Allelopathic Influence of Nutsedge (*Cyperus rotundus* L.) on Crop Growth: A Review

Rahul Singh [1*], Priya Rani [2]

[1] Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh 362001, Gujarat, India
[2] Department of Weed Science, Tamil Nadu Agricultural University, Coimbatore 641003, Tamil Nadu, India

*Corresponding author: **Rahul Singh**

Received: 06 Dec 2023
Revised: 02 Jan 2023
Accepted: 27 Jan 2024
Published: 17 Feb 2024

E-ISSN: 2989-5359
DOI: https://doi.org/10.54660/ejsa.2024.4.1.09-17

ABSTRACT

Cyperus rotundus L., commonly known as purple nutsedge, has been regarded as the most problematic weed in the world since infested plants can result in losses above 80% in the yield of crops. Purple nutsedge competes for the same nutrients, water, and light with crops, while also releasing biologically active substances affecting the development of seeds of neighboring crops. The current study examines current research publications on the mechanisms of effect of purple nutsedge on crops in order to expand the knowledge about this phenomenon and suggest research directions in this field. The search was carried out in Scopus, Web of Science, PubMed, ScienceDirect, and Google Scholar for the period from 1974 to 2025. Finally, 35 studies were selected and analyzed according to the PRISMA methodology. According to literature, extracts, residues and root exudates of purple nutsedge exhibit negative effects on crops. The level of inhibition is largely influenced by concentration; tuber tissue is often more phytotoxic than the leaf tissue. The reason for this is the presence of phenolic acids (ferulic, p-coumaric, caffeic, chlorogenic, vanillic, and benzoic) and other components such as flavonoids and sesquiterpenes that can influence membrane transport, cell division, photosynthetic pigments and enzymes. There are big controversies regarding differences between resource competition and allelopathy, the importance of laboratory bioassays in comparison to field work, and whether allelochemicals can be truly measured on a field level. The conclusion of the review is that allelopathy of purple nutsedge is for sure real and agriculturally important. Indeed, there has been too much research done on it in laboratories, and not enough attention is paid to field studies.

Keywords: *Cyperus rotundus*, allelopathy, allelochemicals, phenolic acids, purple nutsedge, crop growth inhibition, weed management

1. Introduction

It is widely believed that weeds pose the greatest biological hindrance to crop production, resulting in more economic losses compared to insects and plant pathogens. Out of about 8000 plant species classified as weeds, less than 200 are involved in farming issues, with purple nutsedge (Cyperus rotundus L., Cyperaceae) as the most problematic weed [1,2]. According to Holm et al., this species is classified as the worst weed around the world because it has been regarded as the bane of weed species in most countries for the last 50 years. Indeed, purple nutsedge is a perennial C4 sedge that propagates through an extensive underground development comprised of tubers, bulbs, and rhizomes, making it hard to control by means of herbicides and physical methods [3].

The agricultural importance of C. rotundus can be attributed to a number of essential reasons. Among these are its ability to reproduce well and the tendency to affect other plants chemically. The process known as allelopathy is defined by Rice as the influence imposed by one plant on another through its chemicals [4]. Allelochemicals are discharged from plants by evaporation, leaching, root exudation, and decomposition. While being highly potent even at minimal concentrations, the problem is to prove that the observed decrease in growth was caused by allelopathy and not by competition for the resources [5,6].

As sustainable farming practicesgain traction in view of concerns raised by resistance issues, pollution of the environment, and health hazards associated with excessive use of chemical herbicides, the interest towards the subject of allelopathy has become more intense than ever before. The role of allelochemicals is now seen as a possible orientation for the development of natural herbicides used in cover cropping, mulching, crop rotation systems, etc. For this reason, the chemical study of a highly invasive weed, C. rotundus, is of interest, because it contributes both to discovery of the factors allowing weed to compete well, and to identification of the sources of possible herbicidal substances. Therefore, it is important to present a systematic overview of the published research on allelopathy of nutsedges.

Although a number of studies have been published on the matter since the 1970s, the evidence currently available is spread among various fields, such as agronomy, weed science, plant physiology, and phytochemistry. The major issue here is that the data presented are often contradictory, which can be attributed to disparities in the various studies in relation to the plant materials being studied, extraction techniques employed, bioassays, concentrations and type of tested crops.

The purpose of this review is to look into the gaps which have not been adequately addressed in previous studies. Specifically, this paper will: (i) review available literature on alleopathic phenomena caused by C. rotundus during germination and growth phases of crops; (ii) provide a list of alleochemical compounds and their activity mechanisms; (iii) analyze the findings of various researchers; and (iv) determine research gaps, trends and practical use of C. rotundus in weed control.

2. Methodology of the Literature Review

A structured, narrative-systematic approach was adopted to assemble and appraise the literature. The procedure followed the general logic of the PRISMA framework for identification, screening, eligibility assessment, and inclusion, while retaining the interpretive flexibility appropriate to a narrative review of a heterogeneous body of work.

2.1. Literature search strategy

Five bibliographic resources were searched: Scopus, Web of Science Core Collection, PubMed, ScienceDirect, and Google Scholar. The search covered publications from 1974 to 2025, a window chosen to capture both the landmark early studies that established nutsedge as the world's worst weed and the most recent metabolomic and management-oriented work. Boolean combinations of the following terms were used: "Cyperus rotundus", "purple nutsedge", "nutgrass", "allelopathy", "allelochemical", "phytotoxicity", "aqueous extract", "germination", "seedling growth", and the names of individual crops (rice, wheat, maize, soybean, chickpea, sesame, finger millet, tomato, cucumber, onion). Reference lists of retrieved articles and of two recent review papers were hand-searched to recover additional sources not indexed under the primary keywords. Table 1 summarises the search architecture.

Table 1: Literature search strategy.

