ORIGINAL ARTICLE

Chemical characterization and male fertility-enhancing potentials of selected medicinal plants from Egypt: A systematic review

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ABSTRACT

Introduction: The use of medicinal plants for the treatment of human diseases has deep historical roots in ancient Egypt, where herbal remedies were integral to traditional healthcare systems. This systematic review aimed to evaluate current evidence on the effects of native Egyptian medicinal plants on male fertility outcomes, alongside the chemical characterization of these plants' bioactive constituents.

Methods: A systematic review was conducted following the PRISMA guidelines. Literature research was performed in PubMed and Scopus databases for studies published between 1968 and 2024. Search terms included ("Extract" OR "Medicinal Plants") AND ("Male infertility" OR "Male fertility"). Inclusion criteria were randomized controlled trials using experimental animal models, examining the impact of Egyptian medicinal plants on male fertility outcomes with appropriate control groups.

Results: Out of the initial search, 9 studies met the inclusion criteria and were included in the final synthesis. These studies identified several plant species—Moringa oleifera, Allium sativum, Epimedium brevicornum, Punica granatum (Pomegranate), Sargassum virgatum, and Artemisia annua—as having fertility-enhancing properties in male animal models. These medicinal plant extracts improved fertility outcomes by modulating oxidative stress, reducing inflammatory biomarkers, and enhancing reproductive hormones such as follicle-stimulating hormone, testosterone, and luteinizing hormone. Chemical characterization consistently revealed the presence of bioactive compounds, including flavonoids, o-coumaric acid, alkaloids, ferulic acid, glycosides, p-coumaric acid, cardiac glycosides, chlorogenic acid, saponins, vanillic acid, phenols, p-hydroxybenzoic acid, sterols, catechin, tannins, gallic acid, and rutin.

Conclusion: Egyptian medicinal plants represent a promising and culturally relevant approach for managing male infertility through mechanisms involving reductions in oxidative stress and inflammation. However, further well-designed studies are necessary to validate these findings and explore their broader therapeutic applications across different populations.

Keywords: Medicinal plant, Fertility enhancement, Sperm quality, Egypt

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Introduction

Infertility affects approximately 8–12% of couples globally, imposing significant psychological, social, and cultural burdens [1]. Among these cases, male subfertility accounts for a substantial proportion, with etiologies ranging from congenital and acquired disorders to idiopathic factors that impair spermatogenesis [2]. Globally, the prevalence of male infertility varies widely; for instance, East Asia reported the highest number of cases in 2019 (14,936.8 thousand; 95% UI: 7,597.5–25,349), while Australasia reported the lowest (78.7 thousand; 95% UI: 44.4–128.2) [3]. In sub-Saharan Africa, male infertility constitutes over 50% of infertility cases [4]–[6]. Despite this considerable burden, male infertility remains under-researched, particularly in developing regions, where access to diagnostic and therapeutic resources is often limited, and cultural stigmas further hinder intervention efforts [7].

Although conventional medicine provides several treatment modalities, their effectiveness is often limited, expensive, or accompanied by undesirable side effects. This gap has spurred growing interest in complementary and alternative therapies, particularly those rooted in traditional medicinal knowledge [8]–[13]. Historically, ancient Egypt was a center of botanical medicine, with well-documented use of medicinal plants for treating various ailments, including reproductive health issues [14]. However, despite this rich heritage, there remains a significant gap in systematically evaluating and synthesizing the current evidence on Egyptian medicinal plants and their potential benefits for male fertility.

Many of these traditional plants are rich in bioactive phytochemicals—such as tannins, flavonoids, phenolics, alkaloids, triterpenoids, steroids, and terpenoids—that have demonstrated efficacy in improving key fertility parameters, including sperm morphology, motility, viability, and count [15], [16]. Egypt's unique geography and climate, shaped by the Mediterranean and the Nile, foster a diverse botanical landscape with high phytochemical diversity and therapeutic potential [17], [18]. Yet, there is a paucity of consolidated evidence detailing which specific Egyptian plants have been studied for male fertility, their phytochemical profiles, and their mechanisms of action.

This systematic review addresses this gap by critically examining existing literature on native Egyptian medicinal plants with potential male fertility-enhancing properties. It aims to clarify the plant species investigated, their active phytoconstituents, and the mechanistic pathways through which they may support male reproductive health. This work provides a comprehensive synthesis of current knowledge and identifies areas for future research, with the ultimate goal of informing culturally relevant, evidence-based interventions for male infertility.

Method

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [19]. Eligible studies were randomized controlled trials with experimental animal models that examined the impact of Egyptian medicinal plants on male fertility outcomes, including a control group.

Only studies published in English-language between 1968 and 2024 on medicinal plants from Egypt were included in the study. Studies were excluded if they did not involve Egyptian medicinal plants or if they were unrelated to male fertility outcomes. Additionally, studies were excluded if they were non-randomized, lacked a control group, or were purely in vitro without the use of animal models. Review articles, conference abstracts, book chapters, editorials, and studies published in languages other than English were also excluded. Furthermore, studies involving medicinal plants from regions outside Egypt or those lacking sufficient methodological detail or outcome reporting were not considered. A thorough literature search was performed in PubMed and Scopus using the following search terms combined with the Boolean operator as follows: ("Extract" OR "Medicinal Plants") AND ("Male infertility" OR "Male fertility"). After removing duplicates, two independent reviewers (IAA and IAJ) screened titles and abstracts, with disagreements resolved by a third reviewer (OO or DO). Full-text screening and risk of bias assessment were performed by EO, EA and EME using the SYRCLE risk of bias tool for animal studies [20], and visualized via the ROBVIS tool. Synthesis and data extraction were carried out by AO, PMA, and JI.

