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Inhibitory Efficacy of *Selected Seuada* Extracts Against Pathogenic Microbs

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Abstract:

This study aims to evaluate the inhibitory efficacy of some species of the genus *Suaeda* extracted from three *Seuada* species; *S. altissima***,** *S. carnosissima***,** and *S. fruticosa* against a selected group of pathogenic bacteria, including *S.aureus , S. epidermidis* , *E. coli ,* and *P. aeruginosa* and dermatophytic fungi, including *Epidermophyton floccosum* and *Microsporum canis.*. Plant extracts were prepared following standardized protocols, and their antimicrobial activity was assessed using the agar well diffusion method at four concentrations (10, 25, 50, and 100 mg/mL). The results revealed that antimicrobial activity clearly dependent on both extract type and concentration. Tannins and glycosides were the primary bioactive compounds contributing to significant zones of inhibition, particularly in extracts of *S. fruticosa***.** Dermatophytic fungi and Gram-positive bacteria showed the highest susceptibility to the extracts, whereas Gram-negative bacteria exhibited lower sensitivity. The findings highlight the promising potential of the *Suaeda* genus, particularly *S. fruticosa*, as a valuable natural source of antimicrobial compounds. These bioactive constituents could be further explored and developed for pharmaceutical applications, with relevance to the treatment of skin infections and combating antibiotic-resistant bacteria.

Keywords: Agar well diffusion test, Antimicrobial activity, dermatophytes, *S. fruticosa, S. altissima, S. carnosissima*.

اختبار الفعالية التثبيطية
لبعض مستخلصات *Seuada* من نباتات السويداء ضد بعض المكروبات

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مستخلص:

تهدف هذه الدراسة إلى تقييم الفعالية التثبيطية لبعض أنواع جنس *Suaeda* المستخلصة من ثلاثة أنواع، وهي: *S. altissima*، *S. carnosissima*، و *S. fruticosa*، ضد مجموعة مختارة من البكتيريا الممرِضة ، تشمل *S.au-reus , S. epidermidis , E. coli* و *P. aeruginosa* والفطريات الجلدية ، تشمل *Epidermophyton floccosum* و *Microsporum canis*. تم تحضير مستخلصات النباتات وفقا لبروتوكولات قياسية، وتم تقييم نشاطها المضاد للميكروبات باستخدام طريقة حفر الآكار (Agar well diffusion) بأربع تراكيز مختلفة (10، 25، 50، و100 ملغم/ مل). كشفت النتائج أن النشاط المضاد للميكروبات يعتمد بشكل واضح على نوع المستخلص وتركيزه. كانت التانينات والكليكوسيدات المركبات النشطة بيولوجيا الرئيسية التي ساهمت في إحداث مناطق تثبيط كبيرة، لا سيما في مستخلصات *S. fruticose*. أظهرت الفطريات الجلدية والبكتيريا موجبة الغرام أعلى درجات الحساسية تجاه المستخلصات، في حين أظهرت البكتيريا سالبة الغرام حساسية أقل. وتبرز هذه النتائج الإمكانات الواعدة لجنس *Suaeda*، وبشكل خاص *S. fruticosa*، كمصدر طبيعي ثمين للمركبات المضادة للميكروبات. ويمكن استكشاف هذه المركبات الفعالة بيولوجيا وتطويرها بشكل أكبر لاستخدامها في التطبيقات الصيدلانية، خاصة في علاج التهابات الجلد ومكافحة البكتيريا المقاومة للمضادات الحيوية.

الكلمات المفتاحية: اختبار حفر الآكار، النشاط المضاد للميكروبات، الفطريات الجلدية، *S. fruticosa*، *S. al-tissima*، *S. carnosissima* .

1. Introduction:

The global escalation of microbial resistance to conventional antibiotics has necessitated an intensified search for alternative antimicrobial agents, particularly from natural sources (Rios & Recio, 2005; Cowan, 1999). Among the most promising are **halophytic plants**, which are adapted to survive in extreme saline and arid environments. These plants often produce a diverse array of secondary metabolites as survival mechanisms, many of which exhibit significant antimicrobial properties (Mansour et al., 2020; Elansary et al., 2024).

