analysing the relevance of treatments and the analysis of variance for randomized block design produced dependable results, according to Gomez and Gomez (1984). The 'F' test of significance was employed to investigate the variations in treatment means based on the null hypothesis. The standard error of mean (SEm±) and critical differences (CD) were computed and interpreted to explain findings if the variance ratios (F-test) proved to be significant at the 5% level of significance. The structure of the analysis of variance (ANOVA) is illustrated in Table 4.

RESULTS AND DISCUSSION

An attempt has been made to talk about the possible cause of some of the significant outcomes mentioned in the preceding chapter. Because yield is the last factor used to assess how effective various weed management methods are. The results of previous studies and data collected on a number of parameters throughout the examination have also been used to corroborate the findings of this one.

Table 3: Treatment details of the experiment.

Treatments	Herbicides	Rate of application (g/ha)
T_1	Diclosulam 0.9% + Pendimethalin 35% SE	18+700
T_2	Diclosulam 0.9% + Pendimethalin 35% SE	20.25+787.5
T_3	Diclosulam 0.9% + Pendimethalin 35% SE	22.5+875
T_4	Diclosulam 0.9% + Pendimethalin 35% SE	45+1750
T_5	Diclosulam 84% WG	20.25
T_6	Diclosulam 84% WG	22.50
T_7	Pendimethalin 30% EC	787.5
T_8	Pendimethalin 30% EC	875
T_9	Pendimethalin 30% EC + Imazethapyr 2% EC	900+60
T_{10}	Hand weeding (Twice)	20 and 40 DAS
T_{11}	Weedy check	-

Table 4: The analysis of variance (ANOVA) skeleton is provided below.

Source of variation		d. f.	S. S.	M. S. S.	"F"cal.	
					5%	1%
Replications	(3-1)	2				
Treatments	(10-1)	10				
Error	(3-1) (11-1)	20				
Total (rt-1)		32				

S. Ed.= SEm x √2 CD = SEd X t 5% for error d.f.

Whereas,

S. Em= Standard error of treatment means.

S.Ed= Standard error of difference between treatment means.

C.D.= Critical difference.

r= Number of replications.

edf= Error degree of freedom.

Table 5: Correlation coefficient between weed population with weed dry weight.

	Echinochloa colona	*Cyperus iria*	*Alternenthera philoxeroides*	*Mollugo pentaphylla*	*Phyllanthus urinaria*	Weed dry weight g/m^2
	X1	X2	X3	X4	X5	Y
X1	1.0	-	-	-	-	-
X2	0.926**	1.0	-	-	-	-
X3	0.889**	0.984**	1.0	-	-	-
X4	0.793**	0.929**	0.887**	1.0	-	-
X5	0.975**	0.979**	0.945**	0.900**	1.0	-
Y	0.763**	0.912**	0.864**	0.992**	0.879**	1.0

**. Correlation is significant at the 0.01 level.

Correlation and regression studies on weed population with weed dry weight

The correlation amongst weed density of different weed species with total weed dry weight production was found positive and significant are present in Table 5. The findings revealed a strong and favorable relationship between the total dry weight produced by weeds and the weed density of various weed species present in Table 5.

The correlation analysis revealed that *Mollugo pentaphylla* (0.992), *Cyperus iria* (0.912) and *Phyllanthus urinaria* (0.879) had highest positive correlation with the weed dry weight. However, the *Echinochloa colona* had lowest correlation coefficient with weed dry weight (0.763). The regression analysis (Table 6) revealed that the *Phyllanthus urinaria* contributed the greater extent for weed dry weight production with increase one plant, the increase in weed dry weight could be predicted by 7.48 g m^{-2} followed by *Alternenthera philoxeroides* 6.84 g m^{-2}.

The highest variation in the dry weight of weeds was recorded by *Mollugo pentaphylla i.e.* increase per unit area even one plant *Mollugo pentaphylla* is increase 5.60 kg of dry weight and its followed by *Cyperus iria* and same trends followed by other weeds. Van Acker *et al.* (1993) explains that weed competition in the environment determines how many pods each plant produces. There would be fewer pods per plant if the weeds were shaded and had more dry matter. According to Hume *et al.,* (1985), the factor of yield, such as the number of pods, is related to the treatment. These findings are supported by the research conducted by (Bhan *et al.* 1974 and Jain *et al.* 1993).

Table 6: Regression between weed populations with weed dry weight.