Result

Study Selection

Out of 465 articles initially identified through database searches, 50 duplicates were removed, leaving 415 for title and abstract screening. This process led to the exclusion of 323 articles. Of the 93 full-text articles assessed for eligibility, 8 could not be retrieved despite repeated efforts. After full-text review, 60 studies were excluded for involving non-Egyptian plant sources, and 2 were dismissed due to poor methodological quality. Ultimately, 9 studies fulfilled the inclusion criteria and were selected for qualitative synthesis and data extraction (Figure 1).

Quality Assessment

Using the SYRCLE 10-domain risk of bias tool, the included studies demonstrated an overall low risk of bias (Figure 2). However, three domains—D5 (blinding of caregivers or investigators), D6 (randomization in outcome assessment), and D7 (blinding of outcome assessors)—were frequently marked as unclear, indicating limited reporting on these specific methodological practices (Figure 3).

Study Characteristics

All nine included studies (9/9; 100%) were conducted in Egypt and employed in vivo experimental designs using male animal models (Table 1). The studies investigated a range of native and naturalized plant species, including *Allium sativum* [21], *Moringa oleifera* [22], *Punica granatum* [23], *Sargassum virgatum* [24], *Artemisia annua* [25] , *Panax ginseng* [26], *Anacyclus pyrethrum* [27], and *Ulva lactuca* [28], [29] (Table 2). Aqueous and crude extracts were the most frequently used (6/9; 66.7%), with aqueous extracts derived from *Ulva lactuca*, *Punica granatum*, and *Sargassum virgatum*, while crude extracts—often in powdered or dietary supplement form—were used for *Allium sativum*, *Artemisia annua*, and *Panax ginseng*. Methanolic extracts appeared in 3/9 (33.3%) studies, including those on *Ulva lactuca* and *Anacyclus pyrethrum*, while one study utilized an ethanolic extract of *Sargassum virgatum* (11.1%). Overall, solvents of extraction across the studies included aqueous (55%), methanol (27%), ethanol (9%), and oil-based (9%) preparations (Figure 4). In terms of plant parts used, roots accounted for 22%, leaves for 11%, and 67% of studies did not specify the plant part (Figure 5). All studies utilized male rodents, with Wistar rats used in 6/9 (66.7%) studies, Sprague Dawley rats in 2/9 (22.2%), and albino rats in 1/9 (11.1%). Animal weights generally ranged from 120g to 400g, maintaining consistency in experimental standards. Most studies (7/9; 77.8%) employed reproductive toxicity models, using agents such as monosodium glutamate, gossypol, bisphenol A, and Adriamycin to induce testicular damage. The remaining studies (2/9; 22.2%) focused on metabolic toxicity induced by high-fat diets (Table 1). These models enabled a comprehensive evaluation of plant extract efficacy across diverse pathological states.

Evaluation, Intervention, and Mechanism of Action

The reviewed studies administered plant extracts at varying doses (100–2430 mg/kg) over durations ranging from 14 to 130 days, delivered either orally or intraperitoneally using methanolic, ethanolic, or aqueous preparations [24], [29] (Table 1). Evaluations focused on key indicators of male reproductive health, including sperm parameters, testicular integrity, and reproductive hormone levels (Table 2). Several studies also assessed oxidative stress biomarkers—such as glutathione peroxidase (GPx), catalase (CAT), superoxide dismutase (SOD)—as well as inflammatory markers [24], [28]. Circulating levels of luteinizing hormone (LH) and lipid peroxidation, testosterone, and follicle-stimulating hormone (FSH) were commonly measured to assess testicular function [27]. Structural analyses of the testes and accessory reproductive organs further elucidated the extracts' impact on fertility potential and spermatogenesis [21].

Mechanistically, the plant extracts exerted beneficial effects by modulating oxidative stress, reducing inflammation, and restoring hormonal balance. These effects are largely attributed to phyto-constituents such as flavonoids, polyphenols, and alkaloids, which enhance antioxidant capacity, suppress reactive oxygen species, and support hormonal homeostasis. Notably, some extracts demonstrated androgenic effects, contributing to improved function of accessory sex organs and enhanced fertility outcomes [21], [22], [24] (Table 2).

Chemical Characterization of the Plants

High-performance liquid chromatography (HPLC) was the

most frequently used method for phytochemical analysis, used in 5 out of 9 studies (55.5%). Other techniques included Fourier-transform infrared spectroscopy (FTIR) and gas chromatography-mass spectrometry (GC-MS), each used in one study (11.1%) (Figure 4). These methods facilitated the identification of a wide range of bioactive compounds, as summarized in Table 3. HPLC profiling of *Ulva lactuca* revealed compounds such as dicaffeoyl quinic acid isomers (3,4-, 3,5-, and 4,5-), retinol , caffeic acid, quercetin, gallic acid, tannic acid, rutin, and chlorogenic acid [28], [29]. In *Punica granatum*, HPLC analysis identified flavonoids, alkaloids, sterols, glycosides, phenols, tannins, cardiac glycosides, and saponins [23].

