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Weed management options under organic farming: A review

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Abstract
Organic farming which promotes and enhances Agro-ecosystem health, including biodiversity, biological cycles and soil biological activities, may be more conducive to get long term sustainability in agriculture and to restore the productivity of degraded soils. Weeds as a key constraint in organic field decrease crop yields by increasing competition for inputs while serving as alternate host for pathogens. Weed management under organic farming is a holistic management system where farmer is not interested in eliminating all weeds but wants to keep them at a threshold level which is economical and manageable. Organic weed management relies on mechanical (tillage, cutting and pulling of weeds) biological (use of predatory or parasitic microorganisms or insects) and cultural methods (crop rotation, enhanced crop competitive ability, delayed or early seeding, flooding, mulching, inclusion of green manure and cover crops and intercropping) but these must be used in an integrated way to get effective and economical results. Adoption of appropriate crop rotations and smother/cover crops is very helpful for breaking pest cycles including weeds and it suppress weed population due to smothering and allopathic effects. Thorough understanding of bio control and allelopathy helps in weed control under organic farming. Crop competitive ability improvement using most suitable genotype, appropriate sowing/planting pattern and timely fertilization strategy may also be a viable approach to achieve desired weed management.

Keywords: Organic farming, weed management, cover crops, crop rotation, allelopathy, mulching

Introduction

Due to adoption of nutrient-responsive, high yielding crop cultivars together with the indiscriminate use of synthetic agrochemicals like fertilizers and insecticides deterioration of soil and environment has recently been the subject of repeated concerns. Therefore, it is vital to reduce environmental deterioration to the absolute minimum and increase the productivity of damaged soils. The practice of organic farming is one way to do this. Organic agriculture promotes and enhances agro-ecosystem health, including biodiversity, biological cycles, and soil biological activity. Due to weeds competition with crops for nutrients, air, light, and moisture, crop production losses from weeds are a significant factor (Kumar *et al*., 2013; Das *et al*., 2016) [26, 16]. Weeds generate more losses (34%) to agriculture than any other type of agricultural pest (Oerke, 2005) [38]. Moreover, weeds can serve as a home for some plant viruses and host insects. Without carefully thought-out weed management measures, organic farming cannot produce crops profitably. The potential yield of the majority of cultivated crops is decreased by weeds because they naturally expand more quickly, occupy agricultural habitats, and do so. Since the widespread use of agro-chemicals has allegedly led to issues with the environment and human health, there is currently resurgence in interest in organic weed management techniques. In some instances, the usage of herbicides has been proven to contribute to the dominance of certain weed species in fields because such weeds become resistant to the herbicides. Moreover, some herbicides have the power to eliminate weeds that are not harmful to crops, which could lead to a decline in biodiversity. It's crucial to realize that weeds can never truly be eradicated under an organic system; they can only be managed. The main objective of a weed management strategy in an organic system is to lower weed competition and reproduction to a level that the farmer can tolerate. The use of non-chemical weed control techniques is encouraged for the protection of human health, the environment, and weeds that are resistant to herbicides (Ofuoku *et al*., 2008) [39].

Weed management options

An integrated weed management (IWM) system strategy is used to manage weeds on an organic farm. To keep weed populations below the point at which they cause economic harm, and environmental quality preservation is main objective of IWM. Crop plants and weeds should coexist in harmony in an organic agricultural system.

A. Preventive strategies

The least expensive yet frequently underutilized control technique is prevention. This can be accomplished by planting weed-free seed, adopting adequate watering techniques, and managing agricultural machines carefully. Utilize only crop seeds that are clean, weed-free, and certified. Little seed canary grass infected with wheat seed has been a significant factor in both its short- and long-distance spread (Singh, 2007) [56]. Use hygienic farm machinery and equipments. Eliminate weeds before they may go to seed. Control the weeds in areas used for animal bedding, feed, and fodder since certain weed seeds continue to be active and viable after passing through an animal's digestive system. Utilize only fully rotted manure (minimum 4-5 months old material), as viable weed seeds can reach fields through partially rotten or unrotted manures (Singh and Singh, 2005) [55]. Planting certified seed, suppressing weeds before they set seed, managing weeds in fencerows and ditches, and cleaning tillage and harvesting equipment before switching from one field to another are all ways that growers can keep weeds out of their fields. Field bindweed, Johnsongrass, sandbur, and Palmer amaranth are just a few of the unpleasant plants that can move from one field to another with harvesting machinery. In order to practice preventive management, fields must be continuously checked for weed issues (Patil and Bainade, 2022) [44]. In order to create the best crop management strategy, it is crucial to have a solid understanding of the dynamics of the weed population and how various weed management techniques affect it.

B. Cultural strategies

Tillage: Tillage affects weed survival by burying whole plants and weed seed, exposing the root system to drying and cold, and reducing the food reserves of weed plants. Tillage also lessens compaction, prepares the seed bed, and incorporates fertilizer and wastes. The possibility of pesticide carryover from the previous crop is reduced by ploughing the upper 30-35 cm layer. Due to less soil disturbance and limited emergence of little seed canary grass weed, zero tillage technique lowered crop weed competition. Moreover, early planting gives wheat an edge over little seed canarygrass weed in rice wheat cropping systems in heavy soils (Singh, 2007) [56]. Zero till sowing in standing stubbles significantly outperformed conventional tillage in terms of growth parameters, yield attributes, and grain yield of wheat by reducing the growth and development of Phalaris minor as well as broad leaf weeds (Brar and Walia, 2009) [13]. In comparison to conventional till crops, zero till wheat had the lowest density and dry weight of *Phalaris minor* may be due to deep burial of *Phalaris minor* seeds in a deeper soil layer (Mishra *et al*. (2005); Bisen *et al*., 2006) [35, 12]. Summer fellow and deep summer ploughing may be viable cultural option to stop weed development, stop weed seed production, decrease soil seed stocks, and starve weed roots in organic farming. Conventional tillage had a greater overall population of narrow leaf weeds than minimum tillage (Ranjit and Suwanketnikom, 2003) [46]. According to Tewari and Singh (1991) [61], summer ploughings aid in managing the *Cyperus rotundus*. Weed occurrence is decreased by puddling in rice. One of the methods used in organic agriculture for weed control is night tillage (Gallagher and Cardina, 1998) [21]. Compared to no tillage and conventional tillage, deep tillage with a mould board plough reduced the population of *Phalaris minor* by 13.7% and 8.5%, respectively. When the soil was inverted using a mould board plough, weed seeds were deeply buried and were unable to sprout, which led to a decline in the population of *Phalaris minor* (Chahal *et al.*, 2003) [14]. Physical mixing or turning under the soil are two ways that tillage affects the dynamics of the weed seed bank. Inversion tillage techniques like mould board ploughing cause a greater percentage of seeds to be buried in the tillage layer than non-inversion techniques like chiselling. After ploughing, low weed intensity occurs the next season because deep-buried weed seeds do not emerge. Providing the rhizomes are collected and destroyed after tilling, deep ploughing can also be used successfully against perennial weeds like *Cynodon dactylon*. The areas between the rows are suitable for mowing. Regular mowing is necessary to avoid weed-crop competition and to stop weeds from entering their reproductive phase, which would otherwise result in the development of seeds for the next generation (Sanbagavalli *et al*., 2020) [50].

