Turkish Journal of Agriculture - Food Science and Technology, 11(6): 1080-1086, 2023
DOI: https://doi.org/10.24925/turjaf.v11i6.1080-1086.5795

Turkish Journal of Agriculture - Food Science and Technology

Available online, ISSN: 2148-127X | www.agrifoodscience.com | Turkish Science and Technology Publishing (TURSTEP)

Evaluation of Sweet Blue Lupin (*Lupinus angustifolius* L.) Intercropped with Maize (*Zea mays* L.) at Different Planting Time Under Irrigation in the Highlands of Ethiopia

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ARTICLE INFO

Research Article

Received : 20-11-2022
Accepted : 13-06-2023

Keywords:
Sweet blue lupin
Dry matter
Intercropping
Grain yield
Planting date

ABSTRACT

A field experiment was conducted to evaluate the performance of sweet blue Lupin intercropped with maize at different planting time under irrigation in Ethiopia. For the experiment, sweet lupin (cultivar Sanabor) and Maize (cultivar PBH 3253) were used. The experiment was conducted in a randomized complete block design with four replications. The treatments were sweet lupin intercropped with maize simultaneously, 1, 2, 3, 4 and 5 weeks after maize planting. Sole maize was planted as control. Maize was planted in rows with spacing of 75 cm and 30 cm between rows and between plants, respectively. Lupin was planted between two maize rows (one maize row: two lupin row) 22.5 cm apart from maize row. The distance between lupin plants is 7 cm. In addition, maize rows were top-dressed N-fertilizer at the rate of 100 Kg ha^{-1} by dividing in to two at planting and at vegetative stage. Intercropping time had a significant effect on yield and yield components of sweet lupin, but not on maize. Lupin intercropped simultaneous with maize gave significantly higher dry matter and seed yield 1.05 and 1.71t/ha, respectively as compared to the four intercropping dates. Maize grain yield and maize stover yield were not affected by sweet lupin intercropping dates. This study showed that sweet lupin intercropped simultaneously with maize could be optimum sowing date for better grain and dry matter yield of sweet lupin without affecting maize grain and stover yield under irrigation condition.

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Introduction

Ethiopia has a huge livestock population. However, compared to the potential the contribution of the sector to the economy is low. Feed problem is one of the major factors that hinder the development of the sector. Out of the total supply of livestock feeds in Ethiopia, 55% is derived from green forage (grazing), 31% from crop residues, 1% from improved feeds, 7% from hay, 2% from agro-industrial by-products and 4% from other sources (CSA, 2021). In Ethiopia, local feed resources such as crop residues and natural pasture are generally high in fiber, deficient in many minerals and vitamins, low in protein and energy, yet they form the main source of animal feed. This has resulted in significant decrease in milk production, loss of body weight, reduced draught power, increased susceptibility to diseases, and reduced reproductive performance, retarded growth rate and high mortalities of young animals which is especially severe during the long dry season (Alemayehu, 2006). To utilize the potentials of the livestock sector, use of commercial feed or home-grown forage legumes as supplement feed to fill the nutrient deficit gap of the locally available feed resources is one option. However, commercial concentrate feeds are currently becoming very expensive and inaccessible to our smallholder farmers. Hence, there is a need to introduce multipurpose forage legume like lupin to our farming system. Lupin is a good source of nutrients, not only proteins but also lipids, dietary fiber, minerals and vitamins (Martínez-Villaluenga et al., 2009). Lupin generally contains about twice the amount of proteins found in those legumes, which are commonly consumed, by humans and livestock. In recent years, sweet blue lupins are introduced to Ethiopia and under rain fed condition are found to be adaptive, productive and palatable for livestock (Likawent et al., 2012).