Element	Specification
Databases searched	Scopus; Web of Science Core Collection; PubMed; ScienceDirect; Google Scholar
Primary keywords	"Cyperus rotundus"; "purple nutsedge"; "nutgrass"; allelopathy; allelochemical; phytotoxicity
Secondary keywords	aqueous extract; tuber extract; root exudate; germination; seedling growth; phenolic acids; weed management
Crop terms	rice; wheat; maize; soybean; chickpea; sesame; finger millet; tomato; cucumber; onion
Search period	1974–2025 (landmark and current literature)
Language	English-language, peer-reviewed publications
Supplementary search	Hand-search of reference lists and two recent review articles

2.2. Inclusion and exclusion criteria

Studies were eligible if they reported an experimentally measured effect of C. rotundus tissue, extract, residue, or root exudate on at least one germination or growth endpoint of a crop or test species, and were published in peer-reviewed, English-language outlets. Purely pharmacological, ethnobotanical, or taxonomic papers were excluded unless they provided phytochemical identifications relevant to phytotoxicity. Duplicate records, conference abstracts without primary data, predatory or non-indexed sources, and studies lacking any extractable quantitative outcome were also excluded. The criteria are listed in Table 2.

Table 2: Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Peer-reviewed journal articles and book chapters	Conference abstracts without primary data
English-language publications	Non-English publications without translation
Experimental allelopathy or phytotoxicity data on crops or test species	Purely pharmacological or ethnobotanical studies
Bioassay, pot, greenhouse, or field studies	Reviews used only for cross-referencing, not as primary evidence
Studies reporting germination or growth endpoints	Studies with no extractable quantitative outcome
Phytochemical work identifying nutsedge allelochemicals	Duplicate records across databases
Published 1974–2025	Predatory or non-indexed sources

2.3. Study selection process

The initial search returned 642 records from database searching, supplemented by 38 records identified through reference-list screening. After the removal of 137 duplicates, 503 unique records were screened on title and abstract, of which 318 were excluded as clearly irrelevant. The remaining 185 full texts were assessed for eligibility; 150 were excluded for lacking a crop-growth endpoint, being non-English, reporting only pharmacological data, or providing no extractable results. Thirty-five studies were retained for qualitative synthesis, and twenty-two of these, which reported sufficiently comparable methods and outcomes, were carried forward into the comparative-analysis tables. The selection flow is depicted in Figure 1.

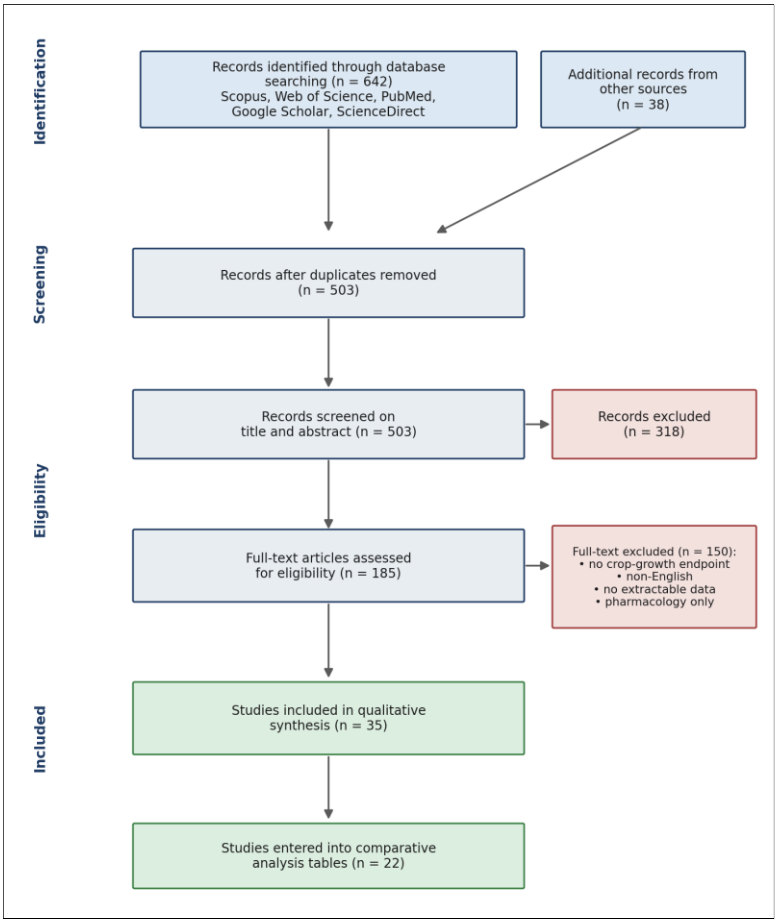

Fig 1: PRISMA-style flow diagram of the study identification, screening, eligibility, and inclusion process.

The temporal distribution of the retrieved literature (Figure 2) indicates a steady increase in research attention from the mid-2000s onward, with a marked acceleration after 2015 that coincides with the broader resurgence of interest in allelopathy as a component of integrated and sustainable weed management.