Species of the *Seuada* genus widely distributed in saline regions have shown notable potential due to their content of alkaloids, flavonoids, tannins, glycosides, phenols, and saponins, in addition to essential minerals that may synergistically contribute to antimicrobial activity (Khalil et al., 2022; Ahmed et al., 2021). These bioactive compounds have been associated with various antimicrobial mechanisms, such as disrupting microbial membranes, inhibiting enzyme function, and interfering with cellular replication (Rauf et al., 2023).

Recent phytochemical profiling studies of halophytes, including *Seuada*, have not only confirmed the presence of such compounds but also demonstrated their inhibitory effects against several pathogenic bacteria and fungi (Khan et al., 2020; Khalil et al., 2022). The unique metabolic profiles of halophytes, shaped by environmental stressors, may provide novel chemotypes with pharmaceutical relevance (Elansary et al., 2024).

This study aims to evaluate the antimicrobial potential of phytochemical extracts from selected *Seuada* species against clinically relevant bacterial and fungal pathogens. By linking extract composition with biological activity, the findings contribute to the understanding of halophytes as natural reservoirs of antimicrobial agents, especially in the context of increasing antimicrobial resistance.

2. Materials and Methods:

2.1 Extraction Methods of Bioactive Compounds

2.1.1 Saponins

Ten grams of finely ground, dried plant material was extracted with 50

mL of 20% ethanol and heated in a water bath at 55°C for 3 hours with continuous stirring. After filtration, the residue was re-extracted with 100 mL of 20% ethanol and heated at 90°C until the volume was reduced to approximately 40 mL. The extract was transferred to a separating funnel, mixed with 20 mL of diethyl ether, and the aqueous layer containing saponins was collected for further analysis *(Adapted from Harborne, 1998).*

2.1.2 Phenolic

Twenty grams of dried, powdered plant material were extracted with 400 mL of 2% acetic acid using a reflux condenser in a water bath at 70°C for 8 hours. The cooled extract was filtered and transferred to a separating funnel with an equal volume of n-propanol and saturated with sodium chloride to induce salting-out. The upper organic layer containing phenolics was concentrated using a rotary evaporator at ≤45°C *(Adapted from Ribereau-Gayon, 1972; Ignat et al., 2011; Dai & Mumper, 2010).*

2.1.3 Glycosides

Ten grams of dried plant powder were soaked in 100 mL of 80% ethanol at 4°C for 24 hours. The extract was filtered and concentrated to one-third of its original volume under reduced pressure at ≤45°C. The concentrate was treated with 50 mL of ether and 5 mL of 3.0 M lead acetate solution in a separating funnel to precipitate interfering compounds. The aqueous layer was collected and dried in an oven at 30°C until completely dry *(Adapted from Ukiya et al. 2006),.*

2.2 Preparation of Microbial Suspensions

To assess the inhibitory activity of the extracts, a stock solution was prepared by dissolving 1 gram of dried plant extract powder in 10 mL of sterile distilled water to obtain a concentration of 100 mg/mL. The solution was filtered through a 0.22 µm membrane filter for sterilization. Serial dilutions were then performed to prepare a range of concentrations (10, 25, 50, and 100 mg/mL) following standard dilution techniques (Mitscher, 1972).

2.2.1 Study of Bacterial Colonies and Interactions

The microbial isolates were obtained from the College of Education for Pure Sciences, University of Tikrit. Four bacterial species were cultured as Gram-negative bacillus: *Escherichia*

coli, *Pseudomonas aeruginosa*, and as Gram-positive coccus, *Staphylococcus aureus* that shows distinct beta-hemolysis on blood agar, and *Staphylococcus epidermidis*. All isolates were incubated on blood agar plates for 24 hours at 37°C under aerobic conditions. The Negative control of Sterile distilled water is used and the Positive control on bacteria applied the Tetracycline disc (30 mg).

The bacterial suspension was prepared from mature 24-hour-old colonies grown on nutrient agar. Colonies were suspended in normal saline and adjusted to a 0.5 McFarland standard, equivalent to approximately 1.5×10^8 CFU/mL, ensuring uniform microbial density (Cowan, 1999).

