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Research Article

Exploring the Impact of *Gypsophila perfoliata* L. Root Extract on Germination and Seedling Growth Parameters of Sweet Sorghum and Hungarian Vetch

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Abstract

In recent years, there has been a growing emphasis on exploring alternative approaches, such as the utilization of medicinal plant extracts and essential oils, to address potential limitations in germination and emergence, as opposed to traditional chemical methods. Biochemicals synthesized in medicinal and aromatic plants can elicit either stimulating or inhibitory effects on the growth and development of other plants. This study aimed to investigate the impact of gypsophila plant root extract on the germination and seedling development of vetch and sorghum, assessing different concentrations of the extract (0%, 5%, and 10%). Upon evaluating the results, it was observed that the sorghum plant exhibited the highest germination rate, mean germination time, germination vigor index, root and shoot length, as well as root and shoot fresh weight when subjected to the control concentration. In contrast, the vetch plant demonstrated optimal results at the 5% concentration. In conclusion, the inhibitory effect of the gypsophila plant root extract on germination and seedling development was more pronounced in the sorghum plant compared to the vetch plant. This suggests that the impact of the extract varies among different plant species, highlighting the need for species-specific considerations when implementing such alternative approaches in agricultural practices.

Keywords: Root extract, gypsophila, vetch, sorghum, germination

Çöven (*Gypsophila perfoliata* L.) Kök Ekstraktının Tatlı Sorgum (*Sorghum bicolor* L.) ve Macar Fiğ (*Vicia sativa* L.) Tohumlarının Çimlenme ve Fide İle İlgili Parametreler Üzerine Etkisi

Öz

Son yıllarda, geleneksel kimyasal yöntemlerin aksine, çimlenme ve ortaya çıkmadaki potansiyel sınırlamaları ele almak için tıbbi bitki ekstraktlarının ve uçucu yağların kullanımı gibi alternatif yaklaşımların araştırılmasına artan bir vurgu yapılmıştır. Tıbbi ve aromatik bitkilerde sentezlenen biyokimyasallar, diğer bitkilerin büyüme ve gelişmesi üzerinde uyarıcı veya engelleyici etkiler ortaya çıkarabilir. Bu çalışma, çöven bitkisi kök ekstraktının fiğ ve sorgumun çimlenmesi ve fide gelişimi üzerindeki etkisini, ekstraktın farklı konsantrasyonlarını (%0, %5 ve %10) değerlendirerek araştırmayı amaçlamıştır. Sonuçlar değerlendirildiğinde sorgum bitkisinin kontrol konsantrasyonunda en yüksek çimlenme oranı, ortalama çimlenme zamanı, çimlenme gücü indeksi, kök ve sürgün uzunluğu ile kök ve sürgün yaş ağırlığına sahip olduğu saptanmıştır. Buna karşılık, fiğ bitkisi %5 konsantrasyonda optimal sonuçlar göstermiştir. Sonuç olarak, çöven bitkisi kök ekstraktının çimlenme ve fide gelişimi üzerindeki inhibitör etkisi sorgum bitkisinde fiğ bitkisine göre daha belirgin olmuştur. Bu sonuç, ekstraktın etkisinin farklı bitki türleri arasında değiştiğini ve tarımsal uygulamalarda bu tür alternatif yaklaşımların uygulanmasında türe özgü değerlendirmelerin daha önemli olduğunu göstermektedir.

Anahtar Kelimeler: Kök özütü, çöven, fiğ, sorgum, çimlenme

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1. Introduction

Forage crop production holds immense significance on international and domestic fronts as it provides a sustainable means to feed animals and supports livestock farming at a reasonable cost [1]. Legumes and cereals are particularly crucial among the plant types cultivated for animal feeding purposes globally. Vetch (Vicia sativa L.), a member of the Fabaceae family, stands out as one of the major genera, encompassing 247 taxa worldwide [2], with approximately 100 taxa found in Türkiye [3]. Vetch serves diverse purposes, including the production of green and dry forage, grain, green manure, and as a source for livestock grazing, owing to its high-quality forage attributes [4]. Its notable forage quality not only makes it a valuable resource for various agricultural purposes but also contributes to reducing the overall costs associated with livestock feeding [5]. Sorghum (*Sorghum bicolor* L.), belonging to the Poaceae family within the Sorghum Moench genus, holds the distinction of being the fifth most important C4 plant globally. Cultivated for various purposes such as fuel, forage, roughage, and food, sorghum stands out due to its versatility [6; 7]. The cultivation of sorghum plays a significant role in meeting diverse agricultural needs, making it a valuable and adaptable resource on a global scale.