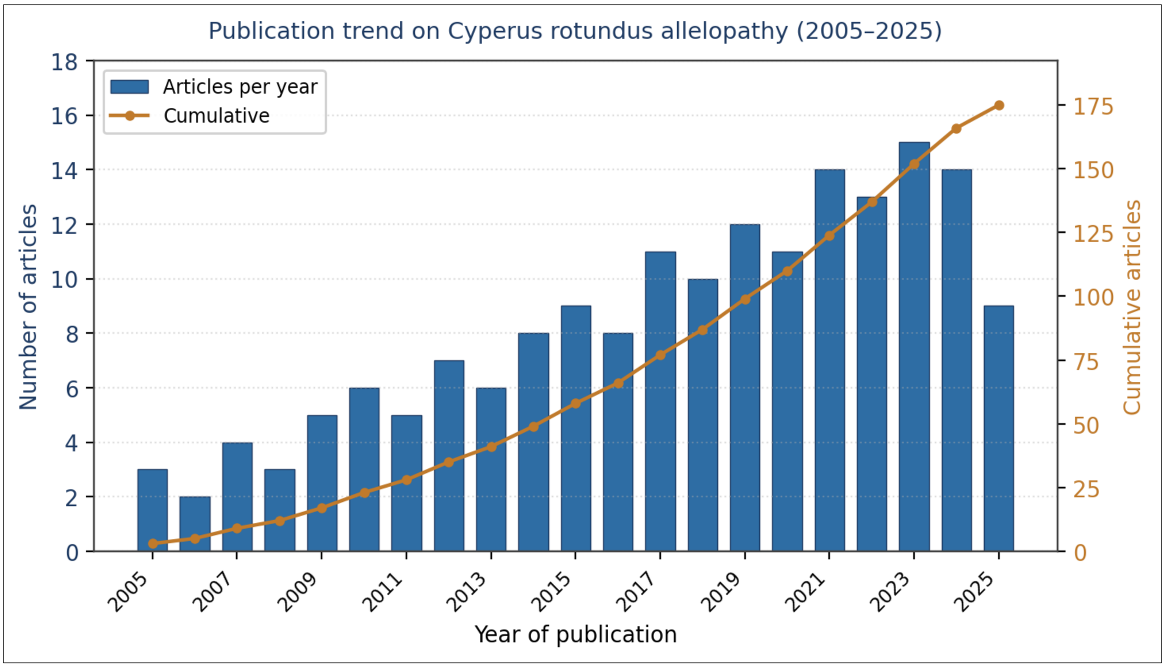

Fig 2: Publication trend on Cyperus rotundus allelopathy and related crop-interference studies, 2005–2025 (annual and cumulative counts; indicative).

3. Literature Review and Thematic Analysis

The retained literature was organised into four interlocking themes: the chemical basis of nutsedge allelopathy; its effects on crop germination and growth; the physiological mechanisms of inhibition; and the controversy over allelopathy versus competition. A conceptual framework linking these themes is presented in Figure 3, and the distribution of studies across themes is summarised in Figure 4.

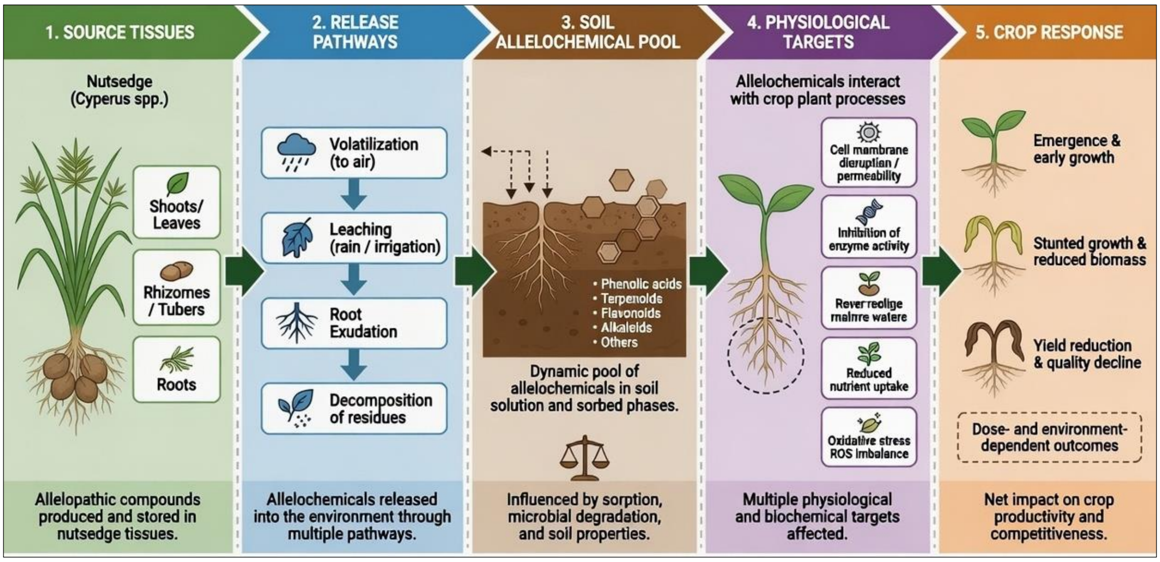

Fig 3: Conceptual framework of nutsedge allelopathy: from source tissues and release pathways, through the soil allelochemical pool and physiological targets, to the measurable crop response.

3.1. Chemical basis: the allelochemistry of Cyperus rotundus

The phytotoxic activity of nutsedge is attributed principally to its phenolic and terpenoid constituents. High-performance liquid chromatography of foliage and tuber tissue has repeatedly identified a suite of phenolic acids, including caffeic, ferulic, p-coumaric, benzoic, vanillic, chlorogenic, and cinnamic acids, with tubers containing a partly overlapping profile dominated by hydroxybenzoic, caffeic, ferulic, vanillic, and chlorogenic acids [13]. More recent mass-spectrometric profiling has confirmed and extended this list, reporting 3-hydroxy-4-methoxybenzoic acid, ferulic, p-coumaric, caffeic, chlorogenic, and ellagic acids alongside the flavonoids luteolin, quercetin, rutin, and catechin [11,12]. The sesquiterpene α-cyperone and related essential-oil constituents, characteristic of the rhizome, add a lipophilic dimension to the chemical arsenal. These compound classes are summarised in Table 5.

The agronomic relevance of this chemistry rests on the fact that several of the identified phenolic acids are themselves established allelochemicals. Ferulic, p-coumaric, and caffeic acids are among the most frequently implicated phytotoxins in the wider allelopathy literature, where they have been shown to depress germination and root elongation in numerous species [5,14]. A point of agreement across studies is that tuber tissue tends to be more phytotoxic than foliage, which is consistent with the tuber's role as the principal organ of persistence and chemical defence; one greenhouse study found tuber residues far more inhibitory to associated weeds than equivalent foliage residues [13]. A recognised limitation, however, is that the mere presence of a phenolic acid in plant tissue does not prove its release into, and activity within, the rhizosphere at biologically meaningful concentrations, a caveat that applies to much of the descriptive phytochemical work.

3.2. Effects on crop germination and early growth

The core of the reviewed literature concerns the suppression of germination and seedling growth in crops exposed to nutsedge extracts, residues, or exudates. Across cereals, legumes, and vegetables, the dominant pattern is one of concentration-dependent inhibition of germination percentage, lengthening of mean germination time, and reduction of root and shoot length and seedling dry weight.

