



# Exploring Weed Management Challenges and Mitigation Strategies in Groundnut (*Arachis hypogaea* L.): A Review

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10.18805/ag.R-2849

## ABSTRACT

Groundnut or peanut (*Arachis hypogaea* L.) is the most important food, cash crop and oilseed of our country. Weeds pose severe constraints to productivity of groundnut with 13-80% yield reduction as it is confronted with repeated flushes of several grasses and broad-leaf weeds due to a slow growth habit at early stage. Unlike other crops, weeds interfere with pegging, pod development and harvesting of groundnut during different stages of crop growth, besides competing for growth resources causing significant reduction in growth characters, yield and yield attributes along with seed quality. Since manual weed control is time consuming and costly, pre- and post-emergence herbicides offers an alternative viable option for effective and timely control of weeds in groundnut. But herbicide resistance is a rising concern due to continuous use of same herbicide group. For this, alternative measures such as integrated and precision weed management are viable options for weed management along with enhancing crop productivity, profitability and sustainability. Hence, a comprehensive and brief review is presented taking important aspects of weed management in groundnut along with recent advancements made in precision weed management in groundnut and other crops.

**Key words:** Herbicide, Nano encapsulated herbicide, Precision weed management.

Groundnut or peanut (*Arachis hypogaea* L.) is the most important food and cash crop of tropics, sub tropics and also one of the most important oil seed of our country. It is considered as “king of oilseeds”, “wonder nut” and “poor man’s cashew nut” and it is an important source of protein (25-28%), oil (43-45%) and essential vitamins and minerals (Kambiranda *et al.*, 2011). In India, groundnut occupied an area of 4.9 million ha area during 2023-24 with a total production of 9.25 mt and productivity of 1893 kg/ha (Odisha Agriculture Statistics, 2023-24), contributing about 40% to the total oilseeds production in the country. Weeds pose severe constraints to productivity of groundnut as it is confronted with repeated flushes of several grassy and broad weeds during its life cycle (Jat *et al.*, 2011), especially in bunch type of varieties with poor competitive ability. The reduction of yield can vary from slight to massive (13-80%) in India (Ghosh *et al.*, 2000) depending on the weed density. A loss estimation of 10% due to weed would amount to a loss of about 25 Mt of food grains (Yaduraju, 2012). During the early stages (7 to 10 days) and up to 45 days after sowing, the crop is severely affected by weeds due to a slow growth rate (Mohapatra, 2005). Unlike other crops, weeds interfere with pegging, pod development and harvesting of groundnut during different stages of crop growth, besides competing for growth resources causing significant reduction in growth characters, yield and yield attributes along with seed quality (Shanwad *et al.*, 2011). Manual weed control is considered as an ancient practice for managing weeds due to its difficulty, time consumption and high cost, especially when there is shortage of manpower. Pre-emergence herbicides have been proved remarkably effective up to 20-25 DAS, but later flushes of weeds interfere with pegging, pod

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**How to cite this article:** Lenka, S., Pramanik, K., Duary, B., Dash, R. and Mohapatra, R. (2026). Exploring Weed Management Challenges and Mitigation Strategies in Groundnut (*Arachis hypogaea* L.): A Review. *Agricultural Reviews*. **47(5)**: 843-850. doi: 10.18805/ag.R-2849.

**Submitted:** 24-03-2026 **Accepted:** 13-07-2026 **Online:** 17-09-2026

development and harvesting. Use of pre and post-emergence herbicides offers an alternative viable option for effective and timely control of weeds in groundnut. Due to continuous use of same herbicide group, 262 weed species constituting 152 dicots and 110 monocots in 70 countries have been found to develop resistance to different herbicides (Rao, 2021). For this, alternative measures such as precision weed management have been developed (site specific and cost effective) for enhancing crop productivity, profitability and sustainability. A detailed insight into weeds, nature of infestation, extent of yield loss and advances in weed management in groundnut are limited across various agro-ecologies in India. But detailed knowledge and summarized information regarding the above aspects are essential to facilitate advancement of research further. In order to fill

these gaps, it was thought appropriate to undertake a comprehensive study by reviewing relevant literature and generate information on the aspects of weed and its management in groundnut in India. This review paper takes into account important aspects of weed management in groundnut along with recent advancements made in precision weed management for crops.