For *Sargassum virgatum*, HPLC revealed gallic acid, protocatechuic acid, catechin, vanillic acid, hesperidin, apigenin-7-glucoside (cosmosiin), rosmarinic acid, cinnamic acid, apigenin, and chrysin [24]. *Anacyclus pyrethrum* was rich in phenolics and flavonoids, including kaempferol, gallic acid, p-hydroxybenzoic acid, p-coumaric acid, catechin, ferulic acid, vanillic acid, chlorogenic acid, o-coumaric acid, quercetin, rutin, myricetin, hesperidin, resveratrol, rosmarinic acid, and apigenin [27]. GC-MS analysis of *Artemisia annua* identified key volatile and therapeutic compounds, such as artemisinin, camphor, 1,8-cineole (eucalyptol), α-terpineol, α-pinene, caryophyllene, β-pinene, limonene, sabinene, and arteannuin B [25]. FTIR analysis of *Panax ginseng* detected functional groups indicative of hydroxyl (OH) stretching and methylene (CH_2) vibrational modes, which are characteristic of various

Discussion

This systematic review underscores the fertility-boosting potential of selected plant species native to North Africa, particularly Egypt, with a focused ethnopharmacological interest in their therapeutic value for managing male infertility. The reviewed studies suggest that these plants exert their beneficial effects primarily through antioxidant, hormonal regulatory, and anti-inflammatory mechanisms. In vivo animal models offered valuable insights into the physiological and biochemical effects of these plant extracts on male reproductive health. Quality assessment indicated an overall low risk of bias, reinforcing the reliability of the findings, despite some ambiguity in blinding procedures and outcome assessments. Chemical characterization was commonly performed using FT-IR, GC-MS, and HPLC, although some studies lacked comprehensive phytochemical profiling, reflecting financial limitations often encountered in African research settings.

When these findings are compared to studies from other global regions, notable similarities and distinctions emerge, emphasizing both the shared therapeutic potentials of medicinal plants and the regional specificity of ethnobotanical practices. For instance, comparable antioxidant, anti-inflammatory, and hormonal benefits have been documented in studies from Asia and other parts of Africa. In South Africa, *Anchomanes difformis* has been shown to enhance male reproductive health through mechanisms similar to those reported for *Punica granatum* and *Ulva lactuca* in Egypt, particularly by reducing oxidative stress and improving hormonal profiles [30]. Likewise, in Malaysia, *Chlorophytum borivilianum* has been reported to exert protective effects against male infertility by modulating oxidative stress pathways and enhancing steroidogenic enzyme activity [31] .

Studies from West Africa, notably Nigeria, align with these findings by demonstrating the fertility-enhancing effects of plants such as *Garcinia kola* and *Newbouldia laevis*, which improve sperm quality and testicular function through antioxidative and hormonal mechanisms akin to those identified in Egyptian studies [32]. Moreover, the antioxidative actions of *Allium sativum* and *Ulva lactuca* through upregulation of antioxidant enzymes such as SOD, CAT, and GPx reflect findings from Iranian and Indian studies, where *Phoenix dactylifera* and *Withania somnifera* have been shown to exert comparable protective effects against oxidative testicular damage [33], [34].

Furthermore, the modulation of Leydig cell function and the enhancement of steroidogenic enzymes reported in Egyptian studies mirror outcomes in Southeast Asia, where *Mucuna pruriens* in Thailand has been widely studied for its role in boosting testosterone production and improving sperm quality through similar hormonal pathways [35]. These parallels underscore the conserved biological mechanisms through which diverse medicinal plants exert

fertility-enhancing effects, despite geographic and botanical differences.

In North Africa and Iran, *Phoenix dactylifera* has been extensively studied for its role in enhancing sperm motility and morphology, attributed primarily to its anti-inflammatory and antioxidative properties [33], [36]. Similar mechanisms were reported in Egypt for *Sargassum virgatum* and *Punica granatum*, highlighting a cross-regional convergence on the importance of oxidative stress reduction and hormonal regulation as therapeutic targets.

These cross-regional comparisons emphasize that, despite variations in plant species, there is a remarkable consistency in the underlying therapeutic mechanisms across studies from Africa, Asia, and the Middle East. Bioactive compounds—particularly polyphenols, flavonoids, alkaloids, and saponins—emerge repeatedly as key mediators of antioxidative, anti-inflammatory, and hormonal effects, suggesting a shared pharmacological foundation underlying traditional fertility-enhancing remedies worldwide.

However, regional differences also persist. While North African research has focused predominantly on marine and terrestrial plants such as *Ulva lactuca* and *Sargassum virgatum*, studies from Asia often prioritize roots and seeds of terrestrial herbs like *Withania somnifera* and *Chlorophytum borivilianum*. These distinctions reflect variations in ethnobotanical knowledge, local flora, and cultural practices surrounding fertility treatments.

The significance of these findings is particularly pronounced in low-resource settings, where conventional infertility treatments may be financially inaccessible or culturally less accepted. In this context, plant-based therapies offer affordable, culturally integrated alternatives for managing male infertility, as similarly observed in other regions facing comparable healthcare challenges. Moreover, these shared insights reinforce the potential of traditional medicinal plants to bridge the gap between folk medicine and modern pharmacology, aligning with global efforts to validate and integrate alternative therapies into mainstream reproductive healthcare.

Consistent with studies from Nigeria, Iran, India, and Southeast Asia, the Egyptian data affirm the efficacy of plant-based interventions in improving key fertility parameters—sperm count, motility, viability, and testicular histoarchitecture—primarily through oxidative stress reduction, hormonal balance, and anti-inflammatory effects. The convergence of evidence across continents strengthens the argument for these plants' potential incorporation into standardized treatment protocols, while also highlighting the need for region-specific clinical validation.