In the high and mid altitude areas of Ethiopia the typical farming system is a mixed crop – livestock farming system. In this type of farming system smallholder farmers can easily intercrop multipurpose crops like lupin with cereals like maize under irrigation to facilitate adoption. Maize is a dominant cereal crop in Mecha district and its area of production is increasing from time to time more than any other crop. Several research works indicated that intercropping of cereals with legume crop is very productive compared to sole cropping (Ghosh et al., 2009). Thus, integration of forage legumes as lupin into maize based cropping system through intercropping is one of the interventions for optimizing the productivity of a given land use. According to Nigussie et al. (2014) maize lupin inter cropping was more productive than sole maize with land equivalent ratio (LER) of 1.6 and 2.18 at Achefer and Merawi, respectively. However, maize with sweet blue lupin intercropping time under irrigation condition in the study area was not known. In addition to studying about sweet blue lupin cultivar Sanabor intercropped with maize at different planting time under irrigation condition information about both yield and yield component is essential. Good timing of planting date is one of the key factors that strongly affect production. The advantage of determining appropriate planting time is necessary to optimum yield of intercropped plants without affecting the main crop. Hence, this experiment was conducted to evaluate the effect of planting date of the intercropped crop (sweet lupin) on yield and yield components of both the main crop, maize and the intercropped crop, sweet lupin.

Materials and Methods

Description of the Study Area

The study was conducted in Mecha District, in north-western Ethiopia. The study site was located at an altitude of 1800 m.a.s.l. The area receives an annual rainfall ranging from 1000 to 2000 mm and daily temperature from 24 -27^{o}C.

Planting Method and Management Practices

The improved maize variety PBH 3253 and the sweet lupin var. Sanabor were used for the experiment. Maize was planted in rows at the beginning of December. Maize was planted with a spacing of 75 cm and 30 cm between rows and plants, respectively on a net plot size of 3.75 m * 3 m. Spacing between blocks and plots was 1.5 m and 1 m, respectively. Fifteen days after the emergence of maize, thinning of maize to one plant per hill was undertaken. Sanabor was planted in double rows between two maize rows at 22.5 cm row spacing from the maize rows. However, the two consecutive lupin (Sanabor) rows had a row spacing of 30 cm in between maize rows and 7 cm plant spacing (Likawent et al., 2012). Lupin was planted simultaneous with maize planting and 2, 3, 4 and 5 weeks after maize planting. Fertilizer was applied at the rate of 87 kg N ha^{-1} and 46 kg P ha^{-1} was applied for maize. The whole DAP was applied at planting. In addition, maize plots were top-dressed nitrogen fertilizer by dividing in to two; at planting and at vegetative stage. The plots were irrigated until field capacity once in a week using furrow irrigation method.

Field Experimental Design and Treatments

The experiment was conducted in a randomized complete block design (RCBD) in four replications. The treatments were Sole maize (Control); T1: Lupin plus maize with simultaneous planting; T2: Lupin planted 2 weeks after maize planting; T3: Lupin planted 3 weeks after maize planting; T4: Lupin planted 4 weeks after maize planting; T5: Lupin planted 5 weeks after maize planting.

Sampling and Sample Processing

Maize was harvested from middle three rows at maturity. Maize cobs were removed, sun-dried for one week and shelled. The seed was separated from the cob manually after drying and finally grain yield was expressed in kg ha^{-1}adjusted to 12% moisture (Zandstra et al., 1981) content using Farmex MT-16 grain moisture tester. Maize stover from the net plot was tied together and left on the plot to sun-dry to a constant weight. Dried stover was weighed on the field to obtain stover yield per plot.

For sweet lupin forage and grain yield sampling each plot was divided in to two equal parts cross-sectional. One half was used for forage sampling and the other for seed sampling. Forage sampling was done when the plants reached around 50% flowering stage and seed sampling at maturity, when the seed pods becoming yellowish. In both cases the sampling was done from the middle four rows excluding the border rows. Immediately after sampling the fresh biomass was weighed to estimate green biomass yield. Forage sample was air dried until constant weight obtained for DM determination. Seed samples were air dried to constant weight.

Data Analysis

Plant height at maturity of maize was taken as an average of ten plants per plot. Similarlyfor lupin plant height (cm) at maturity, number of pods per plant, number of branch per plant and number of seeds per pod were taken as average of ten plants per plot. However, the grain and biomass yield for both crops were taken from the middle rows. The data collected for sweet lupin and maize was subjected to analysis of variance (ANOVA) by using SAS (2014) version 9.1.3.

Results

Effect of Intercropping Time On Growth and Yield Components of Lupin

Lupin plant height at harvest

Time of planting of lupin had significant (P<0.01) effect on plant height (Table 1). Maize plots that had lupin planted simultaneous and two weeks after maize planting were taller compared with the other three lupin planting dates. The tallest and shortest lupin plants were recorded in simultaneous and five weeks after maize plating dates, respectively.