Crop rotation

Crop rotation is the best cultural strategy for integrated weed management programme in organic farming to disrupt the weed's active growth cycle. Due to the fact that both weeds and crops have biologically comparable requirements, many weeds have a strong association with a particular crop. Hence, by switching crops, the ecological needs of the associated weeds are not satisfied, and as a result, weed growth will be reduced. Long rotations and diverse cropping systems are frequently followed by organic farmers to improve soil fertility and economic. Variations in cultural practices connected with each crop cause disruptions to weed germination and growth cycles when a variety of crops are employed in a rotation (tillage, planting dates, crop competition, etc.). Wheat crop rotation with sugarcane, vegetable crops, beans, sunflower, and clover minimizes the weeds (Malik and Singh, 1995) [31]. Many crops, including the potato, onion, winter maize, mustard and sunflower, can take the place of wheat during the winter months to reduce the *Phalaris minor* population. In the northeastern district of Haryana, *Phalaris minor* has few chances to spread in long-term (4 year) rotation of rice-fallow-sugarcane-ratoon. Rotating rice with potatoes, sunflowers, sugarcane, and onions may be the best alternative (Singh, 2007) [56]. When rice and wheat were alternated, 67% of fields showed resistance to isoproturon in *Phalaris minor*, compared to 8, 9, and 16% in the cases of rice-berseem-sunflower-wheat, sugarcane-vegetables-wheat, and cotton-pigeon pea-wheat, respectively (Malik and Singh, 1995) [31]. *Phalaris minor* can be managed by rotating wheat with other *Rabi* crops such as berseem, potato, raya or gobhi sarson, winter maize, oats (fodder), sugarcane, etc. and also by early sowing of wheat in October (Ravisankar *et al*, 2017) [47]. The dominance of *Phalaris minor* can be broken by the addition of sugarcane to crop rotations due to smothering impact during later growth stages (Yaduraju and Ahuja, 1995; Kirkwood *et al*., 1997) [70, 24]. the Use of berseem in the cropping system helped to reduce the seed bank of *Phalaris minor* because the emergent plants of *Phalaris minor* were removed with each cutting of berseem and were not given the chance to set and shed seeds in the field. Digging and earthing up operations in potato-based rotations decreased the soil seed bank of weeds. Rice cultivation can fully eradicate wild oat. Sunflower and cotton encourage *striga* spp. to germinate, but because they are not hosts for this weed, they completely suppress it. Crop rotation is supposed to be an excellent practice for controlling various noxious and mimicry weeds such as *P. minor*. It adversely affects weed seed bank because of change in weed management practices with respect to successive crops. Integration of various vegetables with short life cycle in rice *fb* wheat system may also enhance weed control without any application of herbicides, rice-wheat cropping system is more severely affected by the problem of isoproturon resistance compared to other systems like cotton-pigeonpea-wheat, sugarcane-vegetable-wheat, rice-berseem-sunflower-wheat etc. So, this system should be least followed in farming systems (Wozniak, 2019; Sunil *et al*., 2023) [68, 59].

Cover crops

Weeds are suppressed by the crop's quick growth and dense ground coverage. An organic farming system can gain various advantages from cover crops, including defense against soil erosion, enhanced soil structure, increased soil fertility, and weed control. Including cover crops into the cropping system, such as rice bean, groundnut, rye, red clover, buckwheat, wintering crops like winter wheat, or forages, might inhibit weed development because cover crops have the ability to control weed growth, lower weed populations in the next crop, and lower weed seed inputs into the soil seed bank. In place of a fallow season, annual or short-term perennial cover crops may be taken. Moreover, cover crops can operate as a living mulch or organic mulch to further control weed growth during the growing season.

Intercropping

The weeds can be successfully controlled using intercropping. Fast growing and early maturing intercrops like cowpeas or mung beans between two rows of the primary crop may be taken for this purpose. In addition to providing fodder, intercropping cowpea with maize and harvesting in 40-45 days after seeding effectively controls weeds. The weed problem is significantly reduced when soybean and peanuts are interplanted with upland rice, maize, or sorghum.

Field scouting

It entails the methodical gathering of field data on weeds and crops (weed distribution, growth stage, population, crop stage etc.). Short-term weed management decisions are made using the knowledge to lessen or prevent financial crop loss. Long-term evaluation of weed management programme success or failure and future wise decision-making depend on field scouting.

Mulching

Mulching apart from increasing the economic yield of crops by providing congenial environment for their growth also provides a good control of weeds. The basic idea behind mulching is to keep the weeds' tops dark until their reserve food supply in the roots runs out and they starve. Clean straw, hay or manure, sawdust, crop stolons and black plastic are examples of mulch. With wheat cultivated after rice, straw management is crucial for weed control. The ideal solution is to sow wheat in standing rice stubbles using a happy seeder following a combine harvest, and this approach is gaining popularity among farmers. Kaur (2009) [23] observed better grain yield and net returns over the traditional technique of sowing wheat, as well as a modest decrease in *Phalaris minor* dry matter accumulation in wheat crop sown on standing rice stubbles with Happy seeder. When less light penetrates the soil surface, fewer weed seeds germinate, contributing to the low population of *Phalaris minor* with Happy Seeder. Moreover, a small number of newly emerging seedlings struggle to emerge from the dense layer of straw, which prevents them from growing. It is possible to efficiently employ rice straw as mulch by utilizing a turboseeder (drill), which seeds wheat similarly to a zero-tillage drill by diverting straw in front of the tines and placing it in the space between two rows (20 cm apart). Hence, adding straw mulch between the two wheat rows prevents the emergence of weeds and enriches the soil with organic matter (Singh, 2007) [56]. Zero-till planting in standing stubbles was found to be less weedy than traditional tillage because rice straw served as a mulch and there was less soil disturbance (Rahman *et al*.,2005; Brar and Walia, 2009) [45, 13].

a) **Living mulch:** Clover is an example of a plant species that typically grows densely and low to the ground and is used as living mulch. You can plant living mulches either before or after a crop has begun to grow. In order to prevent living mulch from competing with the actual crop, it is crucial to kill it or somehow regulate it. When transplanting broccoli, spread a live mulch made of *Portulaca oleracea* to control weeds without compromising crop output. Living mulch frequently has other goals besides weed control, such as enhancing soil fertility, reducing pest problems, or improving soil structure.
b) **Organic mulch:** Several materials that can be produced on a farm, including as hay, straw, grass mulch, agricultural wastes, and livestock or poultry bedding, are used as organic mulches. There may also off-farm sources for other materials, like leaves, composted municipal trash, bark, and wood chips. Farmers must take into account the sort and amount of mulch that will be used, as well as the mulch's cost and the machinery required to handle it. Mulching with organic materials can improve soil structure, water infiltration, aggregate stability, and soil biological activity. It can also assist increase soil organic matter.
c) **Degradable plastic mulches:** Plastic mulch that degrade are either photodegradable (they disintegrate after 30 to 60 days of exposure to sunshine) or biodegradable (they degrade when they come into contact with soil microbes). After the growing season, degradable materials do not need to be removed from the field, and some can even be mixed into the soil to hasten the process. In nurseries and with some high-value crops, reusable materials, such as black polypropylene mulch, can be utilized to manage weeds over time (such as strawberry). In order to encourage seed germination and weed prevention in the lettuce, reusable fabric mulch has also been employed (Finney and Creamer, 2008) [20].