Weed	R line ($\hat{Y}$ = a+bx)	R^2
Echinochloa colona	$\hat{Y}$= -1.31 + 4.39X1	0.58
Cyperus iria	$\hat{Y}$= -4.60 + 6.62X2	0.83
Alternenthera philoxeroides	$\hat{Y}$= -2.85 + 6.84X3	0.74
Mollugo pentaphylla	$\hat{Y}$= -0.75 + 5.61X4	0.98
Phyllanthus urinaria	$\hat{Y}$= -5.64 + 7.48X5	0.77

R^2= Coefficient of determination.

Weed population with seed yield

The correlation amongst weed density of different species with total weed dry weight production was production was found positive and significant are present in Table 7. The correlation analysis revealed that *Cyperus iria* (-0.947) had highest negative association with the seed yield. The regression analysis (Table 8) revealed that the reduction in the yield be to extent of 460.66 kg/ha with increase one plant of *Phyllanthus urinaria*. The greater reduction yield can also be recorded due to density of *Alternenthera philoxeroides, Cyperus iria, Mollugo pentaphylla and Echinochloa colona.* The reduction could be predicted by 433.37, 401.37, 299.84 and 291.40 kg/ha respectively. In this table shown the correlation coefficient between weed population with grain and its shown negative correlation coefficient between them. In this table shown the correlation coefficient between weed population with grain and its shown negative correlation coefficient between them. This could be because as the number of pods per plant rises, so will the yield and weight of seeds per plant, together with the number of seeds per pod and per plant. According to Hosseini (2015), weed competition on the plant will result in a notable drop in soybean seed weight. According

Table 7: Correlation coefficient between weed population with seed yield.

	Echinochloa colona	*Cyperus iria*	*Alternenthera philoxeroides*	*Mollugo pentaphylla*	*Phyllanthus urinaria*	Seed yield kg/ha
	X1	X2	X3	X4	X5	Y
X1	1.0	-	-	-	-	-
X2	0.926**	1.0	-	-	-	-
X3	0.889**	0.984**	1.0	-	-	-
X4	0.793**	0.929**	0.887**	1.0	-	-
X5	0.975**	0.979**	0.945**	0.900**	1.0	-
Y	-0.869**	-0.947**	-0.938**	-0.910**	-0.928**	1.0

**. Correlation is significant at the 0.01 level.

*. Correlation is significant at the 0.05 level.

Table 8: Regression between weed populations with seed yield.

	Weed	R line ($\hat{Y}$= a+bx)	R^2
X1	*Echinochloa colona*	$\hat{Y}$= 2536.56 - 291.40 X1	0.75
X2	*Cyperus iria*	$\hat{Y}$= 2639.73 - 401.37 X2	0.89
X3	*Alternenthera philoxeroides*	$\hat{Y}$= 2583.44 - 433.61 X3	0.87
X4	*Mollugo pentaphylla*	$\hat{Y}$= 2294.20 - 299.84 X4	0.82
X5	*Phyllanthus urinaria*	$\hat{Y}$= 2723.88 - 460.66 X5	0.86

R^2= Coefficient of determination.

Table 9: Correlation coefficient between crop growth and yield contributing characters with seed yield.

	Plant population	Plant height	Seeds/ pod	Pods/ plant	No.of nodules	No. of branches	LAI	Seed yield kg/ha
	X1	X2	X3	X4	X5	X6	X7	Y
X1	1.0	-	-	-	-	-	-	-
X2	-0.024	1.0	-	-	-	-	-	-
X3	0.829**	0.294	1.0	-	-	-	-	-
X4	0.920**	0.158	0.962**	1.0	-	-	-	-
X5	0.942**	-0.285	0.758**	0.868**	1.0	-	-	-
X6	0.958**	-0.258	0.748**	0.864**	0.984**	1.0	-	-
X7	0.626*	0.447	0.923**	0.844**	0.567	0.51	1.0	-
Y	0.881**	0.165	0.921**	0.915**	0.842**	0.802**	0.844**	1.0

** Correlation is significant at the 0.01 level.

Table 10: Regression between plant growth parameters with seed yield.