We searched peer-reviewed research articles on the topic “weed management in groundnut” following the updated guideline for reporting systematic reviews. For this purpose various databases such as Google, Google Scholar, Research rabbits, Web of Science, Research gate, Springer, Wiley etc. were utilized to search and retrieve the pertinent literatures. We have used key words such as “weed management in groundnut”, “chemical method of weed management”, “integrated method of weed management”, “nano encapsulated herbicide” and “precision weed management”. In addition to this, books, annual reports of Directorate of Groundnut Research (DGR, Junagadh) and technical reports based on groundnut were thoroughly searched for required information. The selected publications were thoroughly studied and categorised to several groups as per requirement. Emphasis was given on weed management strategies in groundnut covering from basis management strategies to recent developments in weed management such as integrated weed management, nano-encapsulated herbicides and precision weed management. Around 200 papers were identified records through database searching. Out of that, 150 records were screened after discarding and excluding duplicates and conference papers etc. Research publications (10 nos) before the year 2000 were excluded. Out of 150 selected research articles, 107 articles were screened for full text-access and full text records were not available for 43 articles. All the work published between 2000 to 2022 were included for preparation of this review paper. The paper presents an overview on weed flora and its abundance, losses due to weed, critical period of crop weed competition, basic, current and recent weed management strategies in groundnut crop.

### Weed flora and its relative abundance

The weed flora in crop fields varies depending on the agro-ecological conditions and weed management strategies adopted. Weeds in groundnut fields can be categorized into broad leaf, narrow leaf/grasses and sedges, depending on their shape. Although grassy weeds are more, broad leaf weeds also pose a serious threat to the crop (Table 1).

### Yield loss due to weeds

Weeds compete with crop plants primarily for soil moisture, sunlight, nutrients and space thus, reduce both size and number of sink and yield. Unless suitable weed management strategies are adopted, yield losses occur to a large extent. A study conducted under the All India Coordinated Research Project on Groundnut (AICRPG) revealed that the yield losses due to weeds at ten different

locations; Jalgaon, Ratnagiri, Khargone, Chinthamani, Virddhachalam, Kadiri, Jagtial, Dharwad, Durgapura and Junagadh was to the tune of 69, 45, 59, 58, 74, 77, 64, 31, 52 and 57%, respectively (AICRPG, 2009).

Groundnut weeds comprising diverse plant species ranging from grasses to broad leaf weeds and sedges cause substantial yield losses (15-75%) which were more in rainfed Spanish bunch type than in irrigated virginia type groundnut (Jat *et al.*, 2011) and sometimes upto 45-71% yield loss (Gharde *et al.*, 2018).

### Nutrient loss through weeds

The competition for the nutrients between weeds and crops depend on the type of weed flora, stage of the crop, type soil and other related environmental condition of that area. A large amount of nutrients more specifically the major nutrients *i.e.* nitrogen, phosphorus and potassium are siphoned by the weeds in the absence of weed control measures.

The application of fluchloralin @ 1000 g ha<sup>-1</sup> pre plant incorporation (PPI) *fb* imazethapyr @ 80 g ha<sup>-1</sup> as post emergence (POE) and pendimethalin @ 900 g/ha pre emergence (PE) *fb* imazethapyr @ 80 g ha<sup>-1</sup> (POE) resulted in significantly lower nitrogen uptake by the weeds (Savu *et al.*, 2005). Nutrient uptake by weeds was found the lowest in weed free condition (Chaudari *et al.*, 2007) or with pendimethalin + interculture over unweeded plot (Madhu *et al.*, 2006); Rao *et al.* (2011) and Reddy *et al.* (2016) reported reduction in nutrient uptake of nutrients by weeds with pendimethalin @ 1 kg a.i/ha *fb* HW at 40 DAS (6.8, 2.6 and 7.4 N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O kg/ha, respectively) and hand weeding twice at 15 and 40 DAS (2.72, 0.94 and 2.42 kg N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha), respectively.