Number of branches per plant

A highly significant effect of intercropping time was observed on the number of branches, in which highest mean was recorded when lupin was simultaneously planted with maize. The lowest number of branches per plant was observed when lupin was planted 5 weeks after maize planting.

Lupin forage dry matter yield

Dry matter yield of lupin is presented in Table 1. Lupin intercropped with Maize simultaneously and two weeks after maize planting gave significantly higher ($P<0.01$) dry matter yield 1.05 and 1 t/ha, respectively as compared to the other three intercropping dates. Overall, the poorest dry matter yield of lupin was recorded when lupin was introduced four and five weeks after maize planting.

Number of pods per plant

Lupin simultaneously planted with maize had on average higher pods per plant than those planted 2, 3, 4 and 5 weeks after maize planting. Overall, the poorest number of Pods per plant of lupin was recorded when lupin was planted five weeks after maize planting. The lower number of pods per plant recorded in lupin at later planting dates was probably due to the shading effect of the taller component crop maize, which obstructed solar radiation from penetrating into the lupin (lower canopy).

Number of seeds per pod

Lupin simultaneously planted with maize had on average higher number of seeds per pods than those planted 2, 3, 4 and 5 weeks after maize planting. Overall, the poorest number of pods per plant of lupin was recorded when lupin was planted five weeks after maize planting.

Thousand seed weight

Time of lupin planting had significant ($P<0.01$) effect on thousand seed weight. Lupin planted simultaneously and 1, 2, and 3 weeks after maize planting had on average higher thousand seed weight than those planted 4 and 5 weeks after maize planting. Overall, the poorest thousand seed weight of lupin was recorded when lupin was planted five weeks after maize planting.

Lupin grain yield

Lupin simultaneously planted with maize gave the highest lupin grain yield compared to other planting times. In the present study, delayed planting of lupin progressively reduced grain yield of lupin.

Plant Height, Grain and Stover Yield of Maize

Maize plant height at harvest

The finding showed that the intercropping of lupin with maize did not influence the height of maize in all treatments (Table 3).

Maize grain yield, thousand seed weight and stover yield

Results showed that maize grain yield, thousand seed weight and maize stover yield were not affected by lupin intercropping date.

Discussion

Effect of intercropping time on growth and yield components of lupin

Lupin plant height at harvest

High plant height recorded for lupin planted after maize could be associated with competition and shading effect of maize crop. This result is in line with the finding of Sarkodie-Addo and Abdul-Rahaman (2012) who reported that growth rate of soybean was best when planted simultaneously with maize and this effect was significantly different from introducing the soybean at 1 or 2 weeks after maize planting. Similarly, Tamiru (2013) observed that the highest height of intercropped haricot bean was recorded when it is simultaneously planted than4 and 8 weeks after maize planting.

Table 1. Effect of time of planting of lupin when intercropped with maize on lupin plant height (cm), number of branch per plant and Lupin forage dry matter yield t/ha.

Treatment	Plant height at harvest	No of branch per plant	Forage dry matter yield
Sole maize	-	-	-
Lupin planted simultaneously with maize	55.08^{a}	5.73^{a}	1.05^{a}
Lupin planted2 weeks after maize planting	50.90^{ab}	4.65^{ab}	1.00^{ab}
Lupin planted3 weeks after maize planting	49.90^{b}	4.28^{ab}	0.83^{bc}
Lupin planted4 weeks after maize planting	49.55^{b}	3.15^{bc}	0.66^{cd}
Lupin planted5weeks after maize planting	47.93^{b}	2.45^{c}	0.51^{d}
Overall mean	50.67	4.05	0.81
SE	0.69	0.29	0.05
CV	3.85	16.98	9.32

Means within a column followed by different superscript are significantly different ($P<0.01$); SE= standard error; CV= coefficient of variation

Table 2. Effect of time of planting of lupin when intercropped with maize on lupin pod per plant, seeds per pod, grain yield (t/ha), thousand seed weight (g)