Among these species, *S. epidermidis* and *P. aeruginosa* are among the most prevalent in clinical environments. *P. aeruginosa* plays a key pathogenic role through quorum sensing mechanisms, while the pathogenic potential of *S. epidermidis* remains an area of active research due to its high prevalence in clinical samples, especially in surgical sites.

In addition, several key virulence factors associated with *P. aeruginosa* were evaluated, including protease activity, rhamnolipid production, and swarming motility. A biosensor strain of *Escherichia coli* (*E. coli pJN105Lp-SC11*) was also used to assess the effect of *S. epidermidis* on quorum sensing in *P. aeruginosa*.

2.2.2 Study of Fungal Colonies and Their Interactions

The microbial isolates were obtained from the College of Education for Pure Sciences, University of Tikrit. The Negative control as Sterile distilled water and the Positive control on fungi as Nystatin (100 mg/mL) are applied.

For the dermatophytic fungi *Epidermophyton floccosum* and *Microsporum canis*, isolates were activated on Sabouraud Dextrose Agar (SDA) and incubated for 7 days at 25 ± 2°C (CLSI, 2021). After complete growth, spores and hyphal fragments were scraped using a sterile loop and transferred into tubes containing 5 mL of sterile physiological saline (0.85%). The tubes were vortexed for 2 minutes to obtain a homogenous suspension and visually adjusted to a 0.5 McFarland standard to ensure consistency in the inoculum used for bioassays (McGinnis, 1980).

Colonies of *Epidermophyton floc-*

cosum exhibited flat, cottony growth with a yellowish to light brown hue, while *Microsporum canis* colonies appeared as white to yellowish velvety-cottony mats with radiating edges, showing yellow to brown pigmentation on the reverse side of the plates. These morphological characteristics were recorded to confirm preliminary identification.

For bioassay purposes, fungal suspensions were prepared by scraping mature spores from the growing colonies on SDA into sterile physiological saline (0.85%). The suspension was homogenized using a vortex mixer for 2 minutes to ensure even distribution, then visually standardized to 0.5 McFarland turbidity.

These fungal suspensions were used to evaluate bioactivity interactions with the prepared plant extracts and to study the impact of the extracts on fungal growth and pathogenic traits using the agar well diffusion method. Inhibition zone diameters were recorded at regular intervals.

2.3 Bioactivity Testing

The agar well diffusion method (Egorov, 1985) was employed. Agar plates were inoculated with the microbial suspensions, and three wells of 10 mm diameter were punched into each plate. Each well received 50 µL of plant extract at varying concentrations. The plates were incubated at 37 ± 2°C for 24 hours for bacteria and at 25 ± 2°C for 6 days for fungi. Inhibition zones were measured every 72 hours.

2.4 Statistical Analysis

Minitab 17 software was used to conduct the statistical analysis. One-way ANOVA was applied to test the significance of differences among extract concentrations. The use of lowercase letters (a, b, c, etc.) indicates significant differences among means. The letter **"a"** represents the highest significant difference, followed by **"b"**, then **"c"**, and so on, with **"c"** indicating the lowest significant difference. Means that share two letters (e.g., **"ab"** or **"bc"**) are not significantly different from each other, indicating statistical similarity. This lettering system is based on Duncan's Multiple Range Test at a significance level of $P \leq 0.05$.

3. Results

3.1 Analysis of Antimicrobial Activity of Plant Extracts

This section presents and analyzes the laboratory results of the antimicrobial activity of extracts from three *Seuada* species; *S. altissima*, *S. carnosissima*, and *S. fruticosa* against a group of pathogenic bacterial and fungal isolates. The analysis focused on the activity of bioactive compounds such as saponins, phenolics, glycosides, alkaloids, and tannins, tested at concentrations of 10, 25, 50, and 100 mg/mL. The results were assessed using descriptive statistics and ANOVA to determine significant differences between mean values (Khan et al., 2020; Abdel Latef et al., 2021).