Stale seed bed preparation

The only problem to this approach is that the seeding can occasionally be delayed. Nevertheless, it is quite efficient at controlling weed populations. The steps in this weed control method are to provide a fine seedbed, allow weeds to grow (using irrigation or rainfall to provide the required soil moisture), and then remove weed seedlings directly using light cultivation. The moist, weed-free soil can then be sown with crop seeds or transplants. This method aids in giving the crop a chance to emerge and flourish before the subsequent weed flush. This can be done 2-3 times before planting, if time permits.

Soil solarization

A polyethylene sheet is placed over moist soil during soil solarization, which is a unique weed control method that heats the soil for several weeks using solar energy. Due to this polyethylene sheet coating, the northern region's soil reaches high temperatures of 50-60 °C during the summer. When compared to non-solarized soil, solarized soil exhibits a considerable reduction in the total weed flora (grasses, broadleaf weeds, and sedges) (Arora and Tomar, 2012) [5]. Solarization involves heating the soil to destroy nuisance organisms like weed seeds, fungi, bacteria and nematodes. In the summer, soil is covered with clear or black polyethylene plastic, wet underneath the plastic and left in place for at least six weeks. Heat, wetness, and direct contact with the plastic, which results in burning, all kill weed seeds and young sprouts. Research has shown that solarization with transparent or black plastic from July to October effectively controls weeds without lowering crop output (Rieger *et al.*, 2001) [49]. Solarization has also been used to lessen weed competition and boost yields of field-grown cauliflower and fennel. It can also be used to produce weed free soil or potting mix for container production in warm climates (Stapleton *et al.*, 2002) [58].

Sanitation and composting

The introduction and spread of weeds can be minimized by paying special attention to agricultural sanitation and seed sources. When utilized in many locations, equipment and tools should be fully cleaned before being used in another area. Add weed free mulch and compost to field otherwise it may contain seeds that subsequently cause a problem. Wet the straw and allow weeds to sprout rather than preventing them from being carried into a field with straw mulch. Dry out the straw bale to destroy seedlings by tearing it apart after the weed seeds have grown. When applying compost manures to the soil, weeds and other undesirable organisms must be properly eradicated. Compost the materials at a temperature of at least 180°F (82 °C) for not less than three days to kill the bulk of weed seeds in cattle dung (Wiese *et al*., 1998) [66]. Always inspect seeds and transplants before planting to avoid further spread of weeds, and only purchase certified quality seeds from reliable sources.

Selection of crop cultivars: Selection of crop cultivars plays an important role in crop weed competition because of morphological features, canopy structures and relative growth rate. The traditional tall growing varieties perform better than modern dwarf varieties under unweeded situations and this is the reason that most of organic growers grow traditional tall varieties. A cultivar that provides early canopy cover and grows quickly outcompetes weeds. An excellent cultivar should be quick to emerge from the soil, grow quickly as a seedling, expand its leaf surface quickly, maintain a dense canopy for a long time, close its canopy quickly, utilize nutrients effectively, be tall and have unpredictable growth behaviour (Naylor, 2002; Davis *et al*., 2005) [36, 17]. According to Travlos (2012) [62], taller varieties shut their canopies more fully than shorter varieties, which helps shade out weeds. Wheat types that develop a canopy early and accumulate more dry matter can shade grassy weeds. In comparison to HD 2009, WH 291 and S 308, wheat varieties WH 147 and HD 2285 were found to be the most competitive with winter wild oat (Balyan *et al*., 1991; Sunil *et al*., 2023) [7, 59]. In comparison to PDW 233, Mahajan *et al*. (2004) [29] discovered that PBW 343 had more tillers, which has a larger suppressive effect on weeds. So, choosing the right crop kinds is crucial to suffocate weeds.

Sowing time

An essential agronomic practice for managing weeds is changing the sowing window. Crop sowing is scheduled for a time when weed seed germination is unfavourable, but not far enough away to affect crop performance. Wheat seeded in October has less *Phalaris minor* infection. Although late-sown wheat (December) also causes *Phalaris minor* to accumulate less dry matter, crop yields are also negatively impacted. Weeds have different germination preferences; late seeding effectively controls early-germinated weeds, while early seeding causes crop competition with later-germinating weed species. However, postponing sowing past November led to some weeds like *Vicia sativa* and *Lathyrus aphaca* growing less. According to Mahajan and Brar (2001) [28], the crop sown on October 25 at Ludhiana resulted in a 26.9% decrease in the dry matter buildup by *Phalaris minor* and a 21.6% increase in grain yield over the crop sown on November 10. Similarly, compared to the wheat crops sown on November 11 and November 21, Miralavi *et al*. (2010) [33] found less weed density and lower total weed biomass in the early planting (October 22) crop.