The challenges posed by water scarcity, drought, and difficulties in accessing food, compounded by the negative impacts of global warming, are becoming increasingly pronounced with the growing world population [8]. Consequently, there is a pressing need to cultivate plants that exhibit water efficiency, drought tolerance, and high productivity. In semi-arid regions, low humidity levels during germination becomes a limiting factor [9], turning the germination period into a critical phase that significantly influences both yield and quality in agricultural production [10]. Various phytohormones, including brassinosteroids, auxins, ethylene, cytokinins, salicylic acid, jasmonic acid, and strigolactones, along with specific compounds such as karrikins and reactive oxygen species, play a crucial role in dormancy and germination processes [11]. Natural methods that promote germination, such as seaweed, medicinal plant extracts, vinegar, and essential oils, offer environmentally friendly alternatives [12]. However, the conventional use of chemicals in agriculture raises input costs and contributes to environmental pollution. Therefore, there is a growing emphasis on adopting sustainable and eco-friendly practices in agriculture to address these challenges and promote the long-term health of both the agricultural ecosystem and the environment.

Indeed, contemporary agricultural practices need to prioritize techniques that not only enhance the yield and quality of seeds or seedlings but also reduce costs and minimize environmental pollution. Plant-synthesized biochemicals emerge as pivotal players in promoting or inhibiting various plants' growth and development [13]. These secondary metabolites, characterized by their diverse structures, carry significant economic value due to their wide-ranging applications in medicine, antibiotics, antioxidants, flavor sources, food additives, allelochemicals, antifungals, insecticides, fertilization stimulants, and growth regulators [14]. The concept of allelopathy is crucial in this context, referring to the phenomenon whereby plants influence the growth and development of other plants, either positively or negatively, through the synthesis or decomposition of specific compounds [15]. Harnessing the potential of allelopathic interactions and plant-synthesized biochemicals provides an avenue for sustainable agricultural practices that optimize productivity and contribute to environmental conservation and the overall health of agroecosystems. As we navigate the challenges of a changing climate and a growing global population, these approaches become increasingly important in creating resilient and sustainable agricultural systems.

Gypsophila, categorized among medicinal and aromatic plants, possesses diverse features that have captured the interest of various scientific disciplines. The species within the Gypsophila genus, characterized by significant levels of saponins, find application as additives in medicine, cleaning products, and food items. The roots of this plant have been a source of saponins for centuries, valued for their antibiotic, antifungal, and pharmacological effects [16]. Saponins, primarily synthesized by plants, are broadly classified into steroidal and triterpenoid glycoside compounds [17]. These compounds are believed to protect plants against certain insects owing to their antimicrobial properties and enhance resistance in specific plant parts [18]. Furthermore, saponin compounds exhibit high biological activity in plants, fungi, insects, and microorganisms. While low concentrations play a regulatory role in plant rooting, elevated concentrations are reported to inhibit root growth [19]. Therefore, a comprehensive exploration of the detailed physiological effects of saponins and saponin-rich materials on plants remains an open area of research. Soliman et al. [20] demonstrated that priming soybean seeds with 5% and 10% concentrations of saponin effectively alleviated salinity stress. In a study conducted by Yang et al. [21], seven different concentrations of saponin priming were applied to quinoa seeds to mitigate the adverse effects of salinity stress. These findings highlight the potential of saponins in enhancing stress tolerance in plants, opening avenues for further research into their applications in sustainable agriculture, especially in mitigating environmental stresses that can impact crop productivity.

The current research represents a pioneering study aiming to address a gap in the existing literature by investigating the effects of Gypsophila extract on the germination and seedling growth patterns of vetch and sorghum plants. The study was conducted by applying Gypsophila extract to sweet sorghum and Hungarian vetch seeds to determine its effects on germination and seedling growth-related traits.

