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REVIEW ARTICLE

# Allelopathy prospective of oil seed crops for sustainable weed management- A review

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## Abstract

Weeds are a severe menace to crop cultivation as they interfere with crop growth and development and result in considerable loss in yield of oil seed crops. As a result, farmers have widely used synthetic herbicides for weed management. Using herbicides guides various environmental and health issues and researchers have been exploring alternative environmentally friendly ways of controlling weeds. Among these, incorporating allelopathy as a tool in an integrated weed management approach could significantly bring down herbicide usage. Allelopathy refers to the influence of one plant on another in its surroundings or on associated microflora/microfauna through the release of allelochemicals that intervene with the growth of plants. In field crops, allelopathy can be applied through intercropping, crop rotation, cover crops, mulching and allelopathic water extracts to manage weeds. Research evidence indicates that oil seed crops possess potent allelo chemicals that have great potential to be utilized as natural herbicides. This review aims to outline oil seed crops allelopathy that releases effective allelo chemicals with the possibility of being used in oil seed crop cultivation. By applying the allelopathy principles, farmers can pursue environmentally friendly and sustainable weed control techniques and improve crop yield and quality.

## Keywords

weed; allelochemical; groundnut; soybean; sesame; castor; sunflower; rapeseed

## Introduction

Weeds are among the most challenging obstacles affecting agricultural production worldwide. Weeds compete with crops for light, nutrients, water and space, which reduces crop growth and yield. Furthermore, weeds can harbour insect pests and bacterial, fungal and viral pathogens, compromising crop yield. By 2050, the global population is projected to exceed 9 billion, and world food production must avoid substantial yield losses from weed competition (1). Yield losses in crops caused by weeds are influenced by various factors, including the timing of weed emergence, weed density and the types of weeds and crops involved (2). Weeds are a significant biotic stressor, responsible for 37% of yield loss, surpassing insect pests (29%), diseases (22%) and other pests (12%) (3). Weeds cause significant agricultural losses, nationally reducing crop yields by 2.7 million tons of grain annually. In

India, the economic impact is even more substantial, with weeds leading to an annual loss of over USD 11 billion in agricultural productivity. Specifically, yield losses due to weeds are observed in various crops as follows: groundnut (35.8%), soybean (31.4%), greengram (30.8%), pearl millet (27.6%), maize (25.3%), sorghum (25.1%), sesame (23.7%), mustard (21.4%), direct-seeded rice (21.4%), wheat (18.6%) and transplanted rice (13.8%)(4).

Presently, weeds are managed using various conventional and modern approaches. Synthetic herbicides are very common due to their prompt response and availability (5). Use of synthetic herbicides persist in the environment and causes biomagnification. Concern about the toxicity and development of resistance against synthetic herbicides have demanded looking for alternative weed management approaches, so eco-friendly herbicides are needed. In 2022-23, herbicide use in India's oil seed crops led to a notable production of 413.55 lakh tonnes, marking a considerable increase from the previous year's output of 379.63 lakh tonnes (Food and Agriculture Organization, 2023). The total herbicide production in India has been outlined, highlighting the annual growth rate, with 2,4-D being the most produced herbicide between 2015-2016 and 2021-22. Fig 1.(6). The use of various herbicides in oil seed crops in India has been documented, with paraquat being the most widely used, reaching 4,060 metric tonnes in 2022-23(7) Fig.2. Additionally, Fig.3 presents a forecast for global agricultural herbicide consumption from 2023 to 2027, predicting that thousands of metric tonnes will be required in India by 2024(8). Paraquat is frequently preferred over other herbicides due to its rapid, non-selective action, effectively controlling many weeds. This makes it particularly beneficial in situations requiring fast weed suppression, allowing farmers to prepare fields for planting more efficiently (9). However, its high toxicity poses significant risks to human health and the environment (10).

Herbicide residues can seep into groundwater or surface water, resulting in environmental pollution. This has profound implications for ecosystem health and agricultural sustainability (11). Additionally, herbicide use can alter soil microbial communities, potentially reducing soil biodiversity and disrupting nutrient cycling. Glyphosate, a commonly used herbicide, has been observed to influence soil bacteria and fungi, impacting soil health (12).