Despite these promising outcomes, the predominance of preclinical studies and the scarcity of human clinical trials remain universal limitations, not unique to North Africa. Addressing this gap through well-designed, multicenter clinical trials across various populations would provide the necessary evidence base for regulatory approval and integration of these plant-based treatments into global fertility management strategies.

Furthermore, future research should prioritize the standardization of extracts by clearly defining the phytochemical composition and ensuring reproducibility across studies. The lack of standardized extraction methods and characterization hampers comparability and clinical translation. Dose-ranging studies are also urgently needed to establish safe and effective dosing parameters and to understand potential toxicity profiles. Such studies should be coupled with longitudinal research to evaluate the sustainability of treatment effects and potential long-term risks.

Pilot clinical trials in human populations should be initiated to provide preliminary evidence of efficacy, safety, and tolerability. These trials would help determine whether the beneficial effects observed in animal models can be replicated in humans. In addition, detailed mechanistic studies are necessary to further elucidate how these bioactive compounds exert their effects at the molecular level, particularly concerning reproductive hormone regulation and oxidative stress pathways.

Policy implications include the need for structured frameworks that encourage investment in the scientific validation of traditional medicines while ensuring quality control and patient safety. Governments and healthcare policymakers should support the development of regulatory guidelines that facilitate the ethical commercialization of standardized herbal products with proven efficacy. Encouraging collaborations between academic institutions, traditional practitioners, and

pharmaceutical industries will also help translate these findings into accessible, affordable, and culturally appropriate fertility treatments.

In conclusion, the reviewed Egyptian studies align with global research trends in demonstrating the fertility-enhancing potential of medicinal plants through antioxidative, anti-inflammatory, and hormonal pathways. Cross-regional comparisons reinforce the universality of these mechanisms, despite differences in plant species and cultural practices. These insights highlight the critical need for expanded research—both geographically and methodologically—to fully realize the potential of traditional medicinal plants in addressing the pervasive challenge of male infertility**.** Addressing existing research gaps through standardization, dose optimization, and clinical validation will be crucial for the future integration of these plant-based therapies into evidence-based reproductive healthcare and policy frameworks.

Conclusion

This review highlights the potential of selected North African plant species to influence male reproductive health positively, primarily through mechanisms involving hormonal regulation, antioxidant activity, and anti-inflammatory effects. However, these findings are based solely on a small number of preclinical studies conducted in animal models, and their applicability to human fertility remains unverified. While the preliminary evidence suggests these plants may offer natural and culturally relevant options for managing male infertility, further rigorous research—including detailed phytochemical analyses, standardized experimental protocols, and well-designed clinical trials—is necessary to confirm their efficacy and safety before they can be considered for integration into reproductive health strategies within the region.

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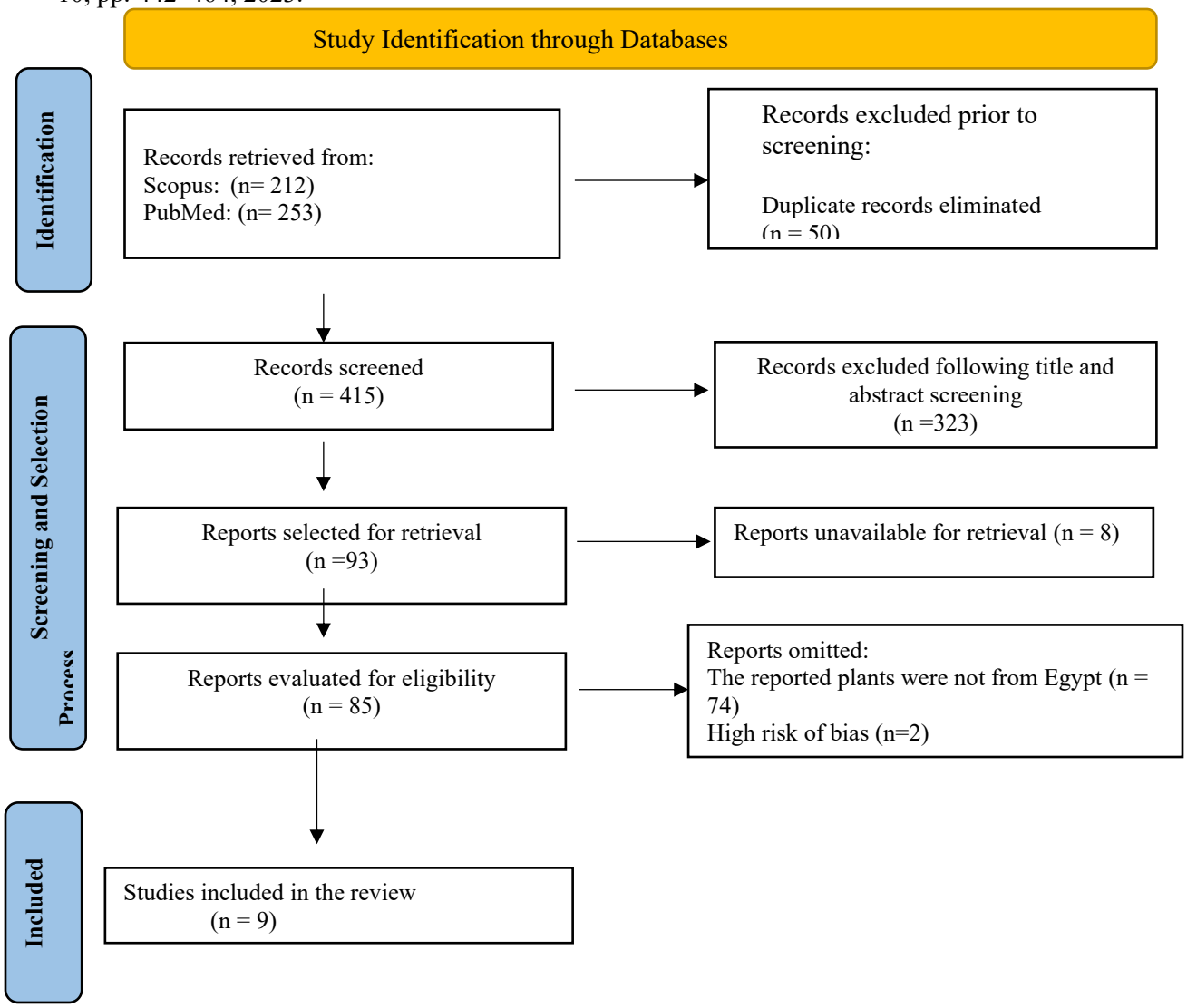