Treatments	No of pod per plant	No of seeds per pod	Grain yield	Thousand Seed weight
Sole maize	-	-	-	-
Lupin simultaneously with Maize	12.30^{a}	4.63^{a}	1.71^{a}	138.80^{ab}
Lupin 2 weeks after Maize planting	11.32^{ab}	4.03^{b}	1.39^{ab}	142.18^{a}
Lupin 3 weeks after Maize planting	9.13^{bc}	3.83^{bc}	1.05^{bc}	139.23^{ab}
Lupin 4 weeks after Maize planting	7.15^{cd}	3.40^{cd}	0.52^{cd}	132.65^{bc}
Lupin 5weeks after Maize planting	6.58^{d}	3.15^{d}	0.37^{d}	131.85^{c}
Overall mean	9.29	3.81	1.01	136.94
SE	0.552	0.12	0.125	1.081
CV	11.24	6.43	25.79	2.23

Means within a column followed by different superscript are significantly different ($P<0.01$); SE= standard error; CV= coefficient of variation

Table 3. Effect of time of planting of lupin when intercropped with maize on maize plant height (cm), thousand seed weight (g), grain and stover yield (t/ha)

Treatments	Plant height at harvest	Thousand seed weight	Maize grain yield	Maize Stover dry matter yield
Sole maize	206.83	494.65	9.19	11.73
Lupin simultaneously with Maize	208.96	510.98	9.69	11.19
Lupin 2 weeks after Maize planting	205.38	489.30	8.95	10.97
Lupin 3 weeks after Maize planting	206.25	498.88	8.45	10.49
Lupin 4 weeks after Maize planting	210.45	520.98	9.37	11.01
Lupin 5weeks after Maize planting	207.00	534.83	8.95	11.13
Overall mean	207.50	508.14	9.10	11.09
SE	0.738	5.514	0.185	0.213
CV	1.23	4.42	10.08	9.28

Means within a column followed by different superscript are significantly different (P<0.01); SE= standard error; CV= coefficient of variation

Number of branches per plant

High mean number of branches for lupin which was planted together with maize in the current finding agrees with Tamiru (2013) who reported that a highly significant effect of intercropping time was observed on the number of branches, in which highest mean number of branch being recorded when legumes were simultaneously planted with maize. This result is in line with Adipala et al. (2002) who reported that cowpea simultaneously planted with maize had on average more branches per plant than those planted two and four weeks after maize planting. The same authors reported that simultaneous seeding of legume crops with maize resulted in taller plant with better canopy than the mono-crop; whereas delayed intercropping of legumes in established maize stand were observed to result in inferior plants with poor canopy. Accordingly, simultaneously intercropped legumes exhibited a high degree of morphological plasticity compared to sole crop, presumably in response to increased competition for light (Redfearn et al., 1999; Carruthers et al., 2000).

Lupin forage dry matter yield

The current result indicated that, when planting date of lupin delayed dry matter yield decreased. This might be attributed to competition to resources especially light as maize in its shading effect reduces lupin growth. Samuel and Mesfin (2003) reported mean dry matter forage yield of 2.1 t/ha and 0.82 t/ha for Lablab and Cow pea, respectively when intercropped with Sorghum in Eastern Amhara. This result is lower than the values reported in this study which could be associated with difference in forage legume species and date of intercropping**.**

The Dry matter yield of lupin in this study is lower than Muyekho (1999) who reported as a sole mean forage yield of 2.5 t/ha from the sweet white lupin cultivar (Ultra) when harvested at three months of age. In addition, the forage yield reported by Bhardwaj et al. (2010), of white lupins, in the United States ranged between 0.8 and 2 t/ha. According to Likawent (2012) that narrow leafed lupin forage yield when planted sole ranged between 0.7 and 1.6 t/ha in mid and high attitude areas of Ethiopia, respectively. These differences are associated with the growing situations of lupin and lupin species difference. Ofori and Stern (1987); Russell and Caldwell (1989) working on cereal/legume intercropping noted that higher density of maize in intercropping shaded the cowpea, caused by higher maize height and reduced cowpea growth. This result is in line with Getachew et al. (2013) who reported that above ground dry biomass yield of lablab was significantly reduced by 74.5% in the intercropping as compared to the sole cropping system. Tessema and Demekash (2001) also reported that the growth and yield of under sown forage legumes were lower in contrast to sole cropped forage legumes, which may possibly be due to restricted light penetration and/or competition for light where maize crop was at full vegetative stage. Furthermore, Amede et al. (2005) reported a high vetch biomass reduction in intercropping of two maize varieties, ACV6 and A511.