### Critical period of crop weed competition

Weed competition is expected to be maximum during the active growth stage period depending upon types of weed species, duration and severity of infestation and competing ability of the crop. Critical period of crop weed competition in groundnut has been reported to be the initial 4 to 8 weeks. Weed competition is expected to be maximum during the active growth stage depending upon cultivar and weed species due to slow initial growth. In general maximum period of weed competition that can be tolerated by the groundnut crop without any adverse effect on yield is around 30 DAS (Jat *et al.*, 2011). The critical period for weeding was 7 to 16 days after planting and the critical weed free period was 26 to 65 days after planting, assuming a yield loss of 5% (Agostinho *et al.*, 2006) and key period for weeds in a mixed population was 3-8 weeks following sowing (Wesley *et al.* (2008), Annadurai *et al.*, 2010). *Rabi* groundnut was also noted to be more vulnerable to weed competition during the early phases of the crop than *kharif* groundnut and up to 15-16 DAE (Korav *et al.*, 2020). Nambi and Sundari (2008) established that critical period of grass control was from 4 to 9 weeks after sowing and 2-8 weeks after sowing for broad leaf weed control.

**Table 1:** Season wise common annual weeds in groundnut crop in India.

| Grasses                                                                                                                     | Broad leaf                                                                                                                                                                                                                                               | Sedges                                  | References                       |
|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------|----------------------------------|
| <b>Kharif season</b>                                                                                                        |                                                                                                                                                                                                                                                          |                                         |                                  |
| Cynodon dactylon, Dactyloctenium aegyptium, Echinochloa colona, Eleusine indica and Cyperus rotundus                        | Achyranthes aspera, Ageratum conyzoides, Alternanthera sessilis, Borreria articularis                                                                                                                                                                    | -                                       | Karthik and Mudalagiriappa, 2020 |
| Digitaria sanguinalis and Cynodon dactylon                                                                                  | Commelina benghalensis and Trianthema portulacastrum                                                                                                                                                                                                     | Cyperus rotundus                        | Sheoran et al., 2015             |
| Cynodon dactylon, Echinochloa colona                                                                                        | Digera arvensis, Commelina benghalensis, Boerhaavia diffusa, Amaranthus viridis, Parthenium hysterophorus, Trianthema portulacastrum, Acalypha indica, Phyllanthus niruri and Leucas aspera                                                              | Cyperus rotundus                        | Suseendran et al., 2019          |
| Digitaria sanguinalis, Dactyloctenium aegyptium                                                                             |                                                                                                                                                                                                                                                          |                                         |                                  |
| <b>Rabi season</b>                                                                                                          |                                                                                                                                                                                                                                                          |                                         |                                  |
| Chloris barbata, Panicum repens and Dactyloctenium aegyptium                                                                | Celosia argentea, Trianthema portulacastrum, Tridax procumbens, Euphorbia geniculata, Digera arvensis, Parthenium hysterophorus, Portulaca oleracea and Phyllanthus niruri                                                                               | Cyperus rotundus and Cyperus esculentus | Kalaichevi et al., 2015          |
| Cynodon dactylon, Echinochloa colonua                                                                                       | Trianthema portulacastrum, Commelina benghalensis, Tridax procumbens, Trichodesma indicum, Parthenium hysterophorus, Phyllanthus niruri, Amaranthus viridis, Cleome viscosa, Acanthospermum hispidum, Eclipta alba, Celosia argentea and Acalypha indica |                                         | Devi et al., 2017                |
| Digitaria sanguinalis, Cyperus rotundus, Digitaria ciliaris, Digitaria sanguinalis Dactyloctenium aegyptium, Elusine indica | Ageratum conyzoides, Amaranthus sp., Celosia argentea, Borreria hispida, Borreria latifolia, Mimosa pudica, Borreria hispida, Borreria latifolia                                                                                                         |                                         | Korav et al., 2018               |
| Cynodon dactylon, Digitaria sanguinalis and Echinochloa crusgalli                                                           | Parthenium hysterophorus                                                                                                                                                                                                                                 | Cyperus rotundus                        | Das et al., 2016                 |
| <b>Summer season</b>                                                                                                        |                                                                                                                                                                                                                                                          |                                         |                                  |
| Cynodon dactylon and Eleusine indica                                                                                        | Portulaca oleracea                                                                                                                                                                                                                                       | Cyperus rotundus                        | Sarin et al., 2021               |
| Cynodon dactylon, Dactyloctenium aegyptium, Panicum repens, Echinochloa colona                                              | Cleome viscosa, Phyllanthus niruri, Eclipta alba                                                                                                                                                                                                         | Cyperus rotundus among the sedges       | Nambi et al., 2019               |