3.2.1 Antibacterial Activity of Saponins Extracts from Seuada Species

The antibacterial activity of ***Saponins*** extracts from *Seuada altissima*, *S. carnosissima*, and *S. fruticosa* was evaluated against four bacterial strains: *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* at concentrations of 10, 25, 50, and 100 mg/mL. The results indicate that *S. altissima* exhibited mild antibacterial activity only against *P. aeruginosa*, with a dose-dependent response reaching a maximum inhibition zone of 24 mm at 100 mg/mL. No inhibition was observed for the remaining bacterial strains tested with *S. altissima*, nor for any of the strains with extracts from *S. carnosissima* or *S. fruticosa*. These findings suggest that *P. aeruginosa* is moderately susceptible to bioactive compounds present in *S. altissima*, potentially due to the presence of saponins, shown in Table 1. However, the absence of inhibition in the other strains highlights a selective or limited spectrum of antibacterial activity. Statistical analysis confirmed significant differences in inhibition between *S. altissima* and the other species ($P \leq 0.05$), ($a \neq c$).

3.2.2 Antibacterial Activity of Phenols Extracts from Seuada Species

The antibacterial activity of *Seuada altissima*, *S. carnosissima*, and *S. fruticosa* extracts was evaluated against *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* using the agar well diffusion method at concentrations of 10, 25, 50,

Table 1: Inhibition Zone Diameter (mm) from *Saponins* Extracts of *Seuada* Species

Plant Species	Conc. (mg/mL)	P. aeruginosa	E. coli	S. aureus	S. epidermidis	Stat. Group
S. altissima	10	0	0	0	0	c
	25	13	0	0	0	b
	50	20	0	0	0	a
	100	24	0	0	0	a
Average		14.3	0.0	0.0	0.0	a (P. aeruginosa)
S. carnosissima	10–100	0	0	0	0	a
Average		0.0	0.0	0.0	0.0	a
S. fruticosa	10–100	0	0	0	0	a
Average		0.0	0.0	0.0	0.0	a

and 100 mg/mL. The results demonstrated no measurable inhibition zones for any of the bacterial strains across all plant species and concentrations tested. These findings suggest that under the current extraction and testing conditions, the aqueous or Seuada extracts of these Seuada species lacked effective antibacterial properties, as in Table 2. Statistical analysis confirmed the absence of significant differences ($P > 0.05$) (all treatments labeled with the same letter "a"), as all recorded inhibition values were 0.0 mm, indicating a lack of antimicrobial constituents active against the selected bacterial strains.

Table 2: Inhibition Zone Diameter (mm) from ***Phenols*** Extracts of *Suaeda* Species

Plant Species	Conc. (mg/mL)	P. aeruginosa	E. coli	S. aureus	S. epidermidis	Stat. Group
S. altissima	10	0.0	0.0	0.0	0.0	a
	25	0.0	0.0	0.0	0.0	a
	50	0.0	0.0	0.0	0.0	a
	100	0.0	0.0	0.0	0.0	a
Average		0.0	0.0	0.0	0.0	a
S. carnosissima	10–100	0.0	0.0	0.0	0.0	a
Average		0.0	0.0	0.0	0.0	a
S. fruticosa	10–100	0.0	0.0	0.0	0.0	a
Average		0.0	0.0	0.0	0.0	a

3.2.3 Antibacterial Activity of ***Glycosides*** Extracts from ***Seuada*** Species

The antibacterial potential of methanolic extracts from *Seuada altissima*, *S. carnosissima*, and *S. fruticosa forsck* was assessed against *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* at concentrations of 10, 25, 50, and 100 mg/mL. No inhibition zones were observed for *S. altissima* at any tested concentration, indicating a lack of antibacterial activity under the current conditions. In contrast, *S. carnosissima* and *S. fruticosa forsck* exhibited significant inhibition at higher concentrations (50 and 100 mg/mL), with *S. fruticosa* showing the highest average inhibition values across bacterial strains at 100 mg/mL (ranging from 15 to 17 mm). Statistical analysis revealed significant differences between concentrations and species (**$a \neq b \neq c$; $P \leq 0.05$**), especially at higher doses. These findings suggest that *S. carnosissima* and *S. fruticosa forsck* possess moderate to strong antibacterial activity in a dose-dependent manner, particularly against *Pseudomonas aeruginosa* and *S. epidermidis, as* explain in Table 3.