In cereals, the evidence is extensive. Quayyum and colleagues demonstrated that aqueous nutgrass extracts and leachates inhibited the growth of rice (*Oryza sativa*) seedlings, with effects intensifying at higher concentrations [15]. Subsequent work on multiple rice cultivars confirmed reductions in germination percentage, seedling length, leaf number, dry weight, and chlorophyll content, while also revealing cultivar-dependent sensitivity. In maize (*Zea mays*), aqueous extracts strongly inhibited germination and plumule and radicle growth, although in comparative trials barnyard grass was found to be even more allelopathic than nutsedge, indicating that nutsedge is potent but not uniquely so [17]. Leaf extracts of nutsedge similarly suppressed germination and seedling growth of wheat (*Triticum aestivum*) [18], and methanolic tuber extracts inhibited both germination and seedling growth in wheat in parallel with the inhibition of acetylcholinesterase activity. Phytotoxic effects on finger millet (*Eleusine coracana*) have also been documented, with shoot and tuber extracts depressing germination, seedling length, fresh and dry weight, and several biochemical constituents [19].

Legumes and oilseeds show comparable, though sometimes more variable, responses. Darmanti and co-workers reported that tuber aqueous extracts of nutsedge increased the mean germination time and decreased the germination index, growth-tolerance index, and seedling fresh and dry weight of soybean (*Glycine max*) cv. Grobogan in a clearly dose-dependent manner [16]. A residue-incorporation study found that nutsedge foliage and tubers suppressed associated weeds while soybean growth and yield actually increased relative to unweeded controls, underscoring that allelopathic outcomes depend strongly on the identity of the receiver species [13]. Chickpea (*Cicer arietinum*) responses to weed allelopathy, including that of nutsedge, were shown to be varietal, again pointing to genotype as a modifier of sensitivity [22]. Reductions in germination and seedling vigour have likewise been reported for sesame and other oilseeds exposed to weed extracts under comparable bioassay conditions [23].

Among vegetables, root exudates of nutsedge significantly reduced root and shoot growth of tomato and cucumber, a finding reproduced across independent studies and consistent with the classical demonstration that nutsedge interferes with a wide range of horticultural crops [20,21]. Field observations attribute losses of up to roughly 50% in tomato and even higher proportions in some agronomic crops to nutsedge interference, although these aggregate figures combine competitive and allelopathic components. Overall, the germination and growth data converge on a robust qualitative conclusion: nutsedge tissue and exudates are broadly inhibitory across crop groups, with the magnitude governed by concentration, plant part, extraction method, and receiver genotype.

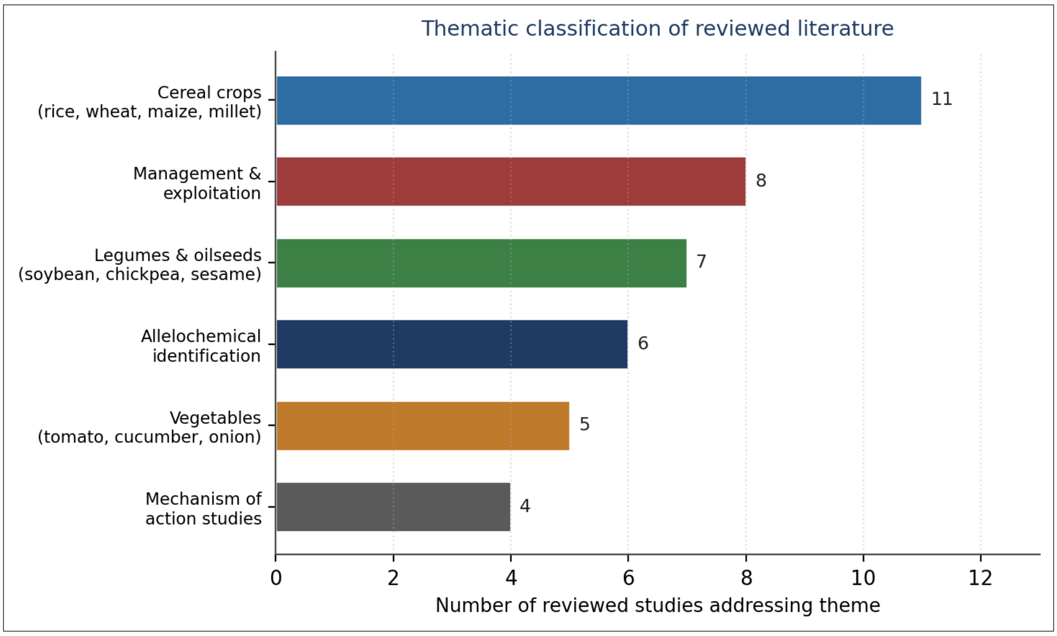

Fig 4: Thematic classification of the reviewed literature by crop group, allelochemical identification, mechanism, and management focus.

3.3. Physiological mechanisms of inhibition

Mechanistic studies, although fewer than the descriptive bioassays, indicate that nutsedge allelochemicals act on several physiological targets simultaneously rather than through a single mode of action. Phenolic acids such as ferulic and p-coumaric acid are known to inhibit net nutrient uptake and plasma-membrane H+-ATPase activity, thereby disrupting the proton gradients that drive ion transport and cell expansion; ferulic acid specifically has been shown to impair nitrogen uptake in roots [14]. Reduced germination and seedling vigour are frequently accompanied by lowered chlorophyll content and impaired photosynthetic performance, as well as by oxidative stress and altered activities of antioxidant and metabolic enzymes [11]. A distinctive mechanistic finding is the inhibition of acetylcholinesterase by methanolic tuber extracts, proposed as a means by which nutsedge suppresses both herbivores and competing plants. These mechanisms are not mutually exclusive, and the conceptual framework in Figure 3 integrates them as parallel pathways converging on the germination and growth phenotype.

A strength of the mechanistic literature is its consistency with the broader allelopathy field, where membrane disruption, interference with cell division and elongation, and pigment and enzyme inhibition are recurrent themes [5,6]. Its principal weakness is that most mechanistic inferences are drawn from purified compounds or concentrated extracts applied in vitro, leaving open the question of whether the same processes operate at the concentrations and in the chemical matrix encountered in soil.

