Environment and Ecology 41 (4A) : 2566—2571, October—December 2023
Article DOI: https://doi.org/10.60151/envec/TTNE8406
ISSN 0970-0420

Sesame (*Sesamum indicum* L.): A Potential Allelopathic Crop - A Review

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Received 10 May 2023, Accepted 5 July 2023, Published on 31 October 2023

ABSTRACT

Sesame (*Sesamum indicum* L.) is one the oldest oilseed crop cultivated in India. It is cultivated as third crop in summer rice fallows or in marginal lands. Seeds of sesame are used for the extraction of oil, that contain many pharmaceutical and cosmetic properties. Research findings revealed that sesame contains many allelochemicals. The present review focuses on the allelopathic effect of sesame on weeds and crops. Exploring the allelopathic potential of sesame would help to develop bio-herbicides in future and reduce the use of synthetic herbicides in weed management. In addition to this, study on allelopathy of sesame would help to select suitable crops in rotation which are compatible to the sesame.

Keywords Allelopathy, Crop, Sesame, Weed.

INTRODUCTION

Sesame renowned as the "queen of oilseeds" is an annual herb belonging to Pedaliaceae family. It is usually known as till, sesamum, benniseed, gingelly or simsim in different places. The crop is remarked as the oldest and important oilseed crop widely cultivated in continents of Asia and Africa. Sesame is well adapted to marginal lands and harsh environments, hence acts as an alternate catch crop for small landholders in developing countries. Sesame is actually considered as an orphan crop and is not a mandatory plant by any of the international research institutes, hence, a few research has been undertaken.

According to the archaeological reports, sesame cultivation started in South Asia ever since Harappan civilization and shifted to Mesopotamia since 2000 BC (Fuller 2003). Akintunde *et al.* (2012) opined that *Sesamum indicum* L. was the major oil seed crop at the time of Indus Valley Civilization. The oil extracted from the seeds of sesame was utilized by the Assyrians for several uses like, food, cosmetics and bio-medicine, while the Hindus regarded it as sacred and represented the symbol of immortality.

Botany and cytogenetics

Carl Linnaeus classified sesame into two species viz., *Sesamum indicum* and *Sesamum orientale* in the book

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Genera plantarum. More than 30 species are included in the genus *Sesamum* (Nayar and Mehra 1970). *Sesamum indicum* is the cultivated species, originated from India (Ogasawara *et al.* 1988). Sesame belongs to family Pedaliaceae which consists of annual or perennial herbs, with leaves opposite to each other or with spirally arranged upper leaves and axillary flowers. The family is distinguished by a two-celled superior ovary, wholly or partially excluded by a false septa, each compartment with single to many ovules attached to placenta.

Morinaga *et al.* (1929) was the first to report chromosome number of sesame as 2n = 26. This was in confirmation with the findings of many other workers in the later years. Raghavan and Krishnamurty (1947) studied the karyotype in sesame and observed that all chromosomes had terminal centromeres. Mukherjee (1959) identified five different types of chromosomes within the nuclei of *Sesamum indicum,* having chromosome length 1.6 to 3.6 A.

The cytogenetical data indicates a close relation with *S. occidentale* and *S. radiatum* (n = 32), *S. laciniatum* and *S. prostratum* (n = 16) and *S. indicum* and *S. indicum* ssp. *malabaricum* (n = 13). Sesame is a self-pollinated crop, even though the extend of cross-pollination varies from 5 to 50 % (Pathirana 1994).

Physico-chemical characteristics of sesame seeds

Seeds of sesame contain 44 to 57% oil, 18 to 25% protein and 13 to 14% carbohydrates (Borchani *et al.* 2010). The average weight of thousand seeds of sesame was 3.86 to 4.40g, true density; 1299.59 kgm^{-3} and moisture content; 3.72 % Sesame is a significant source of calorie with energy 631 k cal. In addition, mineral composition of sesame seed constitutes, potassium (349–851 mg), magnesium (305–79 mg), calcium (80–1263 mg) and phosphorus (50– 890 mg) per hundred gram seeds (Couch *et al.* 2017). Sesame seeds are composed of high level of amino acids like methionine and tryptophan with innumerable benefits.