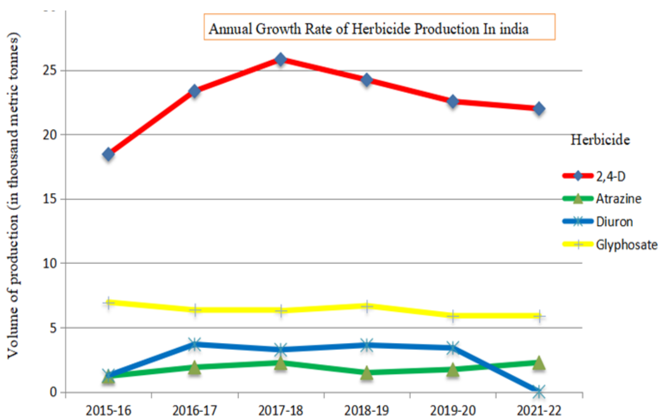


**Fig.1.** Annual growth rate of herbicide production in India (6)

The term "allelopathy," which refers to the harmful effect of one organism on another, is derived from the Greek words *allelon*, meaning "of each other," and *pathos*, meaning "to suffer." According to (13), the term was coined by Austrian scientist Hans Molisch in 1937. Allelopathy encompasses any direct or indirect effect that a plant, including microorganisms, has on the growth and development of other organisms by releasing chemical compounds into the environment (14). Allelochemicals are present in different parts of plants, such as leaves, stems, roots, rhizomes, seeds, flowers and pollen (15). The release of these compounds into the environment differs between species (16).

Integrating the natural allelopathic properties of oil seed crops with herbicide use can promote more sustainable weed management practices, potentially reducing reliance on chemical herbicides (17).

This review paper explores how oil seed crops such as sunflower, rapeseed, castor, sesame, soybean and groundnut release allelochemicals that affect the growth and development of surrounding weeds and crops. It also assesses the potential of the allelopathic properties of these oil seed crops for weed suppression, comparing their effectiveness with that of herbicides and explores the physiological mechanisms that drive plant allelopathy.

## Allelopathy Mechanism

The mechanisms by which allelochemicals act are highly diverse, as the observable effects on target plants, such as reduced seed germination and stunted seedling growth, are often secondary to primary changes. These primary changes may include inhibition of cell division and elongation, disruption of cell membrane permeability and interference with enzymatic activities, respiration and photosynthesis (18).

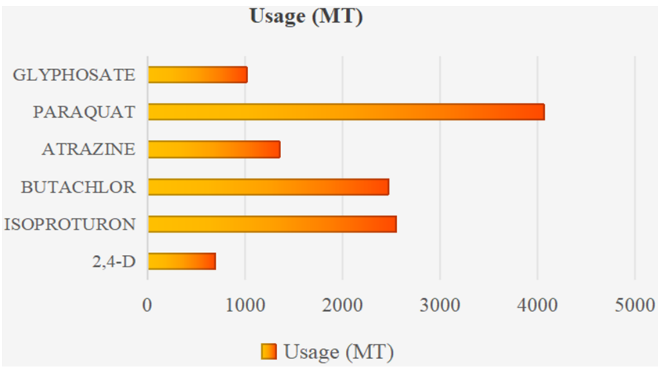


**Fig. 2.** Different herbicides utilize during the year 2022-2023 in India (7)

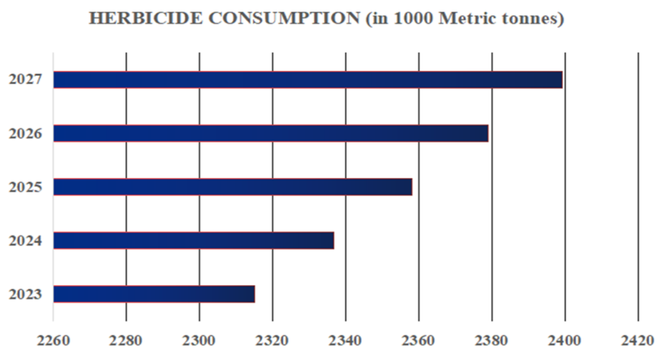


**Fig.3.** Forecast agricultural consumption of herbicides worldwide from 2023 to 2027 (in 1,000 metric tons) (8)

## Role of Allelopathy

Allelopathy can naturally suppress weed growth by releasing chemical compounds inhibiting seed germination, root development, or overall growth, thereby reducing competition for water, nutrients and sunlight. Additionally, it can influence plant community composition by limiting the spread of invasive species and promoting the growth of native species, contributing to ecosystem balance and enhancing biodiversity (19).