	Growth parameters	R line ($\hat{Y}$= a+bx)	R^2
X1	Plant population	$\hat{Y}$= -7786.39+220.51X1	0.77
X2	Plant height	$\hat{Y}$= -273.08+65.33X2	0.03
X3	Seeds/pod	$\hat{Y}$= -1339.45+1204.00X3	0.84
X4	Pods/plant	$\hat{Y}$= -25.14+35.58X4	0.83
X5	No. of nodules	$\hat{Y}$= -946.29+54.84X5	0.71
X6	No. of branches	$\hat{Y}$= -91.94+627.49X6	0.64
X7	LAI	$\hat{Y}$= -527.92+458.93X7	0.71

R^2 = Coefficient of determination.

to Mohammadi and Amiri (2011), the competition between weeds and plants causes a 25.9% drop in soybean seed weight. These conclusions are corroborated by the results of (Urkurkar *et al.,* 1990 and Jain *et al*., 1993).

Plant growth and yield attributing parameters with soybean grain yield

The correlation amongst weed density of different species with total weed dry weight production was production was found positive and significant yield are presented in Table 9. The different plant growth and yield attributing parameters with grain yield indicated that seeds per pod had highest positive correlation (0.921) amongst different yield attributing parameter followed by pods per plant (0.915), plant population (0.881), LAI (0.844), number of nodules (0.842), number of branches (0.802) and plant height (0.165). Amongst different yield attributing parameters, the linear increase in yield was predicted with seeds per pod, number of branches, LAI, plant population, plant height, number of nodules, pods per plant (Table 10). The increase in yield could be predicted by 1204.00, 627.49, 458.93, 220.51, 65.33, 54.84 and 35.58 kg/ha respectively. The total function of the yield components is the seed yield. Since the dry matter increases with improved photosynthesis, weeding the plant at the vital time and at the start of growth is one factor contributing to the increased seed output. Consequently, the plant will produce improved seed characteristics and the nutrients will be well-translocated to the plant (Toppo *et al.,* 2012). The results of Jain *et al.* (1993) and Urkurkar *et al*. (1990) support these conclusions. Variability in yield was observed in the number of pods per plant, followed by seeds per plant. The other weed control treatments showed the same patterns. That is, an increase of merely one pod per plant per unit area results in a 35.58 kg yield ha^{-1}.

CONCLUSION

Based on the results and discussion, it can be inferred that the various plant growth and yield attributing parameters with seed yield showed that the plant height, number of nodules, number of branches, pods per plant, plant population, LAI and seeds per pod had the highest positive correlation among the various yield attributing parameters. On the other hand, *Phyllanthus urinaria, Cyperus iria* and *Mollugo pentaphylla* showed the most positive relation with the dry weight of the weed. *Echinochloa colona*, exhibited the lowest association coefficient with dry weight of weeds. Furthermore, regression analysis showed that *Phyllanthus urinaria* was the main contributor to the generation of weed dry weight; an increase in weed dry weight may be anticipated with the addition of one plant, followed by *Alternenthera philoxeroides*. However, *Cyperus iria* had the strongest negative regrassion with seed yield.

ACKNOWLEDGEMENT

The present investigation entitled “Efficacy of pre plant incorporation of herbicides on weed management, crop

growth and yield of soybean" was planned and taken up within the scope of the subject under study and the objectives framed out to realize the answers for the problem identified, as discussed in the chapter of introduction. A field experiment was conducted at BSP Unit, Department of Agronomy, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (M.P.) during *Kharif* 2019.

Disclaimers

The experiments were conducted in a Randomized Block Design (RBD) with eleven weed control treatment combinations, each consisting of three replications of herbicidal mixtures of Diclosulam 0.9% + Pendimethalin PPI herbicides at varying dose levels. These mixtures were compared to hand weeding and weedy check treatments. Results revealed that *Phyllanthus urinaria*, *Cyperus iria* and *Mollugo pentaphylla* showed the strongest positive association with the dry weight of the weeds and the other hand, *Echinochloa colona* exhibited the lowest association coefficient with dry weight of weeds. Regression analysis showed that *Phyllanthus urinaria* decreased yield to a certain degree. Seeds per pod exhibited the largest positive association among the different yield attributing parameters, followed by pods per plant, plant population, Leaf area index, nodules per plant, branches per plant and plant height, according to the various crop growth and yield attributing parameters with grain production.

Informed consent

The research objectives, procedures, potential hazards and benefits were thoroughly explained to the participants in this study. They were assured that their participation was entirely voluntary and that they could withdraw at any time without incurring any consequences. Confidentiality of personal information and data was preserved throughout the investigation. Prior to the commencement of the investigation, all participants were granted written consent.

Conflict of interest

The authors declare no conflict of interest regarding the research, authorship, or publication of this study.

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