## Weed management practices

### Cultural and mechanical methods

The mechanical methods viz. manual weeding and hand hoeing with mechanical weeder are practices for managing weeds in some parts of the country. The number of hand weedings and hoeing mainly depends on weed intensity and type of weeds.

Hand weeding twice at 20 and 40 DAS (Datta *et al.*, 2001) and HW 20 DAS + hoeing at 20 and 40 DAS (Dharkar *et al.* (2002) recorded lower weed density and higher pod yield. Both narrow and broad-leaf weeds could be managed with 3 hoeings + 3 HW at 15, 30 and 45 DAS with enhanced yield attributes and dry pod yield of groundnut (Bhagat *et al.*, 2002). Plant population of 5.0 lakh ha<sup>-1</sup> with hand weeding (Sharma *et al.*, 2015) and 4.0 lakh ha<sup>-1</sup> (Senthil, 2009) recorded the lowest weed density and weed dry matter at 30, 60 DAS and at harvest. Similarly, two hand weedings at 15 and 30 DAS and one hoeing at 35 DAS recorded significantly lower weed biomass at harvest (Kamble *et al.*, 2006; Walia *et al.*, 2007; Kanagam and Chinnamuthu, 2009) in groundnut crop. Hand weeding twice at 2<sup>nd</sup> and 4<sup>th</sup> week after sowing (Naim *et al.*, 2010 and Bhale *et al.*, 2012), intercultivation and hand weeding at 25 and 40 DAS in *kharif* groundnut (Damor *et al.*, 2019), 3 hand weedings at 15, 30, 40 DAS (Kirde *et al.*, 2019) and two hoeings (Sardana *et al.*, 2006) resulted in higher pod yield and growth parameters (Jitendra *et al.*, 2022) in summer groundnut.

### Chemical method of weed control

Using herbicides in crop fields for weed control is easier, economical and quicker compared to other methods. Application of herbicide is crop stage sensitive. Pre-emergence herbicides avert germination of weed seeds, whereas post-emergence herbicides hinder growth of weed seedlings. Chemical weed control is therefore a more effective addition to traditional techniques and a crucial component of contemporary crop production.

Pendimethalin (900 g/ha) as pre-emergence *fb* premix imazethapyr + imazamox (70 g/ha) as post-emergence spraying at 25 DAS depleted 113 (57.24%) weed seeds per core (soil sample taken from 15 cm depth by core sampler of 4 cm diameter), whereas, subsequent tillage *fb* IC and HW at 45 DAS depleted 101 (51.01%) weed seeds per core as compared to the initial weed seed bank. Unweeded check resulted in to addition of 652 (329.41%) weed seeds per core sample (15 cm depth and 4 cm diameter) in the soil weed seed bank in comparison to initial weed seed bank (Gohil *et al.*, 2020).

Effective control of grasses and broad-leaf weeds and maximum growth, yield attributes and yield in groundnut were observed with pre-emergence application of pendimethalin *fb* imazethapyr at 20 DAS (Sasikala *et al.*, 2004; Walia *et al.*, 2007; Kumar *et al.*, 2013; Mehriya *et al.*, 2021) and one hand weeding at 40 DAS (Shwetha *et al.*,

2016). The highest pod yield (2127 kg/ha) and less weed dry weight (739 kg/ha) were obtained with combined application of oxyfluorfen @ 0.25 kg a.i/ha + pendimethalin @ 0.5 kg a.i/ha (Chaudari *et al.*, 2007). Punia *et al.* (2017) reported the lowest weed density (8.3/m<sup>2</sup>), lowest weed dry weight (7.4 g/m<sup>2</sup>), the highest weed control efficiency (85%) and the highest dry matter accumulation with spraying of imazethapyr + pendimethalin (ready mix) @ 1000 g/ha.