## Allelochemicals as natural herbicides

Allelochemicals are naturally found in all plant types and tissues and they are released into the soil rhizosphere through various mechanisms, such as residue decomposition, volatilization and root exudation (20). Allelochemicals are released into the environment through several processes, such as volatilization or leaching from aerial plant parts, exudation from roots and the decomposition of plant residues in the soil (21). Direct volatilization and precipitation, including rain, fog and dew, also play an essential role in the solubilization and release of allelochemicals from the plants foliar parts, which possess glandular trichomes containing allelochemicals (22).

The need for environmentally safer herbicides and the difficulty of discovering new modes of action, combined with the increase in herbicide-resistant weed strains, have led to the development of natural herbicides. As natural herbicides, the allelochemicals can be especially valuable for weed management due to their novel modes of action, more specific interactions with weeds and environmental friendliness (19).

## Allelochemicals and their structure

Allelochemicals released by plants serve as a defence mechanism against microbial attacks, herbivore predation and competition from other plants (23). Under dry and semi-arid conditions, allelochemicals can be released through volatilization. These substances may be absorbed as vapours by angiosperm plants or taken up from dew formed by the condensation of these vapours. Additionally, the condensate can reach the soil and be absorbed by plant roots (24). Oil seed crops release various allelochemicals that are essential in weed suppression. For instance, rapeseed (*Brassica napus*) produces glucosinolates and their hydrolysis products, like isothiocyanates. Sunflower (*Helianthus annuus*) releases phenolic acids such as chlorogenic and caffeic acid and sesame (*Sesamum indicum*) produces allelochemicals, including sesamin, sesamolin and other phenolic acids.

In contrast, castor (*Ricinus communis*) releases ricin and ricinine (25). As a result, allelopathy has gained substantial support as an effective method for sustainable weed management, reducing the need for chemical herbicides. Plant-based herbicides are viewed as safer and more biodegradable alternatives (26).

The influence of allelochemicals on plant growth is concentration-dependent, as they can inhibit or promote growth, resulting in beneficial, neutral or harmful effects on plants. Furthermore, their activity is shaped by interactions and the kinetics of various processes under particular natural conditions (27). Once released, allelochemicals can inhibit the germination, growth and establishment of nearby plants or alter soil properties in the rhizosphere by affecting the microbial community (28). Allelopathy significantly impacts agriculture by affecting weeds and crops by producing allelochemicals released from roots, leaves, flowers, stems or seeds (29). Cultivars can be classified into those that actively suppress weeds and those that can tolerate the presence of weeds. Several characteristics, such as root pattern, early vigour, leaf size and allelopathic ability, can make one cultivar more competitive against weeds than another (30). Recent studies on allelopathy have made significant advances, particularly with the rapid progress in separation and structural elucidation techniques. These improvements allow for the detection, isolation and characterization of active compounds (31). The allelochemicals released from oil seed crops are simple phenols, benzoic acid and its derivatives, cinnamic acid and its derivatives, coumarin, flavonoids, tannins, terpenoids, steroids, amino acids, peptides, alkaloids and cyanohydrins (20) According to (32), allelochemicals can be categorized into ten classes based on their structure and properties: straight chain alcohols, water-soluble organic acids, ketones and aliphatic aldehydes, simple lactones, polyacetylenes and long chain fatty acids, quinones (including anthraquinones, benzoquinones and complex quinones) cinnamic acid and its derivatives phenolics (such as caffeic acid, coumaric acid, vanillic acid, syringic acid and ferulic acid), coumarins, tannins, flavonoid and terpenoids and steroids.

## Application of allelopathy as a weed management tool

Applying allelochemicals through water extracts, intercropping, crop rotation, cover cropping and mulching is promising for effective weed control and boosting crop production (33).

## Intercropping

Intercropping is the practice of growing more than two crops in the same field simultaneously. Intercropping with allelopathic crops has excellent potential for suppressing weeds in an environmentally friendly approach. Intercropping involves growing compatible crops to improve yield, diversify the farm and provide economic benefits. Furthermore, it is also a great way to improve land, water, nutrients and light efficiency. Factors such as weed-crop competition, release of allelochemical and effect of shade can be used by allelopathic intercrops to control weeds (34).