2. Material and Methods

In this study, the Helvaci Gypsophila (*Gypsophila perfoliata*) plant material was used to determine its impact on germination and seedling-related traits in Cowley sweet sorghum (*Sorghum bicolor*) and Aygün hungarian vetch (*Vicia pannonica* Crantz). Seeds were initially washed with tap water for surface sterilization, followed by soaking in a 10% sodium hypochlorite ($NaClO4$) solution for 25 minutes. Subsequently, the seeds were rinsed three times with sterile distilled water, immersed in a 70% ethyl alcohol solution for 5 minutes. They washed three more times with sterile distilled water to complete the sterilization process. Gypsophila perfoliata, a commercially significant species, was used in three concentrations (0%, 5%, and 10%) according to a completely randomized design with three replications. Gypsophila roots, collected from Adabağ village in Ereğli (Konya), were dried in a dust-free environment without direct sunlight for seven days in the Laboratory of the Department of Field Crops at Necmettin Erbakan University, Ereğli Faculty of Agriculture. Before extraction, the

Gypsophila roots were finely divided into small pieces. For the 10% concentration, 100 grams of dried Gypsophila roots were boiled in 1 liter of distilled water for 20 minutes and then cooled to room temperature. The resulting extract was filtered and stored in a refrigerator (+4°C) during the experiment.

In the trials, containers with base dimensions of 7.5 mm width and 12 mm length were prepared by placing two layers of germination paper (Whatman filter paper No. 1) on the base, and 25 seeds were placed on top. Application groups were treated with 5 ml of Gypsophila root extract, while control groups received 5 ml of distilled water. The seeds were germinated in a 16:8-hour light:dark photoperiod at 24-26°C room temperature over a 14-day period. Germination-related parameters were recorded by counting the seeds each day during this period. Germination rate (GR) (%), germination rate coefficient (GRC), germination rate index (GRI), mean germination time (MGT), and germination vigor index (GVI) were calculated according to Türkoğlu et al. [22]. Seeds with a root length of 1 mm or longer were considered germinated. On the 14th day of the study, five seedlings were randomly selected from each treatment, and root and shoot lengths were measured using a metric ruler, while root and shoot fresh weights were measured using a precision balance [23].

The statistical analysis of the data was subjected to a factorial design variance analysis with plant (2) and application concentration (3) as factors, following a completely randomized trial plan with four replications (SPSS 26 software, SPSS Inc., IBM). The Duncan test determined differences between means for these parameters at a 5% significance level.

3. Results and Discussion

Germination-Related Traits

The seeds placed in the environment at different concentrations germinated within approximately 1-2 days, and their development was ensured over the 14 days.

Germination Rate (GR)

The plant and plant x concentration interaction had a highly significant effect ($p \leq 0.01$) on the germination rate, while the concentration was not significant ($p \geq 0.05$) (Table 1). The mean germination rate data shows that the highest germination rate was observed in the sorghum plant at 88.89%, while the lowest amount was observed in the vetch plant at 56.00% (Table 2). Considering the means of concentrations, the highest germination rate without a significant difference was obtained at the 10% concentration of Gypsophila root extract (Table 2). Looking at the means of the plant x concentration interaction data, the highest germination rate in the sorghum plant was achieved at 96.00% with the control dose of Gypsophila extract, and the lowest germination rate was 44.00% with the control dose in the vetch plant.

Table 1. Analysis of variance results of different concentrations of gypsophila root extract applied to vetch and sorghum plants for the studied traits.

		Mean of squares				
Source of Variation	**SD**	**GR**	**GRC**	**GRI**	**MGT**	**GVI**
Plant (P)	1	4867,56^{**1}	4756,85**	0,03**	17,42**	146008985,74**
Concentration (C) (%)	2	27,56^{ns}	143,36**	0,00^{ns}	0,66**	28440373,23**
P×C	2	491,56**	1306,53**	0,00**	2,72**	52349984,46**
Error	12	43,56	130,51	0,00	0,02	317478,93
Total	18					

[1] : **: significant at $p \leq 0.01$., ns: non-significant at $p \geq 0.05$. GR (%): Germination rate; GRC: Germination rate coefficient; GRI: Germination rate index; MGT: Mean germination time; GVI: Germination vigor index.

Table 2. Means of different concentrations of gypsophila root extract applied to vetch and sorghum plants for the studied traits.