Figure 1: PRISMA Flow Diagram

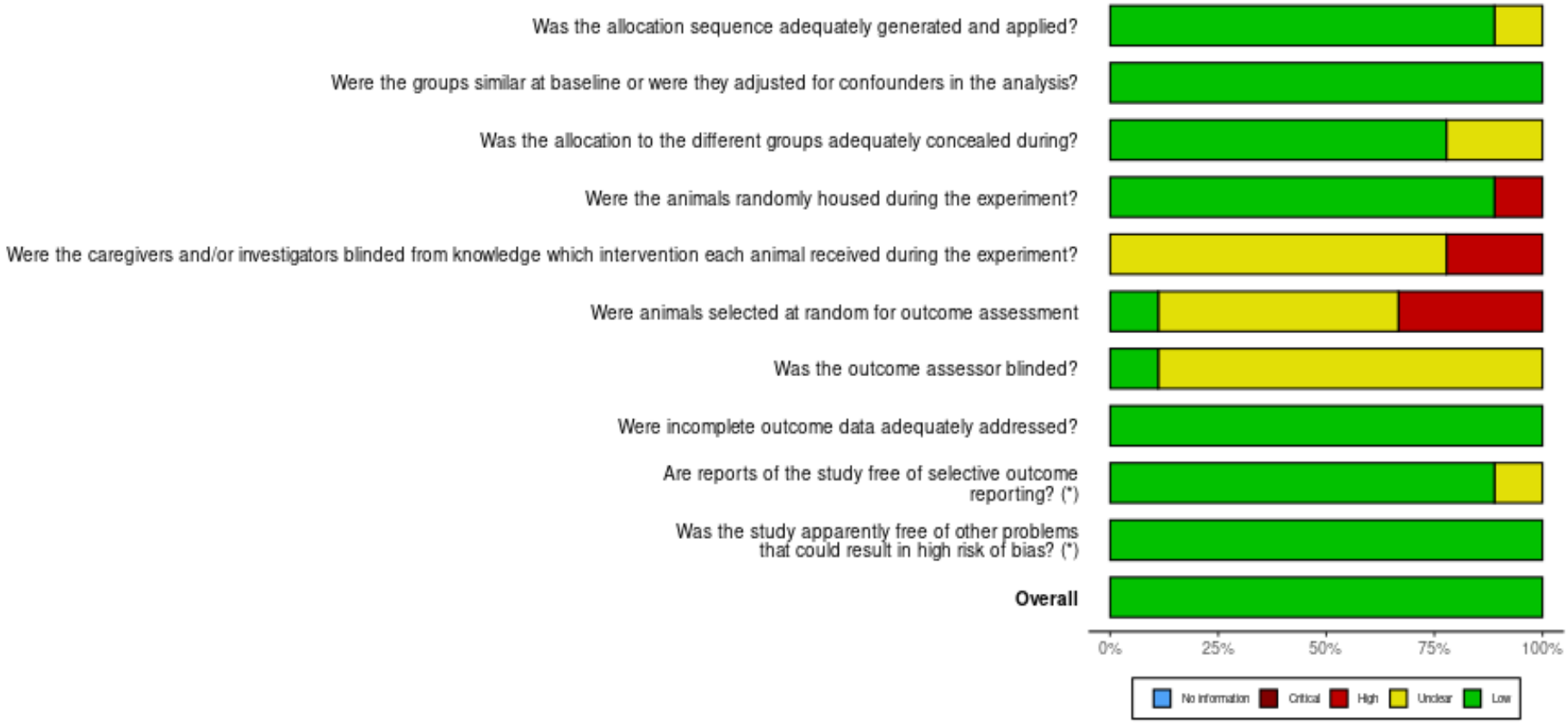

Figure 2: Bias Risk Across 10 Domains

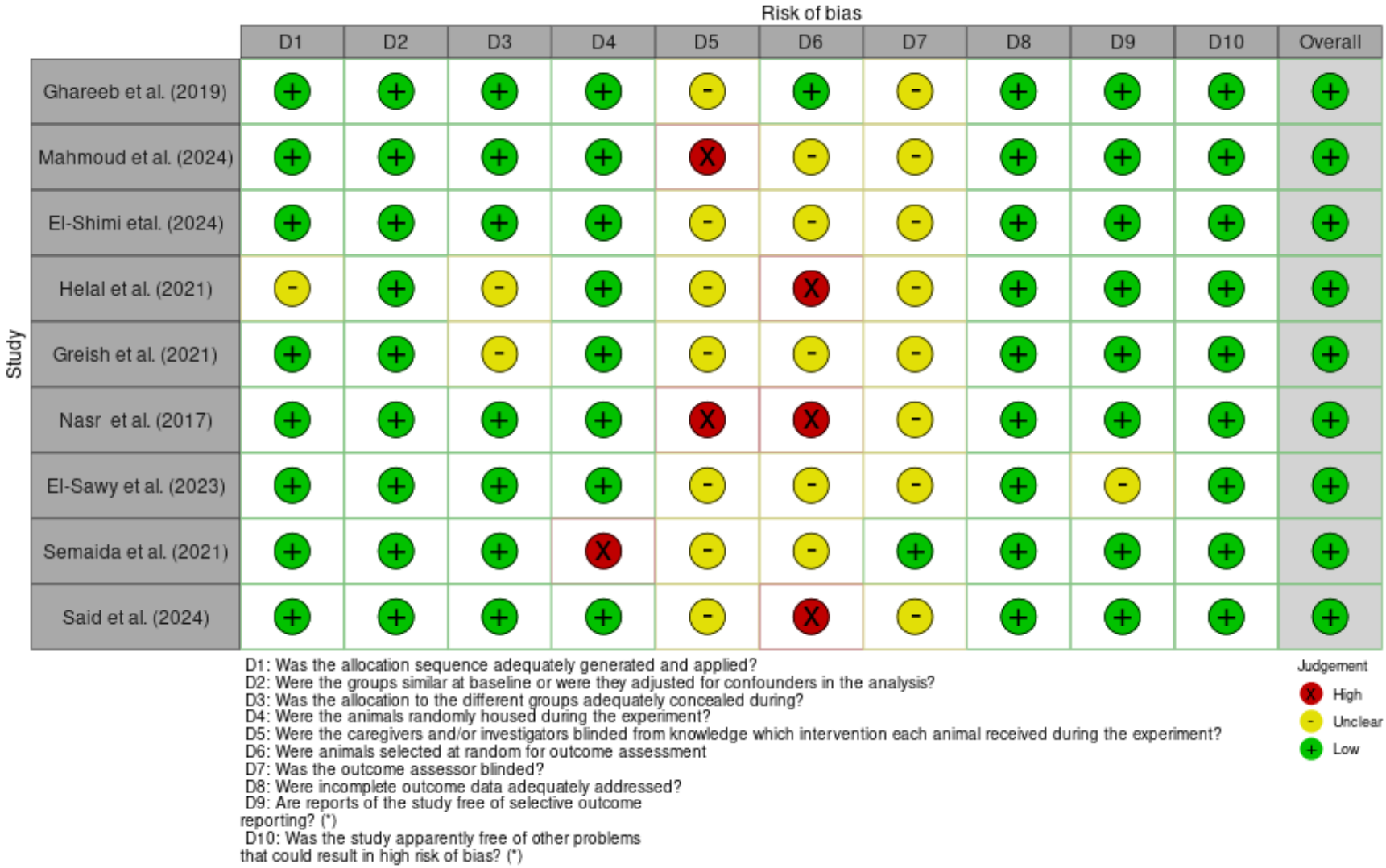

Figure 3: Bias Risk for Individual Articles

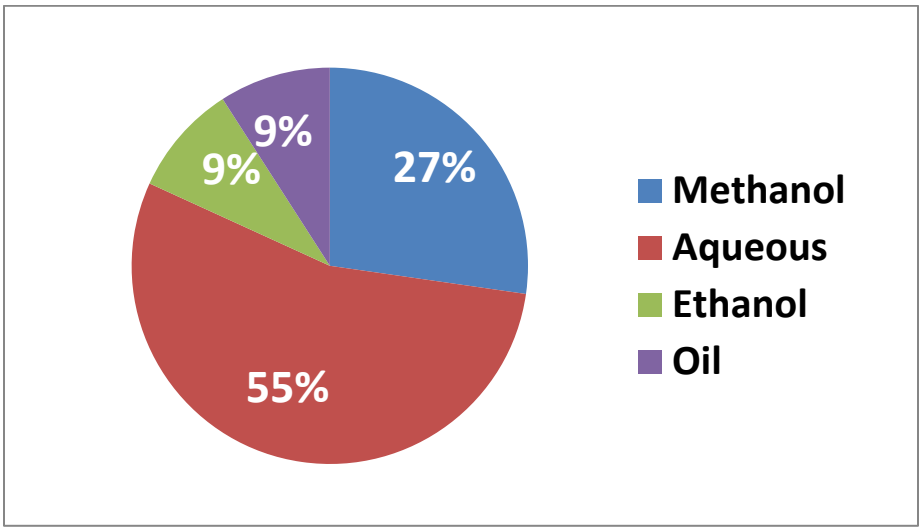

Figure 4: Solvent of extraction used in the different studies

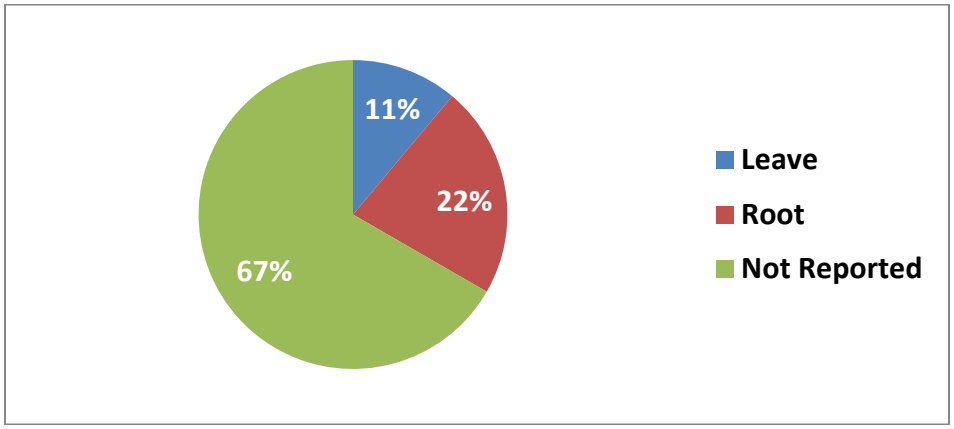

Figure 5: Plant parts used

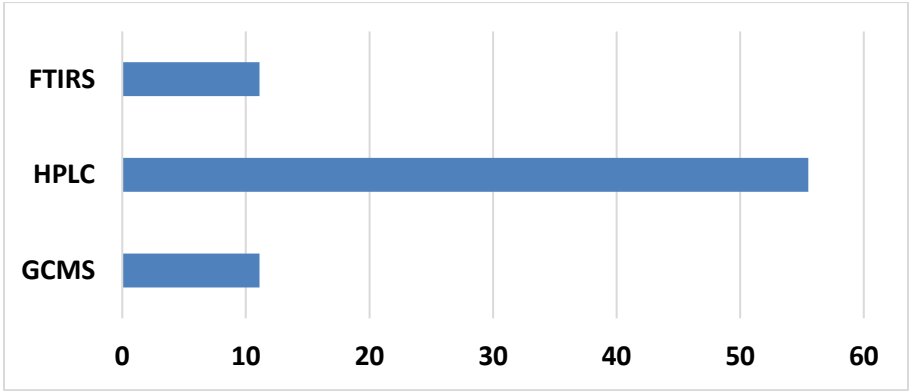

Figure 6: Methods used for the chemical characterization of the plants, including FT-IR (Fourier Transform Infrared Spectroscopy), GC-MS (Gas Chromatography-Mass Spectrometry), and HPLC (High-Performance Liquid Chromatography).

Table 1: Characteristics of Selected Studies

Author/Date	Country	Sex and Strain of Animals	Sample Used/ Disease Model	Dosage/ Treatment
Ghareeb et al. (2019)	Egypt	150 ± 10 g male Sprague-Dawley rats	Gossypol at a dose of 5 mg/kg was administered intraperitoneally on eight occasions	The methanolic extract of *Ulva lactuca* (100 mg/kg) was administered orally for one and two weeks.