Using allelopathic biomass from oil seeds as soil amendments can effectively manage weeds. This method helps reduce synthetic herbicides' environmental impact and curbs herbicide-resistant weeds rise. Incorporating the biomass of allelopathic plants as soil amendments or green manures controls weeds and improves soil health (22). Intercropping sesame (*Sesamum indicum L.*), soybean and sorghum in cotton (*Gossypium hirsutum L.*) significantly reduced purple nut sedge (*Cyperus rotundus*) populations. The density of purple nut sedge decreased by 70% to 96% and its dry biomass was reduced by 71% to 97% (35). Sunflower (*Helianthus annuus*) residues, meals and leaf extracts have effectively suppressed the growth of various weed species, serving as a natural method of weed control. This property makes sunflower an advantageous element in integrated weed management strategies, allowing it to be intercropped or rotated with other crops to lessen weed proliferation without the extensive use of synthetic herbicides (36). Combining camelina (*Camelina sativa*) with lentils has enhanced weed management and soil coverage. However, camelina's yield remains unaffected when grown alongside lentils (37), while castor plants produce allelochemicals with herbicidal properties that effectively suppress weed growth. This is particularly useful in organic farming and systems minimizing chemical herbicide use (38). Soybean crops can have allelopathic effects in inter-cropping systems. The allelochemicals released by soybean roots and residues can inhibit the growth of nearby weeds, enhancing the efficiency of intercropping systems for weed management (39).

## Crop rotation

Crop rotation is systematically and sequentially sowing different crops in the same field over a growing season. Crop rotation has many benefits, from maintaining soil structure, adding organic matter and reducing soil erosion associated with a monoculture system. The relationships between allelochemicals and environmental factors are key for the growth of plants under rotation (40,41,42). Crop rotation offers the best results when considered within an Integrated Weed Management System as prevention against weed establishment and reduction of the soil seed bank (22). Allelopathy drastically impacts crop rotation for oil seed crops by improving weed management and crop health. Crop rotation with castor (*Ricinus communis*) effectively manages weeds. Allelopathic residues from castor suppress weed growth, benefiting subsequent crops by reducing resource competition. This suppression is due to allelochemicals from decomposing residues that inhibit weed germination and development (43). Integrating crop rotation with allelopathic crops like castor can effectively manage weeds. Residues from these crops release allelochemicals during decomposition, which suppress weed germination and growth, benefiting subsequent crops by minimizing resource competition and boosting growth and yield (19).

## Cover crop

Cover cropping is the mono- or inter-cropping of herbaceous plants for part of or an entire year to enhance yields (44). Cover crops are grown for their numerous ecosystem services: protection from soil erosion, reduction of nutrient leaching (especially nitrates), enhancement of soil organic matter levels and microbial activities, improvement of soil structure and hydraulic properties, conservation of soil moisture, pest management and weed control (45,46). Leachates from cereal rye and wheat have been found to reduce the root length of soybean seedlings significantly. This indicates that allelopathic interactions can affect the germination and early growth stages of soybeans and weeds, making it an effective strategy for integrated weed management in sustainable agricultural systems (47). Camelina as cover crop is effective in weed suppression through its vigorous growth and canopy structure, which helps reduce weed populations and associated pathogens. However, selecting the right cover crop species and timing inter-seeding are crucial for maximizing benefits while maintaining optimal sugar beet yield. In North Dakota, interseeding camelina during the $V_1$-$V_3$ growth stages of corn and the $V_1$-$V_2$ growth stages of soybean led to a 14% reduction in corn yield and a 10% reduction in soybean yield (48).

Cover crops are cultivated either during fallow periods or alongside cash crops during the growing season. They are not intended for profit but are grown for their numerous ecological benefits. Suppressing weeds, conserving soil, enhancing soil fertility, attracting beneficial insects, maintaining soil moisture, reducing soil erosion and improving soil structure (46). A significant issue with cover crops is the potential for yield reduction. However, with careful planning and proper management, cover crops can suppress weeds and enhance crop yields (49). Cover crops primary advantage are their capacity to reduce weed growth. Covering crops functions as living mulch, covering bare soil and preventing weed establishment. After termination, they continue suppressing weeds by leaving behind plant residues (50).

Cover crops such as rye, annual ryegrass, hairy vetch and sunflower are noted for their allelopathic properties, which can suppress weed populations and influence the growth of other plants, including groundnuts. These crops release allelochemicals that inhibit weed germination and growth, thereby reducing competition for resources and benefiting subsequent crops (51).

## Mulching

The crop residues from oil seed crops like canola, sunflower and soybeans used as mulch contain allelopathic compounds that can either reduce weed germination or physically suppress weed seedlings (52). Zannopoulos et al. (53) reported that incorporating sorghum, sunflower and Brassica residues into the soil inhibited the sprouting and seedling growth of purple nut sedge and horse purslane. Crop residues from Brassica, sunflower and sorghum applied as mulch more effectively control the growth of horse purslane and purple nut sedge (54).