Nearly, 70% of the seeds of sesame are processed into oil. Sesame oil contains monounsaturated fatty acids and polyunsaturated fatty acids with average values of 35% and 44%, respectively (Hansen 2011). The oil is reckoned for its stability after long exposure to air. The resistance of sesame oil against oxidation has been attributed to the presence of endogenous antioxidants, lignins and tocopherols (Lee *et al.* 2008). Sesamin and sesamolin are two types of lignins in sesame oil.

The structural framework of sesamol includes benzo dioxide and phenolic groups. The former is responsible for the anticancerous property while the latter is involved in the antioxidant property. Recent research found that sesame includes immunoglobulin E mediated food allergens (Agne *et al.* 2004). Sesame oil has lower levels of saturated fatty acids (15 %) and higher level of linoleic acid, hence found to be beneficial in lowering cholesterol, hypertension, diabetes mellitus, atherosclerosis, obesity, renal failure, arthritis, Alzheimer's disease and dermatological problems (Prasad *et al.* 2012).

Trends in area and production of sesame

India is the largest sesame producing country in the world with an area of 1.70 M ha, production and productivity of 0.68 M t and 0.402 t ha^{-1} respectively (Babu *et al.* 2016). It is mainly cultivated in the states of Rajasthan, Gujarat, Uttar Pradesh, Haryana, Madhya Pradesh, Karnataka, Andhra Pradesh and Kerala. However, input starved conditions and rainfed cropping in marginal and submarginal lands have resulted in lower productivity of sesame during the recent past. Adopting improved varieties and production technologies suitable for each agro ecological situations could increase the productivity of sesame. A well established sesame crop can yield an average of 1350 kg ha^{-1} and 900 kg ha^{-1} under irrigated and rainfed conditions respectively.

Allelopathic principles in sesame

Processes inculcating secondary metabolites released by plants, microorganisms, fungi and viruses which may affect the growth and development of agriculture and biological ecosystems is referred as allelopathy (IAS 1996). It can influence both the weeds and crops by the release of allelochemicals via roots, stem, leaves, flowers, or even seeds (Mahmoodzadeh and Mahmoodzadeh 2014). The bio-chemicals released by different plant parts, may have negative allelopathy (inhibitory effect) or positive allelopathy (stimulatory effect), on each other. Therefore, allelopathy can be considered as a chemical warfare amongst several plant species. Many biochemical and physiological processes in plants like respiration, photosynthesis, enzyme activity, water relations, hormone levels, stomatal opening, cell division and elongation, mineral availability and antioxidant system are affected by allelopathy (Zeng *et al.* 2001).

Putnam and Tang (1986) classified allelochemicals into major groups viz., simple water-soluble organic acids, unsaturated lactones, anthraquinones and complex quinones, long-chain fatty acids and polyacetylenes simple phenols, naphthoquinone, benzoic acid derivates, flavonoids, steroids, cinnamic acid derivates, tannins, coumarins, sulphides and glucosides, amino acids and polypeptides, thiocyanates, lactones, alkaloids, cyanohydrins and actogenins.

The proportion of allelochemicals varied with respect to the plant parts. The relative content of flavonoids were two to five times higher in sesame flowers than other parts. Seeds have higher content of lignans, lipids and amino acids while coumarins, tannins, quinones and vitamins were found to be higher in leaves. These findings illustrated that accumulation of metabolic constituents in the sesame occurred in a tissue-specific manner (Fuji *et al.* 2018).