Table 3: Inhibition Zone Diameter (mm) from ***Glycosides*** Extracts of *Seuada* Species

Plant Species	Conc. (mg/mL)	P. aeruginosa	E. coli	S. aureus	S. epidermidis	Stat. Group
S. altissima	10	0.0	0.0	0.0	0.0	a
	25	0.0	0.0	0.0	0.0	a
	50	0.0	0.0	0.0	0.0	a
	100	0.0	0.0	0.0	0.0	a
Average		0.0	0.0	0.0	0.0	a
S. carnosissima	10	0.0	0.0	0.0	0.0	c
	25	0.0	0.0	0.0	0.0	c
	50	7.0	7.0	8.0	12.0	b
	100	16.0	15.0	11.0	20.0	a
Average		5.8	5.5	4.8	8.0	b
S. fruticosa forsck	10	0.0	0.0	0.0	0.0	c
	25	0.0	0.0	0.0	0.0	c
	50	12.0	10.0	11.0	12.0	b
	100	17.0	15.0	16.0	17.0	a
Average		7.3	6.3	6.8	7.3	a

3.2.4 Antibacterial Activity of ***Alkaloids*** Extracts from ***Seuada*** Species

The antibacterial effect of *Alkaloids* extracts from *Seuada altissima*, *S. carnosissima*, and *S. fruticosa forsck* was tested against *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* at concentrations of 10, 25, 50, and 100 mg/mL. No inhibition zones were detected in *S. altissima* or *S. carnosissima* at any concentration, indicating a complete lack of antibacterial activity from their saponin fractions. In contrast, *S. fruticosa forsck* showed limited activity, with a clear inhibition zone (13 mm) observed only against *P. aeruginosa* at 100 mg/mL, as in Table 4. No inhibitory effect was observed against the other bacterial strains, even at the highest concentration. These findings suggest that among the tested species, only *S. fruticosa forsck* exhibits minimal antibacterial activity through its saponin content, and this activity appears to be highly selective and concentration dependent. The statistical analysis indicated slight significant differences, reflecting relatively limited antibacterial efficacy of alkaloids, without strong biological significance.

Table 4: Inhibition Zone Diameter (mm) from ***Alkaloids*** Extracts of *Seuada* Species

Plant Species	Conc. (mg/mL)	P. aeruginosa	E. coli	S. aureus	S. epidermidis	Stat. Group
S. altissima	10	0.0	0.0	0.0	0.0	a
	25	0.0	0.0	0.0	0.0	a
	50	0.0	0.0	0.0	0.0	a
	100	0.0	0.0	0.0	0.0	a
Average		0.0	0.0	0.0	0.0	a
S. carnosissima	10	0.0	0.0	0.0	0.0	a
	25	0.0	0.0	0.0	0.0	a
	50	0.0	0.0	0.0	0.0	a
	100	0.0	0.0	0.0	0.0	a
Average		0.0	0.0	0.0	0.0	a
S. fruticosa forsck	10	0.0	0.0	0.0	0.0	b
	25	0.0	0.0	0.0	0.0	b
	50	0.0	0.0	0.0	0.0	b
	100	13.0	0.0	0.0	0.0	a
Average		3.3	0.0	0.0	0.0	a

3.2.5 Antibacterial Activity of Tannins Extracts from Seuada Species

The antibacterial potential of *tannins* extracts from *Seuada altissima*, *S. carnosissima*, and *S. fruticosa forsck* was evaluated against *Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, and *Staphylococcus epidermidis* at four concentrations: 10, 25, 50, and 100 mg/mL. All three species exhibited dose-dependent inhibition, with activity increasing at higher concentrations. *S. altissima* showed moderate activity, with inhibition zones ranging from 0 mm at 10–25 mg/mL to 38 mm (*P. aeruginosa*) at 100 mg/mL. The average inhibition across all bacteria reached **17.1 mm** at 100 mg/mL. *S. carnosissima* exhibited stronger antibacterial effects, especially against *E. coli* and *P. aeruginosa*, with inhibition zones reaching up to 29 mm. Its average inhibition zone was highest against *E. coli* (19.0 mm) and *S. fruticosa forsck* also showed strong and consistent activity, with inhibition zones reaching up to 37 mm (*P. aeruginosa*) at 100 mg/mL and an overall average of 18.8 mm for both *P. aeruginosa* and *E. coli*.