## Potential of oil seed crops in weed control

The allelopathic potential of crops can vary considerably due to factors such as cultivar, soil fertility, climate conditions, types of competing weeds and water availability. The following section explores the allelopathic potential and allelochemicals of oil seed crops. In modern agriculture, allelopathy can enhance yields, promote crop diversity, improve ecosystem health, facilitate nutrient recycling and conservation and aid in weed management and pest control (25). Additionally, allelopathic compounds are secondary metabolites in plants, passed down from the parent species (55). According to (56), ensuring sustainability and enhancing crop production are significant challenges in addressing future global threats such as overpopulation, degradation of arable land, overuse of resources, environmental stresses and weed management. The worldwide Concern is that synthetic herbicides to control weeds harms the environment, negatively impacts crop yields and poses risks to human health.

### Potential application of biotechnological tools

Genetic engineering offers a valuable strategy to boost the production of allelochemicals in crops, enhancing their ability to suppress weeds. Techniques like CRISPR/Cas9 enable precise modifications of plant genomes, allowing for the targeted activation or deactivation of genes involved in allelochemical synthesis. This allows for developing crops with stronger allelopathic properties, helping to effectively manage weeds and pests (9). Functional genomics is essential for identifying genes linked to allelopathic traits in plants. Genetic research, including the discovery of allelopathic genes and quantitative trait loci (QTLs), holds significant potential for creating more sustainable strategies for weed management in agriculture (57).

### Potentiality of sunflower Allelopathic

Sunflower demonstrates significant allelopathic potential, allowing it to impact the growth of neighbouring plants. Numerous sunflower cultivars have been identified as producing over 200 naturally occurring allelopathic compounds (58). Sunflower extracts have remarkable herbicidal effects on the germination and growth of *Parthenium hysterophorus* (59) and it has the highest average inhibition values, measuring 7.74 for *P. minor* and 12.59 for *V. fabea*. The germination and seedling growth of crabgrass (*D.sanguinalis*), red root pigweed (*Amaranthus retroflexus*), *Erigeron canadensis*, *Rudbeckiahirta*, *Haplopappus ciliatus* and Japanese brome (*Bromus japonicus*) were inhibited by aqueous extracts of sunflower leaves, stem, root, inflorescence and plants (60). Aqueous extracts from the leaves, stems and sunflower roots at a total concentration significantly decreased the germination rate, plumule length and radicle length of *Parthenium* and *Amaranthus* (60). Application of sunflower water extract in wheat effectively controlled *Avena fatua*, *Melilotus officinalis*, *Phalaris minor* and *Rumex obtusifolius,* resulting in a reduction of weed density by 10.6-33.6% and weed dry weight by 2.2-16.5%, while also increasing yield by 1.6-10.7% compared to the control (60). The combined application of sorghum and sunflower water extracts (61) significantly reduced the root length, shoot length, root dry weight and shoot dry weight of three weed species: *Trianthema portulacastrum, Dactyloctenium aegyptium* and *Eleusine indica*. Leachates of dry leaves and stems inhibited the growth of weed seedlings. Still, aqueous extracts from the leaves and stems of various sunflower varieties showed mixed responses to weed seed germination (62). Sunflower allelochemicals have been viable substitutes for attaining sustainable weed control (63). Sharma and Satsangi (64) observed that including sunflower, rice and Brassica in maize fields notably reduced the presence of *Trianthema portulacastrum*. Sunflower allelopathy effectively inhibits weeds (65), demonstrating that sunflower residues significantly suppressed *Chenopodium album* and *Amaranthus retroflexus* germination and growth. Kambikambi (66), Sunflower rhizomes, roots and seeds contain a variety of compounds with allelopathic properties, including phenolic acids, diterpenes, triterpenes, heliannuols, terpenoids and flavonoids. These compounds inhibit weed growth by interfering with seed germination, root development and overall plant growth. The release of these chemicals helps reduce competition from weeds, promoting the growth of sunflower plants while suppressing the development of unwanted vegetation around them. These natural substances offer a sustainable method of weed control in sunflower cultivation.