Sowing methods

The sowing method should be chosen to provide small amount of room for weeds, preventing them from growing correctly while giving crops the most room to grow and flourish. In bed planted and transplanted crops, weed management is simple and more effective. Weeds are less common in wheat that has been planted on raised beds (Aggarwal and Goswami, 2003) [1] and they can be eliminated manually by reshaping the raised beds with a bed planter. Compared to direct seeded, rice that has been transplanted offers greater weed control. Little seed canary grass dried out 18% lighter when planted in rows that were 15 cm apart as opposed to 22.5 cm apart as usual (Walia *et al*., 2003; Mahajan *et al*., 2004) [63, 29]. Due to the more even distribution of crop plants used in cross sowing, there was less room for weed growth and development, which resulted in a decrease in weed density and dry weight. Cross sowing wheat with a row spacing of 22.5 cm under late sowing conditions decreased the dry weight of *Phalaris minor* by 59, 23 and 38%, respectively, compared to broadcast sowing, closer sowing, and regular rows (Singh and Singh, 1996) [54]. Due to better canopy covering over weeds, closer row spacing of 15 cm reduced the dry matter of *Phalaris minor* by 32.3 percent and resulted in a grain yield of wheat that was 8 to 10 percent higher (Chahal *et al*., 2003; Bhullar and Walia, 2004) [14, 10]. According to Mahajan and Brar (2001) [28], closer spacing of 15 cm caused *Phalaris minor* to reduce dry matter by 15.5% compared to a crop sown at 22.5 cm row to row spacing, yielding a 13.2% greater grain yield than usual spacing (22.5 cm). Weeds have less room to grow in narrow spacing because of this, and the crop plants' capacity to smother them resulted in a reduction in weed dry weight and favorable effects on crop yields (Mishra and Tiwari, 1999) [34]. Crisscross sowing yielded 7.29 and 19.93% more grain than traditional line sowing and broad casting, respectively (Pandey and Dwivedi, 2007) [40]. When compared to unidirectional planting, bidirectional seeding of wheat (22.5 x 22.5 cm) dramatically reduced the amount of dry matter that *Phalaris minor* accumulated (22.5 cm). For controlling weeds, unidirectional seeding at closer rows (15 cm) was profitable over bidirectional sowing (Singh, 1996) [53]. Compared to broad casting, crisscross sowing dramatically reduced the number of weeds present and their dry biomass might be due to more crop plants in a given area compete with the weeds nearby, suppressing their growth (Yadav *et al.*, 2001; Pandey and Kumar, 2005) [69, 41]. Bed planting, as opposed to flat seeding of wheat reduced the population of *Phalaris minor* by 12.5% (Walia *et al*., 2003) [63]. By burying the weed seeds deep during bed preparation, bed planting also lessens the weed invasion. Because there is less irrigation water available on top of the bed, weed seeds left there will demonstrate poor germination and grow relatively more slowly. The first flush of *Phalaris minor* seedlings may be killed if the bed is reshaped before wheat is planted. Deep plouging after wheat harvest might bury the seed and have a significant impact on its germination in the following season. *Phalaris minor* seed germinate mostly from shallow depth. Wheat sowed with a rotavator twice as often as farmer's practice and with no tillage had the least amount of weed population and weed dry mass due to the burial of numerous weed seeds present on the soil surface into deeper layers of soil, which later failed to germinate (Pandey *et al*., 2001) [42]. A shallow and uniform seeding depth is necessary for quick crop emergence and good establishment in order to reduce weed crop competition. The faster the crop will emerge if the crop seed is planted in moist soil that is closer to the soil surface, i.e. (3-5 cm). Weed seed placed in deeper layers will take longer to emerge out.

Seed rate/planting density

In order to increase the early smothering capability of crop plants on weeds, increasing seed rate or planting density aims to produce more crop plants per unit area. Wheat seeded with a 20 cm inter row spacing and a seed rate of 150 kg per hectare had the lowest weed population, while wheat sown with a 25 cm inter row spacing and a seed rate of 100 kg per hectare had the highest weed population (Babu *et al.* (2017) [6]. Rice with a higher plant density (44 plants/m^2) has less weed biomass. Higher than usual seed rates can boost crop output and competitiveness, giving the crop the upper hand over weeds. According to Bhullar and Walia (2004) [10], wheat seeded with 150 kg/ ha reduced *Phalaris minor* dry matter accumulation by 35.4% and boosted wheat grain yield by 12.3% over recommended seed rate (100 kg/ha). To be most effective, heavy seeding rates should be utilized in conjunction with other cultural control strategies under ideal irrigation and fertilizer conditions. Increased seed rates between 75 and 150 kg/ha considerably reduced the dry weight of weeds in wheat (Sharma and Singh, 2011) [52]. With wheat variety WH-423, increasing seed rates from 100 to 175 kg/ha resulted in a reduction in weed dry weight from 135 to 96 g/m^2 in unweeded plots (Panwar *et al*., 1995; Yadav *et al*., 2001) [43, 69]. Weed shoot biomass fell dramatically as wheat density rose (Miralavi *et al*., 2010) [33].

Use of manure and compost

Weed populations in crop fields are influenced by the quality of organic manure and the application technique. Usage of legume leftovers in place of chemical nitrogen fertilizer to meet the crop's additional nitrogen needs can improve weed control. Legume residues slowly release nitrogen, which inhibits the growth of weeds. Weed growth can be controlled by applying organic manure close to the rows where it is more likely to be absorbed by the crop. Use of vermicompost and biogas slurry should be preferred over FYM. Farmyard manure should be thoroughly decomposed before being applied to the ground since the uncomposted manure acts as a weed seed bank. Weed problems in organic agriculture systems can be greatly increased by weed seeds in uncomposted manures (Teasdale and Mohler, 1993; Sunil *et al*., 2023) [60, 59].

Water management

In transplanted rice, weeds can be controlled with a 15-day submergence interval. Due to the soil being wetted only around the plant base, drip irrigation in wider row crops minimizes the intensity of weeds and thus has minimal weed development. In dry areas, the alternate furrow technique also reduces weed intensity. Weed growth in a field is influenced by irrigation timing and technique. Careful irrigation management can lessen weed burden on crops effectively.

C) Mechanical strategies

Mechanical and physical methods of weed control, such as hand weeding and pulling, include removing weeds using various tools and instruments. According to Dhiman *et al.* (1985) [18], inter-row cultivation with a wheel hoe or a long-tined hand hoe (Kasola) boosted wheat yields by 26-29% compared to unweeded controls. In general, hand weeding is most effective in light soils and is less effective when grassy weeds are present.

Manual methods

Mechanical removal is most efficient way to manage weeds in organic farming. This includes removing weeds by hand and using hand tools or instruments, such as a wheel hoe, to hand-weed. The best mechanical weed seedling management methods involve burying weed seedlings to a depth of 1 cm and cutting them at the soil surface. The method has a limitation because there isn't enough manpower available. When compared to unweeded control plots, hand weeding and hand hoeing at 4-5 weeks after seeding reduced *Phalaris minor* dry weight by 38 and 69%, respectively (Sharma *et al.*, 1985) [51]. The most successful method for minimizing the buildup of weed dry matter was mechanical weeding performed twice at the 15 and 30 day stages (Sharma and Singh, 2011) [52]. Due to rising labor costs and labour shortages during the busiest weeding times, mechanical weeding has now largely taken the role of manual weeding.

The morphology of the crop and the weeds determines the appropriate implement to use. Inter-row brush weeders are seen to be more efficient for horticultural use, tools like fixed harrows are better suited for arable crops. The competitiveness of the crop and the stage of the weeds' growth affect the best time to use mechanical weed control (Finney and Creamer, 2008) [20].

Flame cultivation

On the majority of organically grown crops, broadcast flame cultivation before sowing the crop can be employed successfully. It works better on a smooth dirt surface than one that is bumpy or cloddy (Smilie *et al*., 1965) [57]. Moreover, it works better against broadleaf weeds than grasses, however it loses power as weeds get older. When flaming burns grasses and perennial weeds to the soil's surface, these weeds can occasionally sprout again. During flame cultivation, it is important to carefully seed or transplant crops to avoid disturbing the soil and promoting the germination and establishment of weed seeds.

D) Biological strategies

The natural method for weed management in organic agriculture would seem to be biological control.