A consistent decline of total biomass yield of the lupin was observed with delay in time of planting. In a similar study, Mburu et al. (2003) reported that intercropping in general and delayed planting of Mucuna in maize in particular, significantly and drastically depressed Mucuna biomass yields compared to sole Mucuna. Reddy and Visser (1997) also found that delaying cowpea sowing by seven weeks after millet led to significantly lower growth and dry matter yields of cowpea compared to simultaneous sowing. Gbaraneh et al. (2004) similarly accounted a consistently reduced biomass accumulation of later-planted lablab in the intercropping system with maize compared to those simultaneously planted.

Number of pods per plant

The result on number of pods in the present result is inconsistent with Likawent et al (2012) who reported that Sanabor cultivar pods per plant ranged from 14.4-42.5 in the mid and high-altitude areas of Ethiopia when grown as a sole crop. The lower number of pods per plant in this study might be due to intercropping situation. According to Munner et al. (2004) maximum number of pods per plant27.81 was recorded in soybean alone and minimum 14.11-14.32 pods per plant were recorded in maize intercropped with soya bean treatments. According to Munner et al. (2004) results indicate that number of pods per plant of soybean was significantly affected by inter cropping treatments. Maximum number of pods 27.81 per plant was recorded in soybean alone and minimum 14.11 and 14.32 pods per plant were recorded in intercropped treatment.

Number of seeds per pod

The overall mean number of seeds per pod reported in this study is lower than the result reported by Yayeh (2014) who reported that the highest and the lowest seed per pod were recorded at sole lupin (6.08) and lupin-cereal combination at 25:100 seeding ratios (4.26), respectively. This could be associated with differences in growing season in which the experiments done and the effects of the associated main crop.

Thousand seed weight

The thousand seed weight recorded in this experiment is lower than the report by Likawent et al. (2012) who reported a thousand seed weight of 295, 156 and 128 g for white, blue and yellow lupins in mid and high attitude of Ethiopia as a sole crop. However, Yayeh (2014) reported that thousand seed weight was improved when lupin is intercropped with cereals. The same author reported that a thousand seed weight of 337 g in sole lupin and 398 g for lupin-cereal combination at 25:100 seeding ratio for white lupin.

Lupin grain yield

The progressive decline in both the growth and yield of the lupin with delayed planting after maize planting indicated that there was inter-specific competition, as maize canopy may have been established resulting in the shading effect on lupin. Earlier report by Akobundu (1993) confirmed that when maize plant becomes taller than the associated cowpeas under intercropping, radiation becomes less available to the cowpeas. Maize had been reported to be a greater competitor in mixtures which has the advantage of being taller than cowpea and might intercept more light than cowpea (Muoneke and Asiegbu, 1997). The results of this study were in agreement with the findings of Gondebe et al. (2010) who reported that the time of introducing cowpea into maize significantly affected the yield of cowpea. The current result is in line with Tariah and Wahua (1985) who found that sowing cowpea two weeks after maize reduced cowpea yield but favored the intercropped maize. The higher lupin grain yield in this study for the simultaneous planting could be attributed to early competition for growth factors. This may be because the lupin did not suffer early shading from the maize because they both started growing around the same time. In the high and mid altitude areas of Ethiopia in the main rainy season it was observed that when blue lupin cultivar Sanabor was grown as sole crop it can give grain yield up to 4.8 t/ha (Likawent, 2012) which is much higher than the result in this study. This may be due to the absence of inter-specific competition, intra-specific competition as well as adequate plant population in the sole plots. Although, there was a general reduction in the yield of lupin as a result of intercropping, highest grain yield among the combination was recorded in lupin-finger millet intercropping (1749 kg/ha) followed by lupin-wheat (1407 kg/ha) intercropping systems as compared to lupin-barley (757 kg/ha) combination (Yayeh, 2014).