Statistical grouping (letters a–e) confirmed significant differences in antibacterial activity between species and concentration levels ($a \neq b \neq c$). Overall, tannin extracts were significantly more effective than saponins or alkaloids in inhibiting bacterial growth, as shown in Table 5.

Table 5: Inhibition Zone Diameter (mm) from *Tannins* Extracts of *Seuada* Species

Plant Species	Conc. (mg/mL)	P. aeruginosa	E. coli	S.aureus	S.epidermidis	Stat.Group
S. altissima	10	0.0	0.0	0.0	0.0	c
	25	0.0	0.0	0.0	0.0	c
	50	32.0	21.0	12.0	18.0	b
	100	38.0	28.0	20.0	25.0	a
Average		17.5	12.3	8.0	10.8	a–d
S. carnosissima	10	9.0	9.0	10.0	11.0	d
	25	11.0	16.0	14.0	15.0	c
	50	20.0	22.0	20.0	20.0	b
	100	28.0	29.0	23.0	24.0	a
Average		17.0	19.0	16.8	17.5	a–b
S. fruticosa forsck	10	8.0	8.0	9.0	7.0	d
	25	12.0	12.0	15.0	12.0	c
	50	18.0	20.0	18.0	19.0	b
	100	37.0	35.0	23.0	24.0	a
Average		18.8	18.8	16.3	15.5	a–b

3.3 Statistical Analysis Against Fungi

The same extracts were tested against the two dermatophytic fungi *Microsporum canis* and *Epidermophyton floccosum*using the same concentrations. The results were as follows:

3.3.1 Antifungal Activity of *Saponins* Extracts from *Seuada* Species

Saponin extracts from three *Seuada* species were tested for antifungal activity against *Microsporum canis* and *Epidermophyton floccosum* at four concentrations (10, 25, 50, and 100 mg/mL). The results revealed that antifungal activity was **concentration-dependent** and varied significantly between species. *S. altissima* showed minimal antifungal activity, with inhibition observed only at 100 mg/mL against *M. canis* (9 mm), while no activity was recorded against *E. floccosum* then *S. carnosissima* exhibited slightly higher activity, with inhibition zones of 7 mm (*M. canis*) and 11 mm (*E. floccosum*) at 100 mg/mL and *S. fruticosa forsck* demonstrated **the** highest antifungal effect, particularly against *M. canis* (22 mm), followed by *E. floccosum* (9 mm) at 100 mg/mL, as in Table 6. Statistical letters indicate significant differences (**a ≠ b ≠ c**; $P < 0.05$) between treatment groups, with *S. fruticosa forsck* ranked highest in activity.

Table 6: Inhibition Zone Diameter (mm) from Saponins Extracts Against Fungi

Plant Species	Conc. (mg/mL)	M. canis	E. floccosum	Stat. Group
S. altissima	10	0.0	0.0	b
	25	0.0	0.0	b
	50	0.0	0.0	b
	100	9.0	0.0	a (M. canis only)
Average		2.25	0.0	a–b
S. carnosissima	10	0.0	0.0	b
	25	0.0	0.0	b
	50	0.0	0.0	b
	100	7.0	11.0	a
Average		1.75	2.75	a–b
S. fruticosa forsck	10	0.0	0.0	b
	25	0.0	0.0	b
	50	0.0	0.0	b
	100	22.0	9.0	a
Average		5.50	2.25	a–b

3.3.2 Antifungal Activity of *Phenols* Extracts from *Seuada* Species

Phenolic extracts from three *Seuada* species were evaluated for antifungal activity against *Microsporum canis* and *Epidermophyton floccosum* at different concentrations (10, 25, 50, 100 mg/mL), Table 7. The antifungal effect varied by species, concentration, and fungal target. S. altissima showed moderate inhibition, with activity increasing at higher concentrations most notably at 100 mg/mL (10 mm for *M. canis*, 13 mm for *E. floccosum*) then S. carnosissima showed no antifungal activity at any concentration and S. fruticosa forsck showed the highest antifungal activity, especially against *M. canis* (up to 21 mm inhibition zone), while activity against *E. floccosum* was moderate (9 mm at 100 mg/mL). The differences were statistically significant (**a ≠ b ≠ c;** $P < 0.05$).