Allelopathy

Allelopathy, meaning mutual harm, is an interference mechanism in which a living or dead plant releases allelochemicals exerting an effect on associated plants which plays an important role in natural and managed ecosystems (Sunil *et al*., 2023) [59]. Several plants express the allelopathic phenomenon through exudation of allelochemicals. For example, rye is among the most important allelopathic crops. Although benzoxazinones [2,4-dihydroxy-1,4(2H)-benzoxazin-3-one (DIBOA) and 2(3H)-benzoxazolinone (BOA)] are the most important allelochemicals responsible for the allelopathic potential of rye, several of other important allelochemicals are also present in rye (Bertholdsson *et al*., 2012; Didon *et al*., 2014; Macias *et al*., 2014) [9, 19, 27]. Rye can be used to suppress weeds in a cropping system as a rotating crop, cover crop, or mulch, but the most popular way to do so is as a cover crop (Norsworthy *et al*., 2011) [37]. Another significant crop that is allelopathic is sorghum. The allelopathic potential of sorghum and its effects on various cropping systems are thoroughly explained in the literature. Sorghum's allelopathic activity varies depending on the cultivar, the location, and the stage of plant development. Sorghum produces a number of allelochemicals, which are how its allelopathic activity is expressed. The hydrophobic p-benzoquinone (sorgoleone), phenolics and acyanogenic glycoside (dhurrin) are the three allelochemicals that are most significant (Weston *et al*., 2013) [64]. The most potent allelochemical released by the roots of sorghum is called sorgoleone. In sorghum plants, sorgoleone is produced by root hair cells (Weston *et al*., 2012) [65]. Brassica plants have the ability to reduce weeds by acting as cover crops, intercropping with the main crop and using the litter from the brassica plants as mulch (Haramoto and Gallandt, 2005; Rice *et al*., 2007; Bangarwa and Norsworthy, 2014) [22, 48, 8]. In a crop rotation, sunflowers may be phytotoxic to the crop that comes after them. It has also been noted that sunflower allelopathy suppresses a number of weed species. Alsaadawi *et al*. (2012) [3] evaluated the allelopathic potential of eight sunflower cultivars against problem weed species in wheat. They either grew the allelopathic sunflower cultivars in a mixture with weeds, or applied the residues (600 or 1400 g m^{-2}) of sunflower cultivars to the wheat crop and its weeds. The sunflower cultivars in the study varied in their allelopathic potential and suppressed total weed density by 10-87% and total weed biomass by 34-81%. Sunflower residues also expressed their allelopathic potential to suppress total weed density (24-75%) and total weed biomass (12-67%) and increased wheat grain yield and yield components over the nontreated control. In sustainable agriculture, breeding new cultivars with high allelopathic potential may have a significant impact on biological weed management. The allelopathic potential of crop plants contributes to the weed suppressing ability of cultivars. (Kong *et al*., 2011; Worthington and Reberg-Horton, 2013) [25, 67]. Mahajan and Chauhan (2013) [30] highlighted the importance of cultivars' allelopathic potential for managing weeds in aerobic rice. In Korea, Ahn *et al*. (2005) [2] investigated the allelopathic activity of 78 local rice cultivars against the most notorious rice weed *Echinochloa crusgalli* (L.) P. Beauv. A number of rice cultivars were found to decrease the biomass, number of tillers, and height of the weed under field conditions. Six out of 78 cultivars had an average E. crus-galli inhibition of above 40%. In another study, Chung *et al*. (2006) [15] evaluated the allelopathic potential of 99 rice cultivars. Five rice cultivars reduced weed germination and growth by more than 50%, while the other five by 40-50%. The rice cultivars which exhibited higher reductions in growth and germination of weeds were found to possess higher concentrations of allelochemicals, including momilactone A and momilactone B. The release of allelochemicals from allelopathic cover crops and their physical effects were responsible for the weed suppression in conservation organic farm fields. In comparison to a single cover crop, mixtures of cover crops have been found to be more successful at suppressing weeds (Altieri *et al*., 2011) [4].

Beneficial organisms

Few studies have been done on the use of predatory, parasitic insects or microorganisms to control weed populations. A weevil for the aquatic weed salvinia, a rust for skeleton weed and possibly the most well-known natural enemy, a caterpillar (*Cactoblastis* sp.) to manage prickly pear have proven effective. Significant research is also being done on microbes and fungus (myco-herbicides) to be more successful in controlling particular weeds. Myco-herbicides are solutions containing pathogenic spores that are sprayed on plants using typical herbicide application tools. Some biocontrol agents and commercial mycoherbicides used for weed control are indicated below:

Table 1: Fungal, viral and bacterial agents for weed control

Pathogens or agents	Weeds
A. cassiae	*Senna obtusifolia* (L.) H. S. Irwin and Barneby *S. occidentalis* (L.) Link *Crotalaria spectabilis* Roth
A. destruens	*Cuscuta*. spp.
A. eichhorniae	*Eichhornia crassipes (Mart.) Solms*
A. helianthi	*Xanthium strumarium* L
Amphobotrys ricini	Euphorbiaceae
Ascochyta caulina Cercospora chenopodii C. dubia	*Chenopodium album* L.
Bipolaris setariae	*Eleusine indica* (L.) Gaertner
C. caricis	*Cyperus esculentus* L
Cochliobolus lunatus	*Echinochloa crus-galli* (L.) P. Beauv.
C. coccodes, F. lateritium	*Abutilon theophrasti* Medik.
C. dematium	Leguminosae
C. gloesporioides	Leguminosae, Malvaceae, Convolvulaceae (C. spp.)
C. graminicola	Gramineae
C. orbiculare	*X. spinosum*
C. truncatum	*Sesbania exaltata* (Raf.) Rydb. ex A.W.Hill
Dichotomophthora indica D. portulacea	*Portulaca oleracea* L.
Exserohilum monoceras	*Echinochloa* spp.
F. lateritium	*Sida spinosa* L. *Anoda cristata* (L.) Schltdl. *Potamogeton* spp.
F. lateritium	*Ambrosia trifida* L.
F. oxysporum	*Phelipanche ramosa* (L.) Pomel
Myrothecium verrucaria	*S. obtusifolia Portulaca* spp. *Euphorbia* spp.
Phoma chenopodicola	*C. album, Cirsium arvense* (L.) Scop., *Setaria viridis* (L.) P. Beauv., *Mercurialis annua* L.
P. herbarum	*Taraxacum officinale* (L.) Weber ex F.H. Wigg
P. macrostoma	*T. officinale*
Phomopsis convolvulus	*Convolvulus arvensis* L.
Phyllachora cyperi	*Cyperus rotundus* L.
Pyricularia sp.	*Digitaria sanguinalis* (L.) Scop.
P. grisea	*E. indica*
Pseudocercospora nigricans	*S. obtusifolia*
Sclerotinia sclerotiorum	Multiple species
S. minor	*T. officinale, Trifolium repens* L., *Plantago minor* Garsault
Septoria tritici f. sp. *avenae*	*Avena fatua* L.
Sphacelotheca holci *B. halepense* *B. sorghicola* *C. graminoicola*	*Sorghum halepense* (L.) Pers.
Pepino mosaic virus	*Solanum nigrum* L.
Araujia mosaic virus	*Araujia hortorum* E. Fourn.
Obuda pepper virus	*S. nigrum*
Pseudomonas syringae pv. *tagetis*	*C. arvense*
P. fluorescens strain BRG100	*S. viridis*
P. fluorescens strain WH6	Multiple weeds
P. fluorescens strain D7	*Bromus tectorum* L.
Zygrogramma bicolarata	*Parthenium hysterophorus*
Crocidosema lantana Teleonnemia scrupulosa	*Lantana camara*
Dactylopiustomentosus D. indicus (Cochineal scale insect)	*Opuntia dilleni*
Neochetina eichhornea N. Bruchi (Hyachinth weevil) *Sameodes alligguttalis* (Hyachinth moth)	*Eichhorneacrassipes*
Crytobagus singularis (weevil) *Paulinia acuminate* (grass hopper) *Samea mutiplicalia*	*Salvinia molesta*
Agasides hygrophilla (flea beetle) *Amynothrip sandersoni*	*Alternanthera philoxaroides*