### Potentiality of rapeseed Allelopathy

According to (67) rapeseed crops are well-known for their quick fall growth, high biomass production and capacity for nutrient scavenging. Major winter oil seed crops, *Brassica juncea, Brassica napus* and *Brassica carinata,* are commonly cited as allelopathic crops (67). Glucosinolates or their catabolic products have the potential to exert competitive biocidal effects if they are released into the rhizosphere (68). Rapeseed species contain allelochemicals that inhibit the germination and growth of other species when grown in rotation. The allelopathic effects of various rapeseed plant parts (*Brassica nigra L.*) on the germination and growth of alfalfa seedlings were investigated by (69). (70) noted that the following order of inhibition could be used to rank the degree of toxicity of various parts of the black mustard plant: leaves > flowers > a blend of every plant component >roots > stem. The suppression of weeds was accomplished through an allelopathic mechanism (67). (70) report that rapeseed root and shoot extracts, seeds, stems and leaves contain isothiocyanate allyl, glucosinolates, sulfur, thioglucoside, glucohydrolase, nitriles and isothiocyanate benzyl.

Compared to grassy weeds, broad-leaf weeds showed a more substantial suppression effect. According to (71), the weeds were suppressed by crops in the following order: Indian mustard (*B. juncea*) > rapeseed (*B. napus*) > (*B. carinata*). (69). Rapeseed root and stem extracts concentration (0,25,50,75 and 100 percent) suppress the weeds, including *Phalaris minor*, *Lolium temulentum* and *Avena fatua* (72). The water extract of rapeseed roots, stems and leaves exhibits substantial allelopathic potential, significantly suppressing the seedling growth of *Phalaris minor*, with the leaves demonstrating the most significant inhibitory effect (73). Increasing the rapeseed seed rate to 100-150 seeds per square meter helps reduce the size and volume of broad-leaf weeds and boost grain yield by up to 40%. This effect likely results from the increased plant density, which enhances competition for light, water and nutrients, leading to suppressed weed growth and improved crop productivity. This strategy effectively combines weed control with yield enhancement in rapeseed cultivation (74).

### Potentiality of Castor Allelopathy

The aqueous extracts from *Ricinus communis*, a species that grows spontaneously and frequently in Tunisian agricultural land, have a very high allelopathic effect on the germination and root growth of six crops (*H. vulgare, M.sativa, C. olitorius, T. foenum-graecum, L. culinaris* and *C. arietinum*). Depending on the species under consideration, this inhibitory effect increases the strength of the shoot and the pericarp, two plant organs (75). All test species, except for Jatropha, showed more significant inhibition in root growth than shoot growth. When comparing the different plant parts, the leaves and roots of the studied plants exhibited the highest allelopathic potential (76). The crude extract of the plants Nerium and Castor positively inhibited tubers and seedling growth of *Cyperus rotundus L* (77). (78) indicate castor roots, leaves, stems and radicals contain alkaloids, glycosides, phenols, monoterpenoids and tannins. These allelochemicals involve inhibiting the weeds. The allelopathic effects of essential oils from *Ferula assa-foetida L.* and castor oil *Ricinus communis L.* were studied as natural herbicides to inhibit the germination of redroot pigweed seeds *Amaranthus retroflexus L*. (79). The allelopathic effects of castor oil, derived from the seeds of *Ricinus communis*, are attributed to compounds like ricin and ricinine. These compounds can influence seed germination and seedling development in various plant species, including the weed *Ipomoea purpurea*(80).

## Potentiality of Groundnut Allelopathy

The aqueous extract of *Calotropis procera* does not exhibit any allelopathic effect (*Pennisetum glaucum*). Additionally, it can be concluded that the plant extract inhibits the plant seedling's growth and seed germination has no allelopathic impact on groundnut (*Arachis hypogeae*) (81). The leaves, roots and stems of groundnuts contain allelochemicals such as phenolic acids, flavonoids, fatty acids and terpenoids, including tetradecanoic, hexadecanoic and octadecanoic acids, which help suppress weeds (82). De Aguiar et al. (83), barley and rapeseed extracts in groundnut crops are an economical approach to weed suppression, reducing the need for haloxyfop by 50-75%.

## Potentiality of sesame Allelopathy

The allelopathic effects of isolated compounds from sesame root exudates on six major weed species tested, *Chenopodium album L.* (Lamb's quarters), *Anagallis arvensis L.* (*Scarlet pimpernel*), *Spergula arvensis L.* (Spurry), *Melilotus alba Medik* (White sweet clover), *Fumaria parviflora Lam.* (Fine -flowered fumitory), *Vicia sativa L.* (Common vetch) were controlled by combination of allelochemicals in sesame (84). Sesame leachate effectively controlled the obnoxious weed *Cyperus rotundus L*. and primarily inhibited the growth of purple nut sedge, as supported by microscopic analysis of all plant organs (85). The allelochemicals from sesame, at different concentrations, suppressed the root length, fresh and dry weight and leaf growth of *Ipomoea* weed species (86). In contrast, a study (87) found that leachate and combined extracts from sesame positively stimulated the seedling growth of *Melochia corchorifolia* L.