Plant Height, Grain and Stover Yield of Maize

Maize plant height at harvest

The maize height in the present study current result is in line with Alemu and Tikunesh (2014) who reported that intercropping of forage legumes like cowpea, lablab and vetch did not influence the height of maize stover. However, the current result contradicts with the result reported by Amujoyegbe and Elemo (2013) who reported that the time of intercropping of cowpea had significant effect on plant height of maize at 6 and 9 weeks after maize planting. Maize in plots that had cowpea introduced early (simultaneous sowing with maize) and with little delay of 14 days were taller compared with those that had cowpea sown at 42 days after sowing maize. The early introduction of cowpea may have facilitated the fixation of N in the soil which is mobile and highly required thus making it available for the growth of the crop. According to Beatrice and Eliakira (2014) maize plant height differed significantly between a maize plant grown under sole and that in intercropping system and their differences ranged between 145.9 and 288.6 cm. The same authors reported that maize plant height (222.9 cm) obtained in sole maize was taller compared with that in the maize intercropped with cowpea (211.6 cm).

Maize grain yield, thousand seed weight and stover yield

Similar result is reported by Gabatshele et al. (2012) who reported that maize dry matter weight was not affected by intercropping legumes. Other result indicated that maize yields were not significantly affected by the inclusion of cowpea which could be associated with the height advantage of maize crop compared to cowpea (Mandal et al., 2010). Maize is usually taller with a faster growing or more extensive root system; particularly a larger mass of fine roots and is competitive for soil nitrogen (Carr et al.,1998; Carruthers et al., 2000).

The current result is also in line with Getachew et al. (2013) who reported that intercropping of both lablab and vetch legumes had no significant influence on the yield (grain and stover) of maize. This indicated the possibility of integration of forage legumes into maize without significant effect on its yield. According to Tamado et al. (2007) growing of common bean in double inter cropping with maize had no significant effect on maize height and grain yield. In this study in all the treatments, the maize plant had the monopoly over sunlight and soil nutrients enabling the maize to establish good stand in growth. In such a case, since the maize plant already has a tall stature than the lupin there is no way the lupin will catch up with the maize again to compete for sunlight as compared to maize. Concerning the soil nutrients, once the maize establishes a good roothold on the soil before the lupin begins to root, the maize root will have advantage on nutrient uptake than the lupin. Most of the reported work on maize-cowpea mixtures indicated a reduction in cowpea yields while maize yields were unaffected. However, the competitive effects from the maize component could be reduced by sowing cowpea early (Haizel, 1974; Isenmilla et al.,1981; Olufajo,1988; Cardoso et al., 1993). Myaka (1995) showed that when sown four weeks after maize, cowpea yields were 67% less than cowpea planted two weeks after maize. In both cases, maize yields were not affected by the cowpea component.

Maize grain yield, thousand seed weight and stover yield

The current yield of maize is similar to the reports of Amujoyegbe and Elemo (2013) reported that the time of introducing cowpea had no effect on the yield of the maize planted. Time of sowing cowpea had highly significant effect on the grain yield of cowpea. Optimum yields were obtained at 0 to 14 days after planting of maize after which the grain yield reduced significantly. The same authors reported that it is not beneficial to introduce cowpea into a maize system after 14 days of establishing maize as maize canopy will affect the agronomy, yield and productivity of cowpea. According to Getachew et al. (2013) integration of forage legumes (lablab and vetch) into maize as an intercropping system can increase productivity per unit of land, enable additional forage crop production without significant sacrifice of maize grain and stover yield and can improve the stover feed value.

Conclusion

Good timing of planting date is one of the key factors that strongly affect crop productivity. The advantage of determining appropriate planting time is necessary to get optimum yield of intercropped plants without affecting the main crop. Lupin intercropping with maize had no significant effect on the yield of maize in terms of maize grain yield and maize stover yield under irrigation condition. Lupin intercropped with maize simultaneously and two weeks after maize planting gave significantly higher dry matter and grain yield as compared to the other three intercropping dates (three, four and five weeks after maize planting). Overall, the poorest dry matter and grain yield of lupin was recorded when lupin was planted four and five weeks after maize planting. From the result of this study delayed planting date of sweet lupin when intercropped with maize under irrigation had a negative effect on dry matter and grain yield of lupin which could be associated with the shade effect of maize plant. This study showed that Lupin intercropped simultaneously with maize could be optimum sowing date for better dry matter and grain yield of lupin without affecting maize grain and stover yield under irrigation condition.

Declarations

***Funding*:** Not applicable

Authors' contributions: All authors contributed in research conceptualization, experimental design, data collection and analysis, and final draft manuscript writing.

***Conflict of interest*:** The authors declare there is no conflict of interest in the publication of this paper.

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