Table 7: Inhibition Zone Diameter (mm) from *Phenols* Extracts Against Fungi

Plant Species	Conc. (mg/mL)	M. canis	E. floccosum	Stat. Group
S. altissima	10	0.0	0.0	c
	25	0.0	0.0	c
	50	0.0	5.0	b
	100	10.0	13.0	a
Average		2.50	4.50	b–a
S. carnosissima	10–100	0.0	0.0	a
Average		0.0	0.0	a
S. fruticosa forsck	10	0.0	0.0	d
	25	8.0	0.0	c
	50	15.0	0.0	b
	100	21.0	9.0	a
Average		11.0	2.25	a–b

3.3.3 Antifungal Activity of *Glycosides* Extracts from *Seuada* Species

Glycosides extracts from the three *Seuada* species were tested against two dermatophytic fungi. The response varied across plant types and concentrations. ***S. altissima*** showed no antifungal activity at any tested concentration (0–100 mg/mL). ***S. carnosissima*** showed selective inhibition of *E. floccosum* at 100 mg/mL (25 mm zone), with no effect on *M. canis*. ***S. fruticosa forsck*** displayed the highest antifungal activity, with inhibition

zones reaching up to 20 mm against *M. canis* at 100 mg/mL. It showed no effect on *E. floccosum*. The results indicate statistically significant differences (**P ≤ 0.05**), as shown in Table 8.

Table 8: Inhibition Zone Diameter (mm) from *Glycosides* Extracts Against Fungi

Plant Species	Conc. (mg/mL)	M. canis	E. floccosum	Stat. Group
S. altissima	10–100	0.0	0.0	a
Average		0.0	0.0	a
S. carnosissima	10–50	0.0	0.0	b
	100	0.0	25.0	a
Average		0.0	6.25	b–a
S. fruticosa forsck	10–25	0.0	0.0	c
	50	15.0	0.0	b
	100	20.0	0.0	a
Average		8.75	0.0	a–b

3.3.4 **Antifungal Activity of *Alkaloids* Extracts from *Seuada* Species**

Alkaloids extracts demonstrated varying levels of antifungal effectiveness. *S. altissima* showed strong inhibition at 100 mg/mL, particularly against *E. floccosum* (15 mm) and *M. canis* (9 mm). *S. carnosissima* exhibited no antifungal activity at any concentration. *S. fruticosa forsck* exhibited the highest overall activity, with increasing inhibition from 25 mg/mL to 100 mg/mL, reaching *21 mm against E. floccosum* and 19 mm against *M. canis*. Statistically significant differences were observed in favor of *S. fruticosa, as shown in Table 9.*

Table 9: Inhibition Zone Diameter (mm) from *Alkaloids* Extracts Against Fungi

Plant Species	Conc. (mg/mL)	M. canis	E. floccosum	Stat. Group
S. altissima	10–50	0.0	0.0	b
	100	9.0	15.0	a
Average		2.25	3.75	b–a
S. carnosissima	All	0.0	0.0	a
Average		0.0	0.0	a
S. fruticosa forsck	10	0.0	0.0	d
	25	7.0	5.0	c
	50	11.0	13.0	b
	100	19.0	21.0	a
Average		9.25	9.75	a

3.3.5 Antifungal Activity of Tannins Extracts from **Seuada** Species

The antifungal efficacy of plant extracts from *Seuada altissima*, *S. carnosissima*, and *S. fruticosa* was tested against two dermatophytic fungi (*Microsporum canis* and *Epidermophyton floccosum*) at concentrations of 10, 25, 50, and 100 mg/mL. The results, that shown in Table 10, indicated a concentration dependent inhibition in all species, with *S. fruticosa* showing the highest overall activity. At 100 mg/mL, *S. fruticosa* produced the largest inhibition zones: 28 mm against *M. canis* and 38 mm against *E. floccosum*. *S. carnosissima* showed moderate activity, reaching 26 mm and 28 mm at the highest concentration, respectively. In contrast, *S. altissima* displayed relatively weaker inhibition, with a maximum of 17 mm and 14 mm against *M. canis* and *E. floccosum*. The average inhibition zones across concentrations showed that *S. fruticosa* had the strongest antifungal effect (16.0 mm for *M. canis*, 23.3 mm for *E. floccosum*), followed by *S. carnosissima* and *S. altissima*. Statistically significant differences ($P \leq 0.05$) were observed between species and concentrations, as indicated by different lowercase letters ($a \neq b \neq c$).