Table 2: Commercial Bio herbicides

Products and Pathogens or Agents	Target Weed
Acremonium diospyri	*Diospyros virginiana* L. trees in rangelands
LuBao 1, *Colletrichum gloeosporioides* f. sp. *cuscutae*	*Cuscuta* spp. in soybean
DeVine®, *Phytophtora palmivora*	*Morrenia odorata* (*Strangler vine*.) in citrus orchard
Collego™/LockDown™, *C. gloeosporioides* f. sp. *aeschynomene*	*Aeschynomene virginica* (L.) (Northern joint vetch) in soybean and rice
Casst™, *A. cassiae*	*Cassia obtusifolia* L., *C. occidentalis* L., *C. spectabilis* DC. In soybean and peanut
ABG-5003, *C. rodmanii*	*Eichhornia crassipes* (Mart.) Solms

Dr. BioSedge®, *P. canaliculata*	*Cyperus esculentus L.* in soybean, potato, corn, and cotton
Velgo®, *C. coccodes*	*Abutilon theophrasti Medik.* In corn and soybean
BioMal®, *C. gloeosporioides* f. sp. *Malvae*	*Malva pusilla* Sm. In wheat, lentil, and flax
Stumpout™, *Cylindrobasidium laeve*	*Poa annua* L. in golf courses; *A. mearnsii* (De Wild) and *A. pycnantha* (Benth.) in native vegetations
Biochon™, *Chondrostereum purpureum*	*Prunus serotina* (Ehrh.) in forests
Camperico®, *Xanthomonas campestris* pv. *Poae*	*P. annua* in golf courses
Woad Warrior®, *P. thalaspeos*	*Isatis tinctoria* L. in farms, rangelands, and roadsides
Chontrol™ = Ecoclear™, *C.purpureum*	Hardwoods in forests
Myco-Tech™ paste, *C. purpureum*	Deciduous tree species in forests
Sarritor®, *S. minor*	*Taraxacum officinale* (L.) *Weber ex F.H.* Wigg in lawns, turf
Smolder®, *A. destruens*	*Cuscuta* spp. In fields and ornamental nursery
SolviNix™, tobacco mild green mosaic tobamovirus (TMGMV)	*Solanum viarum Dunal* in rangelands
Biopolaris, *Biopolaris sorghicola*	*Sorghum halepense* (Johnson grass)
Organo-Sol®, *Lactobacillus* spp.-fermented milk	*Trifolium*, *Medicago*, and *Oxalis* spp. in rights of way, forests
Emmalocera sp., stem boring moth	*Echinochloa* sp.in Rice and wheat
Tripose, Shrimp	*Echinochloa* sp. in Rice and wheat
Uromyces rumicis, plant pathogen	*Rumex* sp. in Rice and wheat
Gastrophysa, Beetle	*Rumex* sp. in Rice and wheat
Bactra verutana, Shoot boring moth	*Cyprus rotundus* in Rice and wheat

Approved herbicides
A limited number of natural substances can serve as herbicides on organic farms.

Corn gluten meal
Corn gluten meal, a byproduct of the manufacturing of cornflour, is the most extensively used commodity in the country. It is possible to use maize gluten meal as a pre-emergence herbicide (Finney and Creamer, 2008) [20]. The gluten must be present for weed seeds to germinate in order to prevent root formation, hence timing of application is crucial. Redroot pigweed, black nightshade (*Solanum nigrum*), common lambsquarters, curly dock, creeping bentgrass (*Agrostis palustris*), purslane, common dandelion (*Taraxacum officinale*) and smooth crabgrass are among the weeds that are adversely impacted by maize gluten meal. Barnyard grass (*Echinochloa crusgalli*) and velvetleaf (*Abutilon theophrasti*) are the least susceptible weeds to corn gluten meal among those that have been studied (Bingaman and Christians, 1995) [11]. On general, grasses are less vulnerable to corn gluten meal than broadleaf plants. When maize gluten meal was added before planting, weed cover in field studies was reduced by up to 84 percent (McDade and Christians, 2000) [32].

Indigenous practices
These are the indigenous weed management practices which the farmers have been using on their farms.

1. **Calotropis (Akk):** By maintaining chopped calotropis (Akk) branches along irrigation channels or entrances, striga populations are reduced.
2. **Cotton shells:** Cotton ball shells can be used to suppress the noxious plant *Cyprus rotundus*. Before the rainy season, a 3 inch thick coating of nutshells is spread around the pitch. Afterwards, to fully absorb it into the soil, the land is cultivated. This causes the weed's root or sedge to burn or die. For around two to three years, the field remains weed-free. Decomposition transforms it into organic manure and aids in boosting crop yield.
3. **Coriander:** *Striga asiatica* in sorghum is managed with coriander (*Coriandrum sativum*). The sorghum rows are interspersed with coriander seeds. For every three kg of sorghum seeds, 200 g of coriander seeds are sowed. When the coriander plants reach a certain size, the strands begin to wrap themselves around striga weed, which inhibits its growth.