### Integrated weed management

Integration of weed control and hand weeding or hoeing were found successful in managing diverse weed flora in groundnut crop. Pendimethalin was found to be an effective herbicide for controlling weed flora upto 2-3 weeks in groundnut. Pre-emergence application of pendimethalin + hand weeding at 30 DAS (Sagvekar *et al.*, 2015) and inter cultivation at 30 and 45 DAS was found very effective in controlling weeds in groundnut (Attarde *et al.*, 2001). Maximum weed control efficiency was reported in pendimethalin (0.9 kg/ha) as pre emergence followed by imazethapyr (75 g/ha) as PoE, HW twice (20 and 40 DAS) in groundnut (Patel *et al.*, 2006). Pendimethalin + HW at 15 DAS (Bhale *et al.*, 2012) and two HW at 20 and 40 DAS (Kumar and Rana, 2004) recorded higher yield and yield attributes along with lower weed biomass in groundnut. Kalaichelvi *et al.* (2015) reported greater number of pods plant<sup>-1</sup> and pod yield with pre-emergence treatment of pendimethalin at 0.75 kg a.i./ha, alachlor at 1.0 kg a.i/ha and oxyfluorfen at 0.25 kg a.i/ha *fb* hand weeding at 20 DAS. Ready mix application of pendimethalin + imazethapyr @ 1.0 kg/ha + one manual weeding at 25-30 DAS (Sudesh *et al.*, 2019) resulted in remarkable reduction in weed population and dry mass of weeds at different growth stages in groundnut (Fig 1).

### Weed management by nano encapsulated herbicides

Nanoencapsulation is defined as the technology of packaging nanoparticles of solid, liquid, or gas, also known

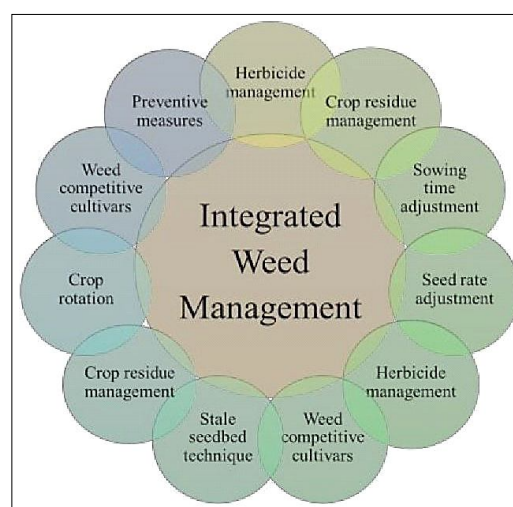


Fig 1: Components of integrated weed management.

as the core or active, within a secondary material, named as the matrix or shell, to form nanocapsules. Nanoparticles encapsulated herbicides have been proven to release the active ingredients of herbicides slowly without imparting any toxic impact to the soil or soil biota. This technology can help to achieve weed control with long term sustainability of soil (Oliveira *et al.*, 2015; Gayatri *et al.*, 2021). Maruyama *et al.* (2016) studied encapsulation efficiency of imazapic and imazapyr, from the nanostructured polymer called chitostan (carrier of the herbicides to the target site). The result showed that encapsulation increased the herbicide efficiency of both the herbicides by 60% which were released at about 20-30% slower rate than the uncoated herbicides. Srimathi *et al.* (2021) concluded that nano encapsulated sulfentrazone herbicide formulation @0.30 kg/ha application one day before sowing registered higher pod and haulm yields compared to control. However, the same herbicide @ 0.40 kg/ha recorded phytotoxic symptoms during the initial period of crop growth. Among sulfentrazone (200 and 250 g/ha), oxyfluorfen (200 and 250 g/ha), diclosulam (20 and 25 g/ha) and metolachlor (1.0 and 1.25 kg/ha), in both commercial and encapsulated forms and hand weeding at 20 and 40 DAS showed that hand weeding at 20 and 40 DAS resulted in maximum productivity of 1802 kg/ha and 1753 kg/ha pod yield during *kharif* and late *rabi*, respectively followed by diclosulam @ 25 g/ha with encapsulation, which also recorded higher profitability (1.80 and 2.01 B:C ratio (Swetha *et al.*, 2022).