Helal et al. (2021)	Egypt	Sprague-Dawley male rats (weight range: 120–150 g)	A 15 mg/kg dose of monosodium glutamate was orally administered for 45 days to induce toxicity	A 100 mg/kg dose of aqueous and methanolic extract of *Ulva lactuca* was administered for 30 days, after 45 days of Monosodium glutamate treatment.
Nasr 2017	Egypt	Male Wistar rats (aged adults; 150–250 g)	Adriamycin at a dose of 10 mg/kg was administered intraperitoneally on day 8	*Allium sativum* (Aged Garlic) extract, at a dose of 250 mg/kg body weight, was administered orally for 14 days.
Greish et al. (2021)	Egypt	Albino Wistar rats (adult males; 120–150 g body weight)	A high-fat diet containing 20 g of fat per 100 g of diet was administered for 12 weeks.	400 mg/kg oil extract of *Moringa oleifera* was administered for 4 weeks, beginning at the 9th week of high-fat diet administration.
Said et al. (2024)	Egypt	Male Wistar rats weighing between 200 and 210 grams	Streptozotocin at a dose of 60 mg/kg body weight was administered via intraperitoneal injection to induce toxicity	Pomegranate extract (60 mg/kg, orally) was administered for 14 days.
Semaida et al. (2021)	Egypt	Male Wistar rats weighing 200–250 grams	Infertility was induced by exposing the rats to 137Cs-gamma rays with a single dose of 3.5 Gy	Aqueous and ethanolic extracts of *Sargassum virgatum* (100 and 400 mg/kg body weight) were administered intraperitoneally daily for two consecutive weeks, for durations of 15 and 60 days.
El-Sawy et al. (2023)	Egypt	Adult male Wistar rats weighing 250–300 grams	Obesity induced by a high-fat diet was administered for 12 weeks	Crude leaf extract of *Artemisia annua* (AAE) at a dose of 100 mg/kg body weight was administered for 8 consecutive weeks.
El-Shimi et al. (2024)	Egypt	Young male Wistar rats (150-200 g) and adult male rats (350-400 g)	Bisphenol-A was given over a period of 40 days to induce toxicity	Panax ginseng dry extract at a dose of 300 mg/kg body weight was administered for 40 days as treatment.
Mahmoud et al. (2024)	**Egypt**	**Male Wistar rats weighing 170–200 grams**	**A single dose of cadmium chloride (1 mg/kg) was administered via intraperitoneal (IP) injection to induce toxicity.**	**An extract of *Anacyclus pyrethrum* (100 mg/kg) was administered orally for 56 consecutive days.**