Plant	**Concentrations**	**GR%**	**GRC**	**GRI**	**MGT (day)**	**GVI**
Vetch	0.00%	44,00±0,00^{b1}	35,48±0,00^{a}	0,10±0,00^{b}	2,82±0,00^{b}	888,80±0,00 ^{b}
	5.00%	65,33±10,07^{a}	21,00±1,13^{c}	0,16±0,02^{a}	4,77±0,25^{a}	3366,13±280,56^{a}
	10.00%	58,67±2,31^{a}	29,57±1,17^{b}	0,14±0,01^{a}	3,39±0,14^{b}	1778,40±318,51^{a}
	Mean	56,00±10,77^{B}	28,68±6,36^{B}	0,13±0,03^{B}	3,66±0,88^{A}	2011,11±1107,35^{B}
Sorghum	0.00%	96,00±0,00^{a}	51,06±0,00^{b}	0,23±0,00^{a}	1,96±0,00^{a}	13401,60±0,00^{a}
	5.00%	81,33±9,24^{a}	76,83±5,41^{a}	0,19±0,02^{a}	1,31±0,09^{b}	5878,13±1281,84^{b}
	10.00%	89,33±8,33^{a}	55,70±5,77^{b}	0,21±0,02^{a}	1,81±0,19^{a}	3842,13±285,67^{a}
	Mean	88,89±8,89^{A}	61,20±12,53^{A}	0,21±0,02^{A}	1,69±0,31^{B}	7707,29±4409,94^{A}
Gypsophila root extract	0.00%	70,00±28,48^{A}	43,27±8,53^{B}	0,17±0,07^{A}	2,39±0,47^{C}	7145,20±6853,54^{A}
	5.00%	73,33±12,31^{A}	48,91±30,78^{A}	0,17±0,03^{A}	3,04±1,91^{A}	4622,13±1606,79^{B}
	10.00%	74,00±17,66^{A}	42,63±14,79^{B}	0,18±0,04^{A}	2,60±0,88^{B}	2810,27±1162,29^{C}

[1]Numbers indicated with similar letters within the same column are statistically indistinguishable within a 1% margin of error according to the Duncan test. GR (%): Germination rate; GRC: Germination rate coefficient; GRI: Germination rate index; MGT: Mean germination time; GVI: Germination vigor index.

Germination Rate Coefficient

The plant, concentration, and plant x concentration interaction had a statistically significant effect ($p \leq 0.01$) on the germination rate coefficient (GRC) (Table 1). According to the mean statistical data, the highest germination rate coefficient was determined in the sorghum plant at 61.20, while the lowest was recorded in the vetch plant at 28.68 (Table 2). Evaluating the mean data of concentrations, the germination rate coefficient at the 5% dose was significant at 48.91 (Table 2). Looking at the mean data of the plant x concentration interaction, the highest germination rate coefficient in the sorghum plant was 76.83 at the 5% concentration, while the lowest in the vetch plant was 21.00 at the 5% concentration (Table 2).

Germination Rate Index

Statistically, the plant and plant x concentration interaction had a highly significant effect ($p \leq 0.01$) on the germination rate index (GRI), while the concentration's effect was found to be insignificant ($p \geq 0.05$) (Table 1). According to the mean data, the highest value in the germination rate index was 0.21 in the sorghum plant, and 0.13 in the vetch plant (Table 2). Evaluating the mean data of concentrations, there was no statistically significant difference, and the highest result, 0.18, was obtained at the 10% concentration (Table 2). Looking at the plant x concentration interaction, the germination rate index was highest in the sorghum plant at 0.23 in the control dose and lowest in the vetch plant at 0.10, again in the control dose (Table 2).

Mean Germination Time

According to the statistical data, the plant, concentration, and plant x concentration interaction had a highly significant effect ($p \leq 0.01$) on the mean germination time (MGT) (Table 1). Looking at the mean data, the mean germination time was highest in the vetch plant at 3.66 and lowest in the sorghum plant at 1.69 (Table 2). Evaluating the mean data of concentrations, the highest mean germination time was 3.04 at the 5% Gypsophila root extract concentration, and the lowest was 2.39 in the control (Table 2). Looking at the plant x concentration interaction data, vetch had the highest mean germination time at 4.77 at the 5% concentration, while sorghum had the lowest value at 1.31 at the 5% concentration (Table 2).