References

1. Aggarwal P, Goswami B. Bed planting system for increasing water-use efficiency of wheat (*Triticum aestivum*) grown on Inceptisol (Typic Ustochrept). Indian journal of agricultural science. 2003;73(8):422-425.
2. Ahn J, Hahn S, Kim J, Khanh T, Chung I. Evaluation of allelopathic potential among rice (*Oryza sativa* L.) germplasm for control of *Echinochloa crusgalli* (L.) P. Beauv. in the field. Crop Protection. 2005;24(5):413-419.
3. Alsaadawi IS, Sarbout AK, Al-Shamma LM. Differential allelopathic potential of sunflower (*Helianthus annuus* L.) genotypes on weeds and wheat (*Triticum aestivum* L.) crop. Archives of agronomy and soil science. 2012;58(10):1139-1148.
4. Altieri MA, Lana MA, Bittencourt HV, Kieling AS, Comin JJ, Lovato PE. Enhancing crop productivity via weed suppression in organic no-till cropping systems in Santa Catarina. Brazil journal of sustainable agriculture. 2011;35(8):855-869.
5. Arora A, Tomar SS. Effect of soil solarization on weed seed bank in soil. Indian Journal of Weed Science. 2012;44(2):122-123.
6. Babu R, Kakraliya SK, Prakash L, Kumar P, Yadav RA. Effect of plant geometry and seed rates on growth, yield attributes, productivity as well as weed dynamics of wheat (*Triticum aestivum* L.). International Journal of Current Microbiology and Applied Sciences. 2017;6(3):81-88.
7. Balyan RS, Malik RK, Panwar RS, Singh S. Competitive ability of winter wheat cultivars with wild oat (*Avena Iudoviciana*). Weed Science. 1991;39(2):154-158.
8. Bangarwa SK, Norsworthy JK. Brassicaceae cover-crop effects on weed management in plasticulture tomato. Journal of Crop Improvement. 2014;28(2):145-158.
9. Bertholdsson NO, Andersson SC, Merker A. Allelopathic potential of *Triticum* spp., *Secale* spp. and *Triticosecale* spp. and use of chromosome substitutions and translocations to improve weed suppression ability in winter wheat. Plant Breeding. 2012;131(1):75-80.

10. Bhullar MS, Walia US. Effect of seed rare and row spacing on the efficacy of clodinafop for combating isoproturon resistant *Phalaris minor* Retz. in wheat. Plant protection Quarterly. 2004;19(4):143-146.
11. Bingaman BR, Christians NE. Greenhouse screening of corn meal gluten as a natural control product for broadleaf and grass weeds. Horticulture Science. 1995;30(6):1256-1259.
12. Bisen PK, Singh RK, Singh RP. Relative composition of weeds and wheat yield as influenced by different weed control and tillage practices. Indian Journal of Weed Science. 2006; 38(1&2):9-11.
13. Brar AS, Walia US. Weed dynamics and wheat (*Triticum aestivum* L.) productivity as influenced by planting techniques and weed control practices. Indian Journal of Weed Science. 2009;41(3&4):161-166.
14. Chahal PS, Brar HS, Walia US. Management of Phalaris minor in wheat through integrated approach. Indian Journal of Weed Science. 2003;35(1&2):1-5.
15. Chung IM, Kim JT, Kim, SH. Evaluation of allelopathic potential and quantification of momilactone A, B from rice hull extracts and assessment of inhibitory bioactivity on paddy field weeds. Journal of Agricultural and Food Chemistry. 2006;54(7):2527-2536.
16. Das A, Kumar M, Ramkrushna GI, Patel DP, Layek J, Naropongla, *et al*. Weed management in maize under rainfed organic farming system. Indian Journal of Weed Science. 2016;48(2):168-172.
17. Davies AS, Renner KA, Sprague C, Dyer L, Mutch D. Integrated weed management. "One year's seeding" Extension Bulletin E-2931, Michigan state University, East Lansing, Michigan; c2005. p. 112.
18. Dhiman SD, Mohan DSR, Sharma HC. Studies on cultural methods of weed control in wheat. Indian Journal of Agronomy. 1985;30:10-14.
19. Didon UM, Kolseth AK, Widmark D, Persson P. Cover crop residues effects on germination and early growth of annual weeds. Weed Science. 2014;62(2):294-302.
20. Finney DM, Creamer NG. Organic Production-Weed Management on Organic Farms. North Carolina A & T State University and the North Carolina Department of Agriculture and Consumer Services. USA; c2008.
21. Gallagher RS, Cardina J. Phytochrome-mediated *Amaranthus* germination I: effect of seed burial and germination temperature. Weed Science. 1998;46(1):48-52.
22. Haramoto ER, Gallandt ER. Brassica cover cropping: I. Effects on weed and crop establishment. Weed Science. 2005;53(5):695-701.
23. Kaur M. Effect of planting pattern and straw management technique on herbicide persistence, productivity and quality of wheat (*Triticum aestivum*) and onion (*Allium cepa*). Ph.D. Thesis, Punjab Agricultural University, Ludhiana, India; c2009.
24. Kirkwood RC, Singh S, Marshall G. Resistance of *Phalaris minor* to isoproturon: mechanism and management implications. In Proceedings of the 16th Asian Pacific Weed Science Society Conference on Integrated Weed Management towards Sustainable Agriculture. Kuala Lumpur, Malaysia; c1997. p. 204-207.
25. Kong CH, Chen XH, Hu F, Zhang SZ. Breeding of commercially acceptable allelopathic rice cultivars in China. Pest Management Science. 2011;67(9):1100-1106.
26. Kumar B, Kumar R, Kalyani S, Haque M. Integrated weed management studies on weed flora and yield in Kharifmaize. Trends in Biosciences. 2013;6(2):161-164.
27. Macias FA, Oliveros-Bastidas A, Marin-Mateos D, Chinchilla N, Castellano D, Gonzalez-Molinillo JM. Evidence for an allelopathic interaction between rye and wild oats. Journal of Agriculture and Food Chemistry. 2014;62(39):9450-9457.
28. Mahajan G, Brar LS. Integrated Management of *Phalaris minor* in wheat. Indian Journal of Weed Science. 2001;33(1&2):9-13.
29. Mahajan G, Brar LS, Sardana V. Efficacy of clodinafop against isoproturon-resistant *Phalaris minor* in relation to wheat cultivars and spacing. Indian Journal of Weed Science. 2004;36(3&4):166-170.
30. Mahajan G, Chauhan BS. The role of cultivars in managing weeds in dry seeded rice production systems. Crop Protection. 2013;49:52-57.
31. Malik RK, Singh S. Little seed canary grass (*Phalaris minor*) resistance to isoproturon in India. Weed Technology. 1995;9:419-425.
32. McDade MC, Christians NE. Corn gluten meal-A natural pre-emergence herbicide: effect on vegetable seedling survival and weed cover. American Journal of Alternative Agriculture. 2000;15(4):189-191.
33. Miralavi SV, Ghorbani R, Kohansal A, Ram P. Effect of different wheat density and sowing dates on weed biomass. In: proc. of third Iranian weed science congress, Babolsar, Iran; c2010 Feb. p. 260-263.
34. Mishra AK, Tiwari RC. Effect of seeding methods and fertilizer application on weed biomass and yield of wheat (*Triticum aestivum*). Indian Journal of Agronomy. 1999;44(2):353-356.
35. Mishra JS, Singh VP, Yaduraju NT. Effect of Tillage Practices and Herbicides on Weed Dynamics and Yield of Wheat Under Transplanted Rice-Wheat System in Vertisol. Indian Journal of Agronomy. 2005;50(2):106-109.
36. Naylor REL. Weed Management Handbook. Blackwell Scientific Publications Oxford, London; c2002. p. 302-310.
37. Norsworthy JK, McClelland M, Griffith G, Bangarwa SK, Still J. Evaluation of cereal and Brassicaceae cover crops in conservation-tillage, enhanced, glyphosate-resistant cotton. Weed Technology. 2011;25(1):6-13.
38. Oerke EC. Crop losses to pests. Journal of Agricultural Science. 2005;144(1):31-43.
39. Ofuoku AU, Egho EO, Enujeke EC. Integrated Pest Management (IPM) adoption among farmers in central agro-ecological zone of Delta State, Nigeria. African Journal of Agricultural Research. 2008;3(12):852-856.
40. Pandey IB, Dwivedi DK. Effect of planning pattern and weed control methods on weed growth and performance of wheat (*Triticum aestivum*). Indian Journal of Agronomy. 2007;52(3):235-238.
41. Pandey IB, Kumar K. Response of wheat (*Triticum aestivum*) to seeding methods and weed management. Indian Journal of Agronomy. 2005;50(1):48-51.
42. Pandey IB, Sharma SL, Tiwari S, Bharati V. Nutrient uptake by wheat and associated weeds as influenced by tillage and weed management. Indian Journal of Weed Science. 2001;33(3-4):107-111.
43. Panwar RS, Malik RK, Balyan RS, Singh DP. Effect of