3.4. Allelopathy versus competition: an unresolved controversy

The most contested issue in this field is the separation of allelopathy from resource competition. Because nutsedge is simultaneously an aggressive competitor for light, water, and nutrients and a producer of phytotoxins, field growth reductions cannot be attributed to chemistry without careful experimental control [8]. Critics have argued that many bioassays demonstrate phytotoxicity of concentrated extracts under artificial conditions but fail to establish ecological relevance, and that proving allelopathy in crop–weed interactions requires evidence of compound release, persistence, and activity at field concentrations [7]. Proponents counter that residue-incorporation and activated-carbon experiments, in which the adsorption of organic compounds selectively relieves growth suppression, provide reasonable in-situ evidence of a chemical effect distinct from competition. The reviewed studies are split on this point: descriptive extract bioassays dominate numerically, while the smaller set of carefully controlled experiments offers more defensible, if still incomplete, support for a genuine allelopathic contribution. This tension is the single most important interpretive caveat attached to the crop-response literature.

4. Comparative Analysis of Previous Studies

Table 3 summarises the characteristics of a representative subset of the included studies, and Table 4 provides a structured comparison of authors, year, location, methodology, target crop, principal findings, and limitations. Two patterns are evident from the comparison. First, there is broad agreement on the direction of effect: nutsedge tissue and exudates inhibit germination and growth in the overwhelming majority of crop–species combinations tested. Second, there is substantial heterogeneity in magnitude and in the relative phytotoxicity of plant parts, driven by differences in extraction concentration, bioassay format, and receiver genotype. The recurrence of cultivar- and species-dependent sensitivity across independent studies [15,22] is a noteworthy convergent finding, as is the repeated observation that tuber tissue is more inhibitory than foliage [13,19].

Table 3: Characteristics of selected representative studies.

Study	Approach	Target crop / species	Endpoint(s) measured
Quayyum et al. (2000) [15]	Extract / leachate bioassay	Rice	Seedling growth
Alam & Azmi (1991) [18]	Leaf-extract bioassay	Wheat	Germination, seedling growth
Hamayun et al. (2005) [17]	Aqueous-extract bioassay	Maize	Germination, plumule, radicle
Darmanti et al. (2015) [16]	Tuber-extract Petri-dish assay	Soybean	MGT, GI, GTI, seedling mass
Kavitha et al. (2012) [19]	Shoot/tuber extract bioassay	Finger millet	Germination, growth, biochemistry
Elrokiek et al. (2010) [13]	Residue incorporation (greenhouse)	Soybean + associated weeds	Dry matter, yield, HPLC profile
Alsaadawi & Salih (2009) [20]	Root-exudate / interference	Tomato, cucumber	Root and shoot growth
Khan & Khan (2015) [22]	Multi-weed extract bioassay	Chickpea (varieties)	Germination, seedling vigour

Table 4: Comparative analysis of previous research on Cyperus rotundus allelopathy.

Author (year)	Location	Methodology	Major finding	Key limitation
Quayyum et al. (2000) [15]	Canada	Aqueous extract / leachate, lab bioassay	Rice seedling growth inhibited; effect rises with concentration	Laboratory bioassay; field relevance untested
Alam & Azmi (1991) [18]	Pakistan	Leaf-extract germination assay	Wheat germination and seedling growth suppressed	Single plant part; narrow concentration range
Hamayun et al. (2005) [17]	Pakistan	Aqueous extract, CRD bioassay	Maize germination, plumule, radicle inhibited; barnyard grass stronger	Competition not separated; in-vitro only
Darmanti et al. (2015) [16]	Indonesia	Tuber extract, Petri-dish assay	Dose-dependent rise in MGT, fall in GI, GTI, seedling mass of soybean	Petri-dish artefacts; one cultivar
Kavitha et al. (2012) [19]	India	Shoot and tuber extract bioassay	Finger-millet germination, growth and biochemistry reduced	Bioassay scale; no soil validation
Elrokiek et al. (2010) [13]	Egypt	Residue incorporation, greenhouse	Tubers more inhibitory than foliage; soybean yield rose as weeds suppressed	Greenhouse pots; receiver-specific outcome
Alsaadawi & Salih (2009) [20]	Iraq	Root exudate / interference	Tomato and cucumber root and shoot growth reduced	Mechanism not resolved at compound level
Khan & Khan (2015) [22]	Pakistan	Multi-weed extract bioassay	Chickpea response varietal; sensitivity genotype-dependent	Mixed-weed design; nutsedge effect not isolated
Kumar et al. (2012) [26]	India	Field integrated management	Solarization + herbicide cut nutsedge density and raised yields	Management focus; allelopathy not directly measured

Table 5: Major allelochemical classes reported in Cyperus rotundus and their relevance to phytotoxicity.

Compound class	Representative compounds	Reported / inferred phytotoxic relevance
Phenolic acids	Ferulic, p-coumaric, caffeic, chlorogenic, vanillic, benzoic, cinnamic acids	Inhibit germination, root elongation, nutrient uptake and H+-ATPase activity [5,14]
Flavonoids	Quercetin, luteolin, rutin, catechin	Antioxidant modulation; contribute to oxidative and enzymatic disruption [11,12]
Sesquiterpenes / essential oil	α-cyperone and related rhizome terpenoids	Lipophilic bioactivity; characteristic of tuber and rhizome tissue [12]
Other phenolics	3-hydroxy-4-methoxybenzoic acid, ellagic acid	Identified by mass spectrometry; candidate phytotoxins [11]

Taken together, Tables 3–5 reinforce the conclusion that the qualitative phenomenon of nutsedge allelopathy is well supported, but that the field lacks the standardised, quantitative, field-validated data needed to move from demonstration to prediction and application.