Germination Vigor Index

According to the variance analysis results, concentration and plant x concentration interaction had a highly significant effect ($p \leq 0.01$) on the germination vigor index (GVI) (Table 1). According to the mean data, the germination vigor index was highest in the sorghum plant at 7707.29 and lowest in the vetch plant at 2011.11 (Table 2). Evaluating the mean data of concentrations, the control concentration was significant at 7145.20 (Table 2). Looking at the plant x concentration interaction, the highest value was observed in the sorghum plant at 13401.60 in the control concentration, while the lowest was in the vetch plant at 888.80, again in the control concentration (Table 2).

Seedling-Related Characteristics

Root Length

Root length was found to be statistically significant ($p \leq 0.01$) concerning plant concentration and plant x concentration interaction (Table 3). Looking at the mean data, the highest root length was recorded in the sorghum plant at 3.81 cm, while the lowest was in the vetch plant at 0.97 cm (Table 4). According to the concentration statistical results, the highest, 3.68 cm, was obtained in the control concentration (Table 4). Regarding the plant x concentration interaction, the highest root length was 6.54 cm in the sorghum plant at the control concentration, and the lowest was 0.76 cm in the vetch plant at the 10% concentration prepared (Table 4).

Table 3. Variance analysis results for different Gypsophila root extract concentrations applied to vetch and sorghum plants for the studied traits.

		Mean of squares			
Source of Variation	**SD**	**RL**	**SL**	**RFW**	**SFW**
Plant (P)	1	3618,17**[1]	2266,89**	0,01**	0,01**
Concentration (C) (%)	2	951,27**	519,96**	0,00*	0,00*
P×C	2	987,63**	1787,95**	0,00*	0,02**
Error	12	2,64	28,93	0,00	0,00
Total	18				

1 : **: significant at $p \leq 0.01$., ns: non-significant at $p \geq 0.05$. RL (cm): Root length; SL (cm): Shoot length; RFW (g): Root fresh weight; SFW (g): Shoot fresh weight.

Table 4. Means of different Gypsophila root extract concentrations applied to vetch and sorghum plants for the studied traits.

Plant	Concentrations	RL (cm)	SL (cm)	RFW (gr)	SFW (gr)
Vetch	0.00%	8,20±0,00^b1	12,00±0,00^a	0,0200±0,0000^a	0,0100±0,0000^b
	5.00%	13,53±2,34^a	38,47±7,20^a	0,0400±0,0100^a	0,1000±0,0100^a
	10.00%	7,60±1,31^b	22,60±5,60^b	0,0233±0,0153^a	0,0533±0,0379^b
	Mean	9,78±3,1^B	24,36±12,41^B	0,0278±0,0130^B	0,0544±0,0436^B
Sorghum	0.00%	65,40±0,00^a	74,20±0,00^a	0,1000±0,0000^a	0,1800±0,0000^a
	5.00%	33,33±1,96^b	38,47±7,20^b	0,0800±0,0400^b	0,0833±0,0252^b
	10.00%	15,67±2,19^c	27,73±6,20^b	0,0400±0,0200^b	0,0633±0,0404^b
	Mean	38,13±21,88^A	46,80±21,60^A	0,0733±0,0346^A	0,1089±0,0590^A
Gypsophila root extract	0.00%	36,80±31,33^A	43,10±34,07^A	0,0600±0,0438^A	0,0950±0,0931^A
	5.00%	23,43±11,02^B	38,47±6,44^A	0,0600±0,0341^A	0,0917±0,0194^A
	10.00%	11,63±4,70^C	25,17±5,99^B	0,0317±0,0183^B	0,0583±0,0354^B

[1]Numbers indicated with similar letters within the same column are statistically indistinguishable within a 1% margin of error according to the Duncan test. RL (cm): Root length; SL (cm): Shoot length; RFW (g): Root fresh weight; SFW (g): Shoot fresh weight.