## Potentiality of soybean Allelopathy

Allelochemicals have been identified in soybean (*Glycine max*), suggesting it could significantly impact weeds through phytotoxicity (88). The allelopathic potential of G. max. shoot and root extracts has been shown to affect the germination, emergence, root elongation and seedling growth of *Phalaris minor*, *Lolium temulentum* and *Avena fatua* (89). According to study (90), the rhizosphere soil contained various organic compounds and decomposition products from soybean stubble, including alcohols, esters, phenols, acetone, hydrocarbons and organic acids.(91) evaluated aqueous extracts and residues from the Korean black soybean (*Glycine max cv. Geomjeong*) against Lucerne (*Medicago sativa*). The extracts or residues of the seeds showed the highest inhibition in the length of the Lucerne roots, Plant height, root length and shoot and root dry weights of barnyard grass. They proposed that the potential for herbicidal properties in black soybean plants existed and that the plant's different parts would exhibit different activity levels. (92) describe that soybean roots, stems, leaves and rhizomes contain vanillic acid, p-hydroxybenzoic acid, organic acids, esters, alcohols, aldehydes, phenols, acetone, hydrocarbons and naphthalenephenyl. The allelopathic activity of several soybean accessions on weeds was studied. The allelochemicals in soybeans dramatically reduced the germination and growth of *Sorghum halepense* and *Secale cereal* (89). According to (93), plant spacing and photoperiod, response caused differences in the competitive ability of different soybean genotypes. Likewise, (94) noted that there were variations in the competitiveness of soybean cultivars against *S. halepense* (Johnson grass) and *Xanthium stromatorum* (cocklebur).