Table 2: Study Evaluation, Mechanism of Action and Outcome

Author/Date	Plant Species	Exp. Design	Evaluation	Key Findings/ Mechanism of Action
Ghareeb et al. (2019)	Ulva lactuca	Invivo	Hyaluronidase enzyme activity, serum testosterone levels, and semen quality	The extract enhanced semen quality, elevated blood testosterone levels, and increased hyaluronidase enzyme activity.
Helal et al. (2021)	Ulva lactuca	Invivo	Histological analysis, antioxidant enzyme activities (including glutathione-S-transferase [GST], superoxide dismutase [SOD], and glutathione peroxidase [GPx]), serum testosterone levels, and semen quality.	The extract restored the histological architecture of the testes. It also reversed the Monosodium glutamate-induced reductions in semen quality, serum testosterone, and antioxidant enzyme activities—including glutathione peroxidase (GPx), glutathione-S-transferase (GST), and superoxide dismutase (SOD).
Nasr (2017)	Allium sativum	invivo	Histological evaluation, sperm count, catalase (CAT), malondialdehyde (MDA) concentration, superoxide dismutase (SOD), glutathione (GSH) level, and activities of glutathione peroxidase (GSH-Px), along with testosterone level.	The extract lowered elevated MDA concentrations. It also reversed the Adriamycin-induced increase in sperm abnormalities and decrease in sperm count, as well as the reductions in testosterone levels, GSH levels, and the activities of GSH-Px, CAT, and SOD. It also Notable histological, biochemical, and ultrastructural improvements in the testes were observed.
Greish et al. (2021)	Moringa oleifera	invivo	Testicular morphology, spermatogenesis, and testicular oxidative stress.	Treatment with the extract preserved testicular morphology, reduced testicular oxidative stress, and enhanced spermatogenesis.
Said et al. (2024)	Pomegranate	invivo	Testicular histology, follicle-stimulating hormone (FSH), luteinizing hormone (LH), glutathione, catalase, and testosterone; sperm quality parameters including morphology, motility, and count; along with semen fructose levels.	The observed effects of the extract in this study may be attributed to its antioxidant potential, which likely aids in neutralizing free radicals generated by streptozotocin. This activity is possibly due to its phytochemical constituents, which enhance antioxidant defenses and promote the recovery of reproductive tissues in ethanol-treated rats toward normal function.
Semaida et al. (2021)	*Sargassum virgatum*	invivo	Levels of antioxidant enzymes (CAT, GPx GSH, and SOD), morphometric data of the testes, and semen quality.	*Sargassum virgatum* was shown to improve the morphometric parameters of the testes and enhance semen quality. Its administration was also associated with increased levels of antioxidant enzymes, including GSH, SOD, GPx, and CAT.
El-Sawy et al. (2023)	Artemisia annua	invivo	Hormonal balance, oxidative stress levels, and reduced apoptosis.	The extract significantly decreased apoptosis, reduced oxidative stress, and restored hormonal balance.
El-Shimi et al. (2024)	Panax ginseng	Invivo	Serum levels of total testosterone, malondialdehyde (MDA), and free testosterone.	The study findings revealed that nanoemulsions of *Panax ginseng* dry extract effectively reversed the progressive damage caused by BPA on male fertility by significantly increasing serum levels of free and total testosterone, while markedly reducing MDA serum levels.
Mahmoud et al. (2024)	Anacyclus pyrethrum	invivo	Sperm parameters, activities of oxidative enzymes, circulating hormone levels, formation of lipid peroxidation byproducts, apoptosis, sperm DNA damage, and gene expression.	The extract reduced the formation of lipid peroxidation byproducts and restored oxidative enzyme activities, thereby mitigating the effects of cadmium on gene expression, sperm parameters, apoptosis, sperm DNA damage, and circulating hormone levels.

Table 3: Biochemical Attributes of the Plants

Author	Plants	GCMS	HPLC	FTIRS
Ghareeb et al. (2019)	Ulva lactuca	Not reported	Chlorogenic acid, Quercetin, Caffeic acid, quinic acid, 3,4-Dicaffeoyl quinic acid, Retinol, 4,5-Ddicaffeoyl Galic acid, Rutin, 3,5-Dicaffeoyl quinic acid, and Tanic acid	Not reported
Helal et al. (2021)	Ulva lactuca	Not reported	Quercetin, Chlorogenic acid, Caffeic acid, Gallic acid, 4,5-Dicaffeoylquinic acid, and Retinol	Not reported
Nasr 2017	Allium sativum	Not reported	Not reported	Not reported
Greish et al. (2021)	Moringa oleifera	Not reported	Not reported	Not reported
Said et al. (2024)	Punica granatum	Not reported	Tannins, Flavonoids, Saponins, Alkaloids, Phenol, Glycosides, Cardiac glycosides, and Sterol,	Not reported
Semaida et al. (2021)	*Sargassum virgatum*	Not reported	Gallic acid, Protocatechuic acid, Catechin, Vanillic acid, Hesperidin, Apigenin-7-glucoside (cosmosiin), Rosmarinic acid, Cinnamic acid, Apigenin, and Chrysin	Not reported
El-Sawy et al. (2023)	Artemisia annua	Artemisinin, limonene, 1,8-cineole (eucalyptol), camphor, α-pinene, arteannuin B, β-pinene, , caryophyllene, α-terpineol, and sabinene.	Not reported	Not reported
El-Shimi et al. (2024)	Panax ginseng	Not reported	Not reported	Samples describe the stretching mode of hydroxyl (OH) group and vibration modes of methylene (CH_2) group
Mahmoud et al. (2024)	Anacyclus pyrethrum	Not reported	Gallic acid, Apigenin, Catechin, Quercetin, Vanillic acid, Chlorogenic acid, Rosemarinic acid, P- coumaric acid, Ferulic acid, Resveratrol, Hesperidin, O- coumaric acid, Myricetin, Rutin, Kaempferol, and P- hydroxybenzoic	Not reported