Shoot Length

Statistical analysis, considering plant, concentration, and plant x concentration interaction, revealed significant effects ($p \leq 0.01$) (Table 3). The mean shoot length was highest in sorghum plants, recorded as 4.68 cm, and lowest in vetch plants, measured at 2.43 cm (Table 4). According to concentration data, control concentration and the concentration prepared at 5% produced the most extended shoots, measuring 4.31 cm and 3.84 cm, respectively (Table 4). Examining the results of plant x concentration interaction, it was found that the highest value was 7.42 cm in sorghum plants at the control concentration, and the lowest was 1.20 cm in vetch plants at the control concentration (Table 4).

Root Fresh Weight

The statistical evaluation of root fresh weight showed significance for plant ($p \leq 0.01$), concentration, and plant x concentration interaction (Table 3). Analyzing the mean values revealed that the highest root fresh weight was 0.0733 g in sorghum plants, and the lowest was 0.0278 g in vetch plants (Table 4). Concentration-wise, control and 5% concentrations showed the highest values without significant differences, both measuring 0.600 g (Table 4). Plant x concentration interaction indicated that sorghum plants had the highest root fresh weight at the control concentration, measuring 0.1000 g. In contrast, vetch plants had the lowest at the control concentration, recording 0.200 g (Table 4).

Shoot Fresh Weight

The statistical analysis revealed the significance of both plant and plant x concentration interaction ($p \leq 0.01$), while concentration showed significance as well (Table 3). The highest shoot fresh weight was obtained in sorghum plants, reaching 0.1089 g, whereas the lowest was recorded in vetch plants at 0.0544 g (Table 4). According to mean values, control and 5% concentrations yielded the highest values, measuring 0.950 g and 0.917 g, respectively (Table 4). Plant x concentration interaction showed that sorghum plants had the highest shoot fresh weight at the control concentration, recording 0.1800 g, while vetch plants had the lowest at the control concentration, with a value of 0.0100 g (Table 4).

4. Conclusion

Over centuries, medicinal and aromatic plants have played an integral role globally in Daily life and culture [24]. These plants harbor bioactive secondary metabolites, including steroids, flavonoids, saponins, alkaloids, terpenes, and phenolic compounds, which exhibit a diverse array of properties such as antimicrobial, antifungal, antiallergic, antidiabetic, cardiovascular protective, antioxidant, anticancer, antithyroid, antihistaminic, antimalarial, anthelmintic, anti-inflammatory, antihypertensive, antispasmodic, and analgesic [25]. This study delves into the effects of Gypsophila plant extract, within the realm of medicinal and aromatic plants, on the germination and seedling-related traits of vetch and sorghum seeds. Upon evaluating the mean values, we observed that the control concentration exhibited the highest germination rate, mean germination time, germination vigor index, root and shoot length, and root and shoot fresh weight in sorghum. The highest values were observed in the 5% concentration of Gypsophila extract in vetch. The existing literature has explored the effects of extracts from various medicinal and aromatic plants on cultivated plants' germination and seedling development [13]. While many studies emphasize the inhibitory effects of plant extracts on germination and seedling development, dependent on factors such as plant species, chemical compound type, and dosage [26; 27], there are also findings indicating stimulatory effects of plant extracts on germination and seedling development [28]. For example, Türkmen and Işık [29] investigated the impact of extracts from different vetch species on germination. The results indicated that extracts from certain vetch species completely inhibited germination at specific doses. Another study by Day [30] explored the effects of extracts from the stem and roots of the ragweed plant on the germination and seedling development of wheat, barley, sunflower, and chickpea seeds, revealing variable effects on different crops. In conclusion, the findings from this research suggest that the root extract obtained from the Gypsophila plant has a more inhibitory effect on germination and seedling development in sorghum plants compared to vetch plants. This adds valuable insights to the existing knowledge on the interactions between medicinal plant extracts and different crop species, emphasizing the need for species-specific considerations in agricultural practices.

Ethics in Publishing

There are no ethical issues regarding the publication of this study.

Author Contributions

Türkoğlu, A. concept; Armağan, M. and Türkoğlu, A. design; Işık, M. I. and Genç, A. resources; Işık, M. I. and Armağan, M. materials; Türkoğlu, A. and Genç, A. data collection and processing; Türkoğlu, A. data validation; Türkoğlu, A. analysis and interpretation; Türkoğlu, A. and Işık, M. I. literature search; Türkoğlu, A. and Işık, M. I. writing; Türkoğlu, A. and Armağan, M. critical reviews. All authors have read and agreed to the published version of the manuscript.

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