### Economics of weed management

Integrated weed management practice involving pre-emergence application of pendimethalin with one interculture/ weeding incurred significantly higher net return and benefit cost ratio. Sasikala *et al.* (2004) observed that application of fluchloralin (PPI) and imazethapyr was the most economical with highest net profit followed by pendimethalin *fb* imazethapyr.

Spraying of pendimethalin @ 1.0 kg a.i/ha *fb* imazethapyr @ 75 g/ha at 20 DAS as pre and post-emergence (Malunekar *et al.*, 2012; Shwetha *et al.*, 2016 and Mehriya *et al.*, 2020) along with one hand weeding at 40/45 DAS was found most economically feasible weed management practice for groundnut, incurring highest net monetary returns and B: C ratio (Christensen *et al.*, 2009; Sheoran *et al.*, 2015).

### Recent advancements in weed management

Precision weed management is a new approach, which aims at reducing herbicidal dose, control of target species using site specific weed management and robotic technology. Site-specific weed management (SSWM) technique uses machinery or equipment embedded with technologies that help to identify weeds growing in association with crops in the field for their successful control (Christensen *et al.*, 2009). Robotic technology is an alternative for site specific weed management. It uses machineries like hand hoeing or spot spraying knap sack

sprayer without need for human operations. An agricultural weeding robot consists of hardware and software and it has an unmanned, self-steered platform that hosts an array of weed detection units. These, in turn, activate an array of weeding tools *i.e.* spray nozzle, microwave unit or tillage tool (Osten and Crook 2016). Robots used for weed management such as Robocorp in U.K., IC Cultivator in Netherlands, Robovator by Denmark, EcoRobot by Switzerland, Lady bird and RIPPA by Australia, Bonirob by Germany and Agribot by India (Rao, 2021; Manisankar *et al.*, 2022). Artificial intelligence (ability of machine to imitate human intelligence) is used for weed identification, precision weed control, predictive modeling and weed mapping in several crops. Machine learning techniques (algorithms used to incorporate intelligence into machine by automatically learning from data sets provided such as CNN (Convolutional Neural Network), DCNN (Deep Convolutional Neural Network), SVM (Support Vector Machine), ANNs(Artificial Neural Networks), RF (Random Forest) and KNNs (K-Nearest Neighbours) are used for weed identification in different field crops (Muchhadiya *et al.*, 2024) and combination of algorithms KNN and SVM also gave the best results than the CNN with respect to the accuracy (Kazmi *et al.*, 2015). When various machine learning algorithms such as SVM, KNN and CNN used with MATLAB, R programming and Python. CNN is the most used machine learning algorithm by the researchers to classify weed and crop due to its accuracy than that of other machine learning algorithms (Bakhshipour and Jafari, 2018). In groundnut crop, Zhang *et al.* (2022) used a weed identification model EM-YOLOv4-Tiny incorporating multiscale detection and attention mechanisms based on YOLOv4-Tiny for identifying weed species. Its network was 28.7 M in size and took 10.4 ms to detect a single image, which meets the requirement of real-time weed detection.

### CONCLUSION

Effective weed management practices are necessary for getting higher growth, yield and economics in groundnut crop. The reviewed investigations revealed that integrated weed management practices were more successful in managing weeds in groundnut crop compared to only herbicides or manual weeding. Among various herbicides, use of pre-emergence herbicides such as pendimethalin, diclosulam or ready mix application of pendimethalin and imazethapyr was successful in effective management of weed flora in groundnut and obtained higher weed control efficiency. But there are problems like environmental contamination, herbicide persistence and weed resistance because of excessive and inappropriate use of chemical herbicides. To combat this, new generation technologies such as nanotechnology, artificial intelligence and robotics can help in managing weed efficiently by precisely applying herbicide in a target site, which in turn will help in reducing herbicidal dose in non-targeted areas, environmental

pollution, increase productivity and profitability of crops in future scenario.

### Conflict of interest

There is no conflict of interest.

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