Using ultra-high-performance liquid chromatography-mass spectrometry (UPLC-MS), a total of 776 metabolites were detected from tissues of sesame (Dossou *et al.* 2021). Allelochemicals viz., 9, 12-octadecadienoic acid (z,z)-, methyl ester and hydroquinone were qualitatively analyzed using gas chromatography–mass spectrometry from sesame (Verma *et al.* 2021). Furthermore, many other secondary metabolites extracted from sesame were responsible for its allelopathic nature. Therefore, it can be used as an effective tool in the field of allelopathy in the forthcoming future.

Allelopathic effect of sesame on weeds

Efficiency of sesame root exudates against important weeds of *rabi* crops viz., *Chenopodium album Anagalis arvensis, Melilotus alba, Spergula arvensis Fumaria parviflora* and *Vicia sativa*, were studied by Kumar and Varshney (2007). For testing the effect of exudates on germination of test weeds, the experiments were laid out in petri plates filled with a layer of sand (150 g) moistened with Hoglands nutrient solution (5.0 mL) and test solution (15 mL).

The exudates inhibited germination and caused considerable delay in speed of germination. Emulsion water concentrate (EW) at 240 µg g^{-1} of soil inhibited germination of *Chenopodium album* by 80% followed by *Anagalis arvensis* (75%), *Melilotus alba* (65%), *Spergula arvensis* (60%), *Fumaria parviflora* (55%) and *Vicia sativa* (50%) over control. At 280 µg g^{-1} of soil, the highest inhibition in shoot biomass, root biomass and total biomass of all the weeds were observed.

Kumar and Varshney (2008) reported the allelopathic influence of sesame root exudates on purple nutsedge. Emulsion water concentrate formulation (EW) of allelochemicals from root exudates of sesame, caused significant delay and inhibition in the germination of purple nutsedge. Emulsion water concentrate formulation of sesame root exudate at 240 µg g^{-1} soil inhibited the shoots and root biomass of purple nut sedge by 81.3 and 91.9%, respectively. In addition, application of purified allelochemicals from root exudates at 240 µg g^{-1} caused decrease in total number of newly emerged tubers and dry weight of newly emerged tubers by 97% and 87.5%, respectively.

The effect of sesame leachate on sprouting of tuber, growth and biochemical parameters of *Cyperus rotundus* were observed by Hussain *et al.* (2017). Leaves of 2 month aged plants were collected and soaked in distilled water at 1:4 (w/v) ratio for 48 hours at room temperature.

Allelochemicals present in sesame leaf leachate inhibited sprouting of tubers. Number of leaves, plant height, dry weight, chlorophyll a, chlorophyll b, carotenoids and protein content decreased with higher concentration of leachate (100 %). The superoxide dismutase activity decreased with concentration of leachate at 100% which enumerated the failure of antioxidant defence. The decrease in growth, photosynthetic pigment, antioxidant activity reflects the potential of sesame leachate to control *Cyperus rotundus* L.

Allelochemicals in the leaf leachate of sesame inhibited expression and elongation of bud cells and cell division. Leaves showed yellowing and necrosis due to degradation of pigment molecules. Extreme allelopathic stress leads to leaf senescence and finally programmed plant death.

Chandrasekhar *et al.* (1998) carried out pot culture experiments under controlled greenhouse conditions with different concentrations (1%, 5%, and 10%) of sesame haulm on *Cynodon dactylon.* The results revealed that the chlorophyll content and soluble protein content were remarkably decreased by spraying sesame haulm extract (10%) and incorporating sesame haulm at 100 g per pot.

Combined effect of extracts of sesame and sorghum on weeds of wheat (*Phalaris minor* and *Avena fatua*) was studied by Jamil *et al.* (2009). Application of sesame and sorghum extracts (each at 6 L ha^{-1}) in 1: 10 (W/V) applied at 30 and 40 days after sowing enhanced the yield of wheat by 44% and decreased the dry weight of *Phalaris minor* and *Avena fatua* biomass (21-24% and 19-24%, respectively).