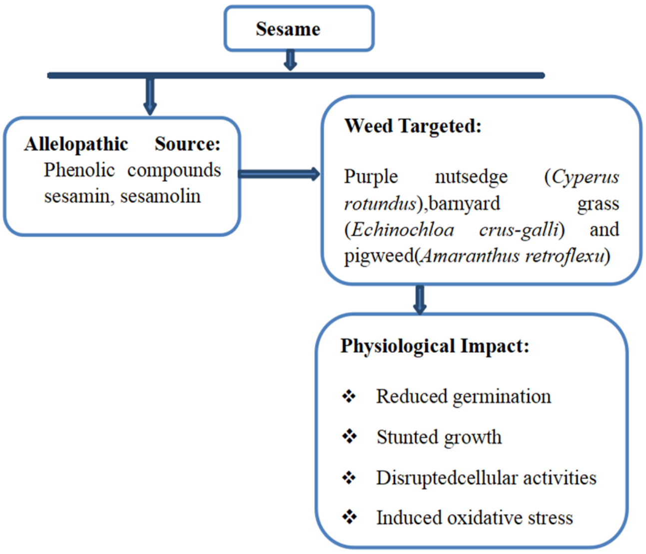


**Fig 4.** Summary of allelopathic source and their impact on target weed in sesame crop (95,96)

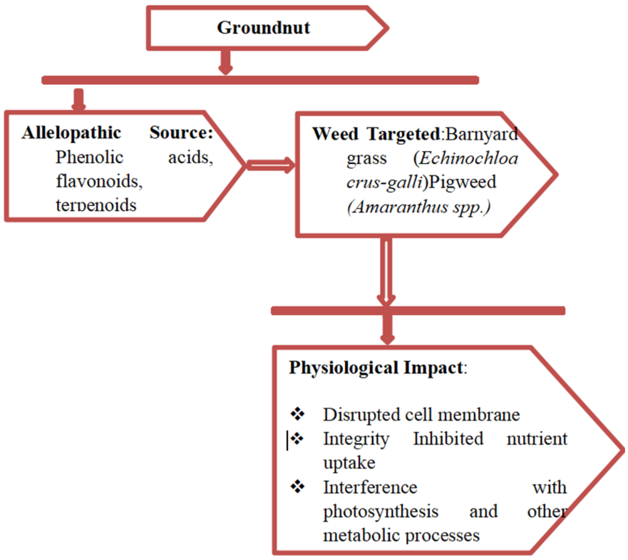


**Fig 5.** Summary of allelopathic source and their impact on target weed in groundnut crop (97,98)

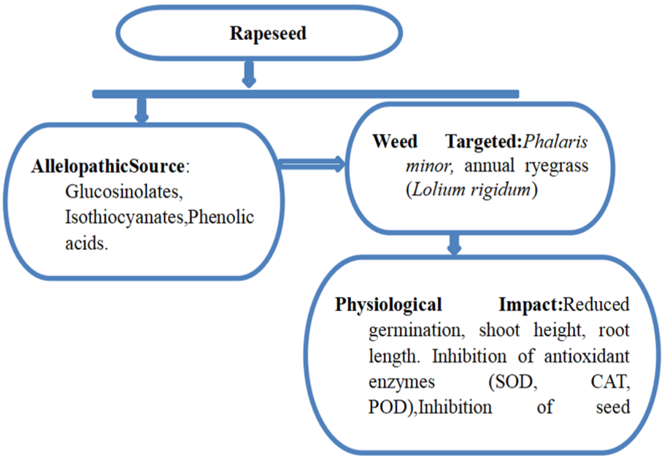


**Fig 6.** Summary of allelopathic source and their impact on target weed in rapeseed crop (75)

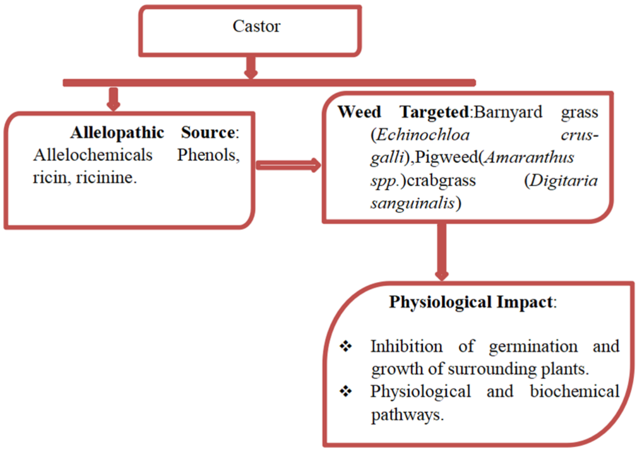


**Fig 7.** Summary of allelopathic source and their impact on target weed in castor crop (99)

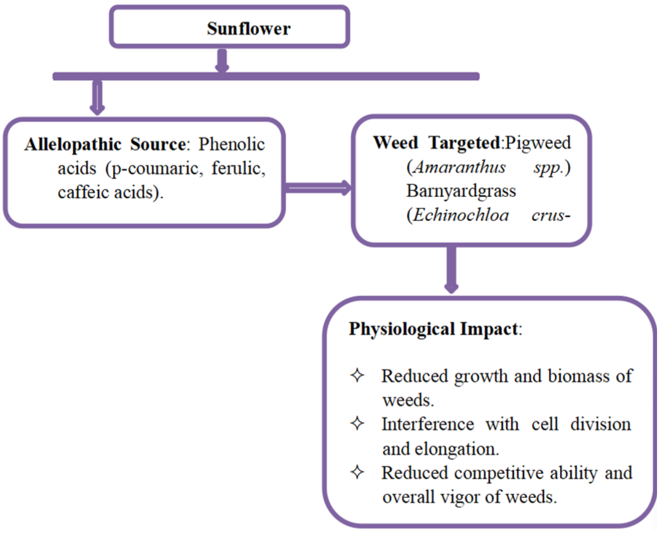


**Fig 8.** Summary of allelopathic source and their impact on target weed in sunflower crop (100,101)

## Conclusion

This review focused on different allelopathic oil seed crops that release some forms of potent allelochemicals that can be employed in the natural management of weeds and reduce heavy reliance on synthetic herbicides. Although practices such as intercropping, crop rotation, cover crops and mulching have been used conventionally for various benefits, integrating allelopathic crops would enhance its weed suppression benefit.

Implementation of allelopathic plant extracts in combination with reduced doses of herbicides could be an alternative strategy for sustainable weed management. With the current biotechnological tools and better extraction methods, more allelochemicals will be recognized, tested and used for weed management.

These allelochemicals or the byproducts of allelopathic oil seed crops can be integrated with other weed management practices to improve weed control and decrease herbicide use.

Additionally, the review highlights potential applications of allelopathy and identifies areas for future research and development. Further exploration of allelopathy is expected to contribute to its integration into sustainable, ecological and integrated weed management systems.

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## Authors' contributions

RR and SKN conceived the idea for this manuscript. RR conducted the literature review and drafted the initial manuscript. RS SRV TR RS provided critical feedback and revisions to the manuscript. RR and SKN prepared the final version of the manuscript. All authors read and approved the final manuscript for submission.

## Compliance with ethical standards

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