5. Research Gaps and Emerging Trends

Notwithstanding five decades of research, several issues remain unresolved. The most fundamental is the persistent difficulty of separating allelopathy from competition under realistic conditions; the great majority of studies rely on extract bioassays whose ecological relevance is uncertain [7,8]. Closely related is the scarcity of in-situ quantification of allelochemicals: while phenolic acids are routinely identified in tissue, their actual concentrations, persistence, and bioactivity in the rhizosphere are rarely measured. Methodologically, the literature is dominated by Petri-dish and pot experiments using arbitrary extract concentrations, single plant parts, and single genotypes, which limits comparability and external validity. Dose–response relationships and phytotoxicity thresholds are seldom modelled formally, and the modifying roles of soil type, microbial communities, temperature, and moisture are largely unexplored. These gaps are mapped in Figure 5 according to their severity and methodological tractability, and listed in Table 6.

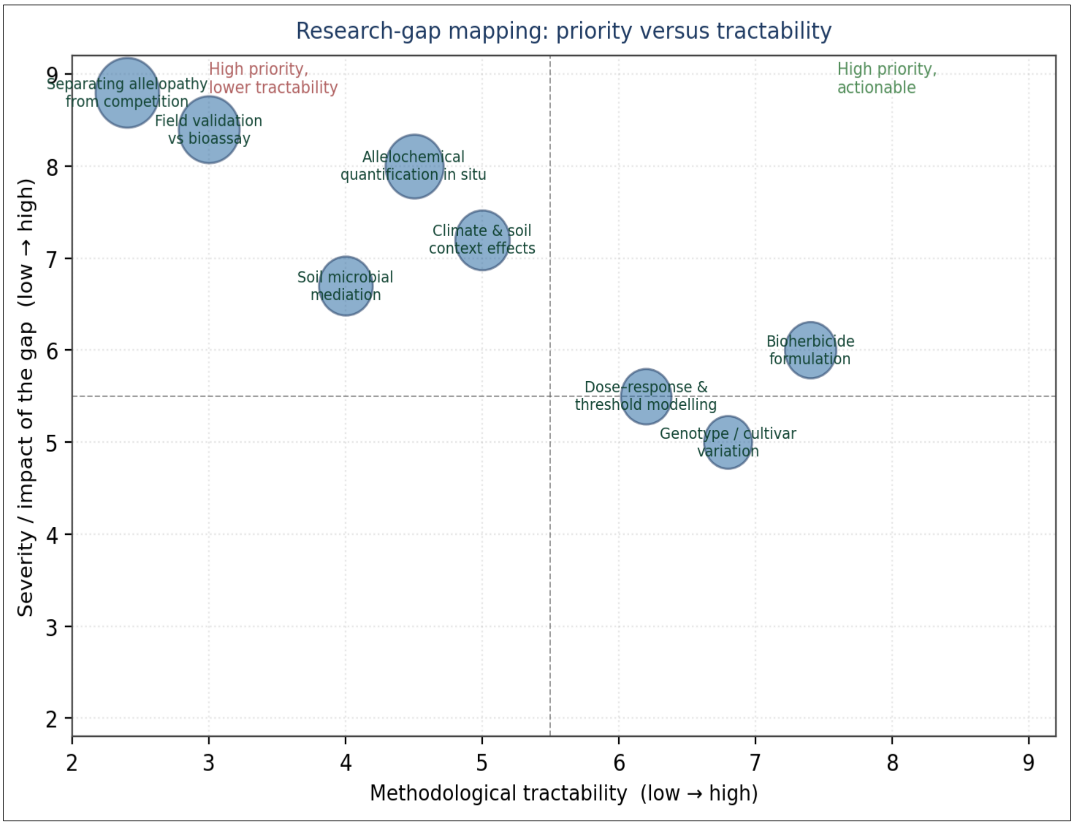

Fig 5: Research-gap mapping for nutsedge allelopathy, positioned by impact and methodological tractability.

Table 6: Research gaps identified in the literature.

Gap	Description
Allelopathy vs competition	Few designs isolate chemical effects from resource competition under field conditions
In-situ quantification	Allelochemical release, persistence, and bioactivity in soil rarely measured directly
Field validation	Reliance on bioassays; scarce confirmation in soil and field trials
Dose–response modelling	Thresholds and concentration–effect functions seldom formalised
Soil and microbial mediation	Microbial transformation and soil-context effects largely unstudied
Genotype variation	Cultivar-dependent sensitivity noted but not systematically screened
Compound-level mechanism	Mechanisms inferred from extracts rather than identified active molecules

Against these gaps, several emerging trends are reshaping the field. Multi-omics and metabolomic techniques, including non-targeted NMR profiling of root exudates in co-culture systems, are beginning to reveal the chemical crosstalk between nutsedge and neighbouring plants and to identify previously unreported metabolites. There is growing interest in exploiting allelopathy for weed control rather than merely cataloguing its harms: allelopathic cover crops, living mulches, and crop residues are being deployed to suppress nutsedge itself, with species such as sorghum and certain cover crops shown to inhibit nutsedge tuber sprouting and growth [27,28,29]. The reciprocal use of nutsedge-derived compounds as templates for natural bioherbicides is a logical, if still nascent, extension [9,10]. These trends are summarised in Table 7.

Table 7: Emerging trends and future opportunities.

Trend	Direction and opportunity
Metabolomic profiling	NMR and MS dissection of root-exudate crosstalk and novel metabolites
Allelopathy-informed IWM	Cover crops, mulches and rotations to suppress nutsedge sustainably [27–29]
Bioherbicide development	Nutsedge and crop allelochemicals as natural-product herbicide templates [9,10]
Cultivar breeding	Selection of allelopathic and nutsedge-tolerant crop genotypes [25]
Soil-microbiome integration	Understanding microbial mediation of allelochemical fate
Predictive modelling	Dose–response and field-context models to guide application

6. Discussion

Synthesising across themes, the reviewed literature supports a coherent overall picture while exposing important fault lines. The convergent finding, replicated across continents, crop groups, plant parts, and decades, is that C. rotundus inhibits the germination and early growth of most crops with which it has been tested, in a concentration-dependent fashion, and that tuber tissue is generally the more potent source. This consistency across heterogeneous methods is itself evidence that the effect is real and not an artefact of any single laboratory or protocol. The phytochemical and mechanistic strands explain the phenomenon plausibly: a tissue rich in ferulic, p-coumaric, caffeic, and related phenolic acids, together with flavonoids and sesquiterpenes, possesses exactly the chemistry expected to disrupt membrane transport, cell division, pigment synthesis, and key enzymes [11,12,14].