Table 10: Inhibition Zone Diameter (mm) from *Tannins* Extracts Against Fungi

Plant Species	Conc. (mg/mL)	M. canis (mm)	E. floccosum (mm)	Statistical Grouping
S. altissima	10	0	0	d
	25	8	0	c
	50	12	6	b
	100	17	14	a
Average		9.3	5.0	
S. carnosissima	10	0	0	d
	25	10	12	c
	50	12	16	b
	100	26	28	a
Average		12.0	14.0	
S. fruticosa	10	0	2	d
	25	15	25	c
	50	21	28	b
	100	28	38	a
Average		16.0	23.3	

The results showed that the presence of *S. epidermidis* at varying concentrations (5.5×10^9, 6×10^9, 7×10^9, 8.5×10^9, and 1.5×10^{10} cells/mL) did not significantly affect the growth of *P. aeruginosa*. Microscopic observations supported the CFU data, revealing no marked changes in cell morphology or density.

However, analyses indicated that *P. aeruginosa* virulence-related factors may be influenced by the presence of *S. epidermidis*, suggesting potential quorum sensing interference or microbial competition that could lead to reduced pathogenicity (Rios & Recio, 2005).

Discussion:

The antimicrobial assessment of *Suaeda* species extracts demonstrated selective and concentration-dependent antibacterial effects, varying by plant species, extract type, and microbial strain. Among the tested phytochemicals, tannins were the most effective, showing strong inhibition across all bacterial strains, particularly at 100 mg/mL. *S. fruticosa* and *S. carnosissima* exhibited inhibition zones exceeding 35 mm against *Pseudomonas aeruginosa*, confirming the potent antibacterial role of tannins, likely due to their ability to disrupt microbial membranes and proteins.

Glycoside extracts also showed promising activity, especially at higher concentrations. *S. fruticosa* produced inhibition zones up to 17 mm against *P. aeruginosa* and *S. epidermidis*, indicating that glycosides may interfere with bacterial function or membrane integrity, particularly in gram-negative strains. In contrast, alkaloid extracts showed limited antibacterial effects, with only *S. fruticosa* displaying minor inhibition (13 mm) at the highest concentration tested, suggesting either low bioavailability or insufficient compound concentration.

Saponins from *S. altissima* showed moderate activity but only against *P. aeruginosa*, reflecting a narrow antimicrobial spectrum. Conversely, saponin extracts from *S. fruticosa* and *S. carnosissima* showed no inhibition. Notably, phenolic extracts were completely inactive across all species and bacterial strains, contradicting typical literature and possibly due to extraction limitations or compound instability.

Statistical analysis (ANOVA) confirmed significant differences ($P \leq 0.05$) between extract types, concen-

trations, and species, reinforcing the reliability of the findings. Overall, tannins and glycosides emerged as the most promising antibacterial agents, particularly in *S. fruticosa* and *S. carnosissima*. These findings support the potential of *Suaeda*species as natural sources for plant-based antibacterial compounds, especially targeting resistant gram-negative bacteria. Further research is recommended to isolate active compounds and clarify their mechanisms of action for pharmaceutical applications.

Conclusion:

The study assessed the antimicrobial activity of phytochemical extracts from three Suaeda species. *S. fruticosa forsck*showed the strongest and broadest activity, especially in tannin and alkaloid extracts, against both bacteria and fungi. *S. altissima* had moderate effects at higher concentrations, while *S. carnosissima* showed minimal activity. Results confirm that extract type, species, and concentration significantly influence antimicrobial efficacy. The findings support the potential of *S. fruticosa forsck* as a source for natural antimicrobial agents and recommend further analysis to isolate active compounds.

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