Total phenol and total terpenoid content in sesame was 13.3 ± 4.7 (mg g^{-1}) and 35.1 ± 15.8 (µg g^{-1}) respectively (Verma *et al.* 2021). These compounds were found to act as bio-herbicides against *Echinochloa crus-galli* under laboratory and glasshouse conditions by disrupting metabolic enzymes engaged in glycolysis and oxidative pentose phosphate pathway.

Aqueous extract of sesame at 100 mg mL^{-1} caused delay in seed germination and growth of moso bamboo (*Phyllostachys edulis* (Carriere) J. Houz.) (Zhao *et al.* 2022). The phenolic acids and alkaloids present in the extract might be the reason for the inhibitory effect.

Stimulatory effect of sesame leachate and blended extract of different concentrations on germination of *Melochia corchorifolia* (chocolate weed) was studied by Unnikrishnan *et al.* (2022). Compared to blended extract, whole plant leachate of sesame at 1:2.5 w/v concentration had more stimulatory effect on the germination and growth of *M. corchorifolia.* Whole plant leachate of *Melochia corchorifolia* (1:2.5 w/v) resulted in higher germination percentage and growth attributes than that of control (distilled water).

Allelopathic effect of sesame in crops

The effect of sesame residues on growth and yield of succeeding crops were observed by Premasthira *et al.* (1999). The plant height, fresh weight and dry weight of rice and sorghum cultivated on soil incorporated with sesame residues were significantly lower than that of the control. Duary (2002) studied the effect of different concentrations of sesame leaf extract on seed germination, growth of seedlings and dry matter production of black gram and rice. Germination of black gram and rice were inhibited by 19% and 26.3 % respectively over control by leaf extract (20%). While, the shoot length, seedling biomass and vigour index (I and II) of both the crops were reduced by leaf extract at 5% concentration. Soleymani and Shahrajabian (2012) studied the allelopathic effect of sesame on canola. Whole plant extract and extract of plant parts, (leaf, root, stem and flower) each at 4 levels (0%, 25%, 50% and 100%) were used for the bioassay. The results demonstrated that canola is sensitive to the allelochemicals exuded from sesame. Inhibition in the growth of canola seedlings might be due to the presence of allelochemicals like terpenes, hydrocarbons, fatty acids, phenolic acids, alkaloids and nitrogen compounds present in the extract.

Allelopathic response of sesame on cotton and green gram grown in replacement series was studied by Shah *et al*. (2016). The results revealed that sesame had stimulatory effect on cotton, while it had inhibitory effect on the growth and yield attributes of green gram.

Allelopathic effect of sesame leaf extract (1:10 w/v) recorded significant effect on germination and seedling vigour of rice (Oudhia and Tripathi 2000). Yuprasoet *et al.* (1992) observed that sesame whole plant extract (5 %) inhibited the seedling shoot and root length of mung bean, peanut, corn and sorghum.

Future line of work

The complexity involved in the extraction of allelochemicals from sesame and the cheap availability of synthetic herbicides counteracts the potential of allelopathy in weed management. Future research on the allelopathic potential of sesame should focus on the following aspects.

a. Structural elucidation of the allelochemicals from different parts of sesame.
b. Clarification on the mechanism of action of allelochemicals
c. Investigation on the interaction among alleochemicals released by the plant, other plants and microorganisms present in the soil.
d. Investigation of the right concentration of allelochemicals that would be effective in suppressing the weeds.
e. Studies on the influence of climatic factors on the allelopathic activity of sesame.

CONCLUSION

Sustainable agriculture requires research, to re-evaluate the current production methodology and inputs. Exploring the allelopathic potential of crops like sesame provides sustainable crop production, through productive effects on soil fertility, organic matter contents, and ecosystem biodiversity. Utilization of allelochemicals from sesame is a promising avenue to mitigate the problems associated with the use of herbicides like, herbicide resistance and environmental pollution. By providing proper emphasis on research investigations, allelopathic effect of sesame can emerge as a platform to establish green agriculture.

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