Yet the same literature reveals a structural imbalance. The phenomenon has been demonstrated far more often than it has been quantified, and quantified far more often in artificial bioassays than under field conditions. The unresolved allelopathy-versus-competition question is not a peripheral technicality but a central interpretive constraint: where growth reductions are reported from intact-plant interference, the chemical and competitive contributions remain entangled [7,8]. The studies that come closest to resolving this, through residue incorporation and activated-carbon controls, are a minority, and even they do not fully reconstruct field reality. The apparent contradictions in the literature, such as nutsedge being strongly inhibitory in one assay yet less so than another weed in a parallel test [17], or suppressing associated weeds while a crop's yield rises [13], are best understood not as conflicting results but as evidence that allelopathic outcome is contingent on receiver identity, concentration, and context. Recognising this contingency dissolves much of the apparent inconsistency.

The practical and theoretical implications point in the same direction. Theoretically, nutsedge offers an instructive model system for the wider question of how a single weed integrates competition and chemistry to achieve dominance, and for testing rigorous criteria for proving allelopathy. Practically, the weed's notorious resistance to conventional control, combined with the herbicidal potential of its own chemistry and of allelopathic crops that suppress it, suggests a reorientation of research effort. Rather than continuing to accumulate extract bioassays, the field would benefit more from field-validated, quantitative studies and from translating allelochemical knowledge into integrated weed-management tools, consistent with the current momentum toward sustainable, lower-input agriculture [10,32]. The increasing application of metabolomic and co-culture approaches is a promising step in that direction, as is the demonstrated capacity of sorghum and cover crops to suppress nutsedge through their own allelopathy [27,28,29].

7. Conclusion

The review compiles information about the allelopathic influence of purple nutsedge on plants. The authors' primary conclusion is categoric: the tissues, waste materials, and secretions from C. rotundus significantly hinder germination and development of cereals, legumes, oilseeds, and vegetables. The allelochemical action depends on its concentration. In particular, the tuber is usually more phytotoxic than the leaves. The major substances providing this effect include different groups of phenolic acids, flavonoids, and sesquiterpenoids.

Researchers have been given the guidance to create methods of research that distinguish between chemical impact and competition, monitor the release and persistence of allelochemicals in nature, validate laboratory results in real field and soil conditions, and depend on dose-response functions rather than utilizing arbitrary thresholds of concentration. The results of such research would be used by government agencies and weed management specialists to develop some weed control technologies where allelopathic plants, mulching, and crops rotation will solve the problem of controlling nutsedge. The integration of metabolomics, field research and agricultural methods could change the way allelopathy works in the weeds area. Details of the plan can be viewed in Picture 6.SS

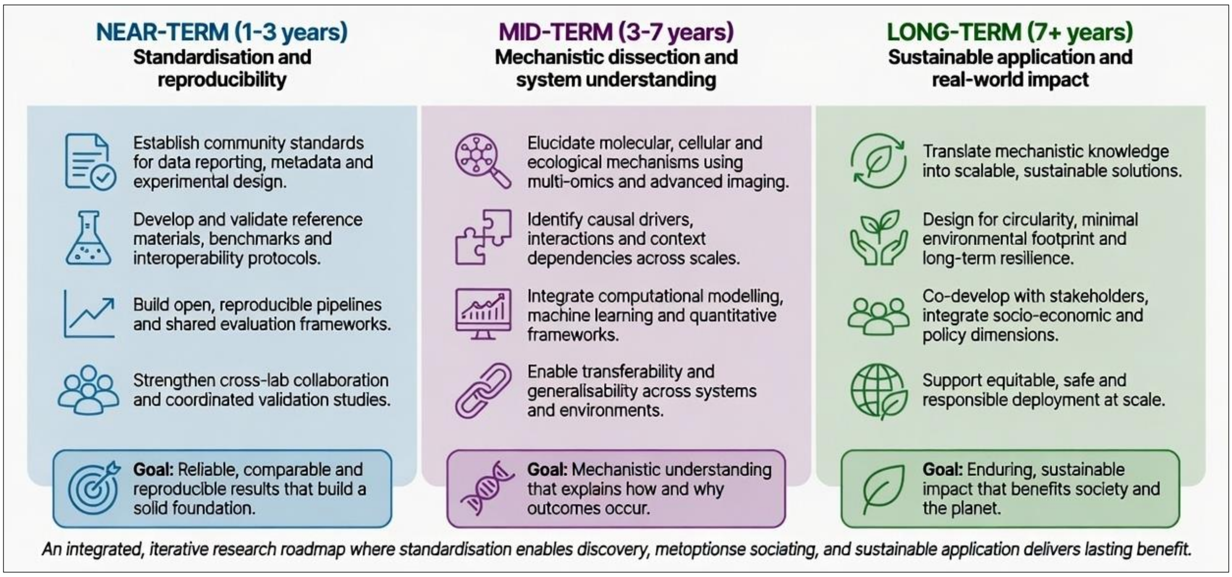

Fig 6: Future research directions, from near-term standardisation through mid-term mechanistic dissection to long-term sustainable application.

References

1. Holm LG, Plucknett DL, Pancho JV, Herberger JP. The World's Worst Weeds: Distribution and Biology. Honolulu (HI): University Press of Hawaii; 1977.
2. Bendixen LE, Nandihalli UB. Worldwide distribution of purple and yellow nutsedge (Cyperus rotundus and C. esculentus). Weed Technol. 1987;1(1):61–65.
3. Peerzada AM, Bajwa AA, Ali HH, Chauhan BS. Biology, agricultural impact, and management of Cyperus rotundus L.: the world's most tenacious weed. Acta Physiol Plant. 2017;39(12):270.
4. Rice EL. Allelopathy. 2nd ed. Orlando (FL): Academic Press; 1984.
5. Singh HP, Batish DR, Kohli RK. Allelopathic interactions and allelochemicals: new possibilities for sustainable weed management. Crit Rev Plant Sci. 2003;22(3–4):239–311.
6. Weston LA, Duke SO. Weed and crop allelopathy. Crit Rev Plant Sci. 2003;22(3–4):367–389.
7. Duke SO. Proving allelopathy in crop–weed interactions. Weed Sci. 2015;63(SP1):121–132.
8. Inderjit, del Moral R. Is separating resource competition from allelopathy realistic? Bot Rev. 1997;63(3):221–230.
9. Macías FA, Molinillo JMG, Varela RM, Galindo JCG. Allelopathy — a natural alternative for weed control. Pest Manag Sci. 2007;63(4):327–348.