isoproturon, sowing method and seed rate on weed and yield of wheat (*Triticum aestivum*). Indian Journal of Agricultural Sciences. 1995;65:109-111.
44. Patil S, Bainade SP. A review integrated weed management practices in cotton. The Pharma Innovation. 2022;11(6):565-568.
45. Rahman MA, Chikushi J, Saifizzaman M, Lauren JG. Rice straw mulching and nitrogen response of no-tillage wheat following rice in Bangladesh. Field Crops Research. 2005;91(1):71-81.
46. Ranjit JD, Suwanketnikom R. Response of weeds and wheat yield to tillage and weed management. Kasetsart Journal Natural Sciences. 2003;37(4):389-400.
47. Ravisankar N, Panwar AS, Prasad K, Kumar V, Bhaskar S. Organic Farming Crop Production Guide, Network Project on Organic Farming, ICAR Indian Institute of Farming Systems Research, Modipuram, Meerut-250 110, Uttar Pradesh, India; c2017. p. 586.
48. Rice A, Johnson-Maynard J, Thill D, Morra M. Vegetable crop emergence and weed control following amendment with different Brassicaceae seed meals. Renewable Agriculture and Food Systems. 2007;22(3):204-212.
49. Rieger M, Krewer G, Lewis P. Solarization and chemical alternatives to methyl bromide for pre plant soil treatment of strawberries. Horticulture Technology. 2001;11(2):258-264.
50. Sanbagavalli S, Jeeva M, Somasundaram E. Eco-friendly weed management options for organic farming: A review. The Pharma Innovation Journal. 2020;9(11):15-18.
51. Sharma KK, Verma SP, Singh CM. Cultural and chemical manipulations for weed management in wheat with reference to grassy weeds. International Journal of Pest Management. 1985;31:133-138.
52. Sharma SN, Singh RK. Productivity and economics of wheat (*Triticum aestivum* L.) as influenced by weed management and seed rate. Progressive Agriculture. 2011;11(2):242-250.
53. Singh B. Efficacy of diclofopmethyl against *Phalaris minor* in relation to genotype and crop geometry in wheat. M.Sc. Thesis, Punjab Agricultural University, Ludhiana, India; c1996.
54. Singh G, Singh OP. Response of late sown wheat (*Triticum aestivum*) to seeding methods and weed control measures in flood prone areas. Indian Journal of Agronomy. 1996;41(2):237-242.
55. Singh G, Singh VP. Compatibility of clodinafop-propargyl and fenoxaprop-p-ethyl with carfentrazone-ethyl, metsulfuron-methyl and 2,4-D. Indian Journal of Weed Science. 2005;37(1-2):1-5.
56. Singh S. Role of management practices on control of Isoproturon-Resistant Littleseed Canarygrass (*Phalaris minor*) in India. Weed Technology. 2007;21(2):339-346.
57. Smilie JL, Thomas CH, Standifer LC. Farm with Flame. Agriculture Extension. 1965;1364:1-16.
58. Stapleton JJ, Prather TS, Mallek SB, Ruiz TS, Elmore CL. High temperature solarization for production of weed-free container soils and potting mixes. Horticulture Technology. 2002;12(4):697-700.
59. Sunil, Loura D, Harender, Dhankar A, Akshit, Kumar S. Weed Management Practices in Wheat (*Triticum aestivum* L.): A Review. Agricultural Reviews. 2023;44(1):01-11.
60. Teasdale JR, Mohler CL. Light transmittance, soil temperature and soil moisture under residue of hairy vetch and rye. Agronomy Journal. 1993;85:673-680.
61. Tewari AN, Singh RD. Studies on *Cyperus rotundus* L. control through summer treatment in maize-potato cropping system. Indian Journal of Weed Science. 1991;23(1-2):6-11.
62. Travlos IS. Reduced herbicide rates for an effective weed control in competitive wheat cultivars. International Journal of Plant Production. 2012;6(1):1-14.
63. Walia US, Brar LS, Jand S. Integrated effect of planting methods and herbicides on *Phalaris minor* in wheat. Indian Journal of Weed Science. 2003;35(3&4):169-172.
64. Weston LA, Alsaadawi IS, Baerson SR. Sorghum allelopathy-from ecosystem to molecule. Journal of Chemical Ecology. 2013;39:142-153.
65. Weston LA, Ryan PR, Watt M. Mechanisms for cellular transport and release of allelochemicals from plant roots into the rhizosphere. Journal of Experimental Botany. 2012;63(9):3445-3454.
66. Wiese AF, Sweeten JM, Bean BW, Salisbury CD, Chenault, EW. High temperature composting of cattle feedlot manure kills weed seed. Applied Engineering in Agriculture. 1998;14(4):377-380.
67. Worthington M, Reberg-Horton C. Breeding cereal crops for enhanced weed suppression: optimizing allelopathy and competitive ability. Journal of Chemical Ecology. 2013;39(2):213-231.
68. Wozniak A. Effect of crop rotation and cereal monoculture on the yield and quality of winter wheat grain and on crop infestation with weeds and soil proper ties. International Journal of Plant Production. 2019;13(3):177-182.
69. Yadav DP, Vaishya RD, Singh G. Response of late sown wheat to method of sowing, seed rate and weed management practices. Annals of Agricultural Research. 2001;22(3):429-431.
70. Yaduraju NT, Ahuja KN. Response of herbicide resistant Phalaris minor to pre-and post-emergence herbicides, herbicide mixtures and adjuvants. Proc. Brighton Crop Protection Conf. Weeds; c1995. p. 225-230.