10. Scavo A, Mauromicale G. Crop allelopathy for sustainable weed management in agroecosystems: knowing the present with a view to the future. Agronomy. 2021;11(11):2104.
11. Akash MSH, Afzaal A, Rehman K, Hussain A, Ibrahim M, Shoaib SM, et al. Identification of secondary metabolites of Cyperus rotundus L. and dose-dependent effects on antioxidant activity and carbohydrate digestion enzymes. Dose Response. 2024;22(4):15593258241308724.
12. Kandikattu HK, Rachitha P, Krupashree K, Jayashree GV, Khanum F. Cyperus rotundus: ancient weed to modern elixir of life. Pharm Biomed Res. 2021;7(4):221–250.
13. Elrokiek KG, El-Din SS, Sharara FA. Allelopathic behaviour of Cyperus rotundus L. on both Chorchorus olitorius (broad-leaved weed) and Echinochloa crus-galli (grassy weed) associated with soybean. J Plant Prot Res. 2010;50(3):274–279.
14. Scavo A, Abbate C, Mauromicale G. Plant allelochemicals: agronomic, nutritional and ecological relevance in the soil system. Plant Soil. 2019;442(1–2):23–48.
15. Quayyum HA, Mallik AU, Leach DM, Gottardo C. Growth inhibitory effects of nutgrass (Cyperus rotundus) on rice (Oryza sativa) seedlings. J Chem Ecol. 2000;26(9):2221–2231.
16. Darmanti S, Santosa, Dewi K, Nugroho LH. Allelopathic effect of Cyperus rotundus L. on seed germination and initial growth of Glycine max L. cv. Grobogan. Bioma. 2015;17(2):61–67.
17. Hamayun M, Hussain F, Afzal S, Ahmad N. Allelopathic effect of Cyperus rotundus and Echinochloa crus-galli on seed germination, and plumule and radicle growth in maize (Zea mays L.). Pak J Weed Sci Res. 2005;11(1–2):81–84.
18. Alam SM, Azmi AR. Allelopathic effect of purple nutsedge (Cyperus rotundus) leaf extracts on germination and seedling growth of wheat. Pak J Weed Sci Res. 1991;4(1):59–61.
19. Kavitha D, Prabhakaran J, Arumugam K. Phytotoxic effect of purple nutsedge (Cyperus rotundus L.) on germination and growth of finger millet (Eleusine coracana Gaertn.). Int J Pharm Biomed Sci. 2012;3(4):615–619.
20. Alsaadawi IS, Salih NMM. Allelopathic potential of Cyperus rotundus L. I. Interference with crops. Allelopathy J. 2009;23(2):297–308.
21. Keeley PE. Interference and interaction of purple and yellow nutsedges (Cyperus rotundus and C. esculentus) with crops. Weed Technol. 1987;1(1):74–81.
22. Khan R, Khan IA. Varietal response of chickpea (Cicer arietinum L.) towards the allelopathy of different weeds. Sains Malays. 2015;44(1):25–30.
23. Zohaib A, Abbas T, Tabassum T. Weeds cause losses in field crops through allelopathy. Not Sci Biol. 2016;8(1):47–56.
24. Chon SU, Kim YM. Herbicidal potential and quantification of suspected allelochemicals from four grass crop extracts. J Agron Crop Sci. 2004;190(2):145–150.
25. Olofsdotter M, Jensen LB, Courtois B. Improving crop competitive ability using allelopathy: an example from rice. Plant Breed. 2002;121(1):1–9.
26. Kumar M, Das TK, Yaduraju NT. An integrated approach for management of Cyperus rotundus (purple nutsedge) in soybean–wheat cropping system. Crop Prot. 2012;33:74–81.
27. Cheema ZA, Khaliq A. Use of sorghum allelopathic properties to control weeds in irrigated wheat in a semi-arid region of Punjab. Agric Ecosyst Environ. 2000;79(2–3):105–112.
28. Mahmood A, Cheema ZA. Influence of sorghum mulch on purple nutsedge (Cyperus rotundus L.). Int J Agric Biol. 2004;6(1):86–88.
29. Kumar L, Srivastava GK, Khare AP. Effect of root-exuded allelochemicals of sorghum (Sorghum bicolor) on growth and development of purple nutsedge (Cyperus rotundus L.) and other weeds of pulses. Indian J Weed Sci. 2013;45(2):131–134.
30. Cirujeda A, Anzalone A, Aibar J, Moreno MM, Zaragoza C. Purple nutsedge (Cyperus rotundus L.) control with paper mulch in processing tomato. Crop Prot. 2012;39:66–71.
31. Silveira HRO, Ferraz EO, Matos CC, Alvarenga ICA, Guilherme DO, Santos LDT, et al. Allelopathy and homeopathy in the management of nutsedge (Cyperus rotundus). Planta Daninha. 2010;28(3):499–506.
32. Bhowmik PC, Inderjit. Challenges and opportunities in implementing allelopathy for natural weed management. Crop Prot. 2003;22(4):661–671.
33. Putnam AR, Duke WB. Biological suppression of weeds: evidence for allelopathy in accessions of cucumber. Science. 1974;185(4148):370–372.
34. Stoller EW, Sweet RD. Biology and life cycle of purple and yellow nutsedges (Cyperus rotundus and C. esculentus). Weed Technol. 1987;1(1):66–73.
35. Tawaha AM, Turk MA. Allelopathic effects of black mustard (Brassica nigra) on germination and growth of wild barley (Hordeum spontaneum). J Agron Crop Sci. 2003;189(5):298–303.