

Integrated weed management in maize

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*In India, maize (*Zea mays* L.) is the third most important cereal crop after rice and wheat. It covers 9.26 mha, having production of 23 mt with average productivity of 3070 kg/ha. The average productivity of maize in India is low compared to USA (9 t/ha). The reasons are imbalanced fertilization and poor weed control practices. It is reported that under unweeded maize yield reduction up to 35-99% can happen, therefore adoption of suitable weed control measures are needed for higher weed control efficiency to achieve higher productivity of maize in India.*

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MAIZE (*Zea mays* L.) is the second most important cereal crop in the world in terms of production. It has highest genetic yield potential and therefore knows as 'Queen of Cereals'. India is one of the top ten maize producing countries in the world, which contributes 2.41% of the total global maize production. The predominate maize growing states are Karnataka (13.69%), Madhya Pradesh (13.52%), Tamil Nadu (9.22%), Telangana (7.46%), Rajasthan (7.19%) and Maharashtra (7.08%). Currently states like Madhya Pradesh has the highest area (1.37 mha) and Karnataka in production (3.73 t/ha) while highest productivity of maize (6651 kg/ha) is recorded in Tamil Nadu. Maize is cultivated throughout the year in all the states of the country for various purposes including grain, fodder, green cobs while sweetcorn, baby corn and pop corn are cultivated in the peri-urban areas. In addition to staple food for human being and quality feed for animals, it serves as a basic raw material as an ingredient to thousands of industrial products that includes starch, oil,

protein, alcoholic beverages, food sweeteners, pharmaceutical, cosmetic, film, textile, gum packages and paper industries etc. Maize is being used in different industrial sectors and activities in India. The biggest user of maize in India is poultry industry with 47% of the share followed by industrial consumption in the form of starch (14%) (Fig. 1). Other uses include, direct consumption (13%), livestock feed (13%) and processed food (7%).

Maize productivity is influenced by numerous biotic and abiotic factors. Among the biotic factors, weeds pose a significant constraint to crop production, leading to substantial reductions in yield and produce quality. Weeds compete with crop plants

for essential resources such as nutrients, water, light, and space, resulting in decreased crop yield. Moreover, weed infestations have adverse economic implications and contribute to environmental and health concerns in terrestrial ecosystems. Maize crop sown at wider row spacing and slow growth during initial stage (2-4 weeks) faces severe competition for nutrients, water and light from the growing weeds. During the *kharif* season, which accounts for 80% of total maize cultivation, the crop faces extensive weed infestation throughout the growth cycle, from sowing to harvest, owing to favourable conditions created by frequent rainfall (Table 1).

Neglecting weed control measures can result in substantial yield losses (35-99%) in maize crop. Therefore, effective weed control measures are needed during the critical period (15-45 DAS) of maize crop growth to achieve higher yield and profits, as this period is particularly susceptible to yield losses caused by weeds. While herbicide application is a cost-effective and efficient method for weed control, it has potential negative impacts on the

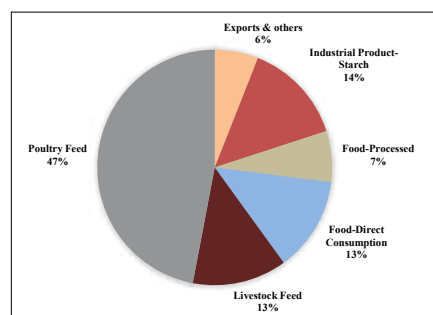


Fig. 1. Maize utilization pattern in India.

Table 1. Predominate weed flora in maize

Narrow-leaved weed	Broad-leaved weed	Sedges
<i>Eleusine indica</i>	<i>Trianthema portulacastrum</i>	<i>Cyperus rotundus</i>
<i>Digitaria sanguinalis</i>	<i>Trianthema monogyna</i>	<i>Cyperus esculentus</i>
<i>Dactyloctenium aegyptium</i>	<i>Amaranthus retroflexus</i>	<i>Cyperus iria</i>
<i>Echinochloa colona</i>	<i>Digera arvensis</i>	
<i>Echinochloa crusgalli</i>	<i>Tribulus terrestris</i>	
<i>Setaria verticillata</i>	<i>Celosia argentea</i>	
<i>Cynodont dactylon</i>	<i>Phyllanthus niruri</i>	
	<i>Ageratum conyzoides</i>	
	<i>Portulaca oleracea</i>	
	<i>Xanthium strumarium</i>	
	<i>Acalypha indica</i>	

environment, human health, and the well-being of domesticated and wild animals. Therefore, integrated weed management which aims to maximize effectiveness, minimize weed resistance, and promote long-term sustainability in crop production is an important strategy to effectively control weeds.

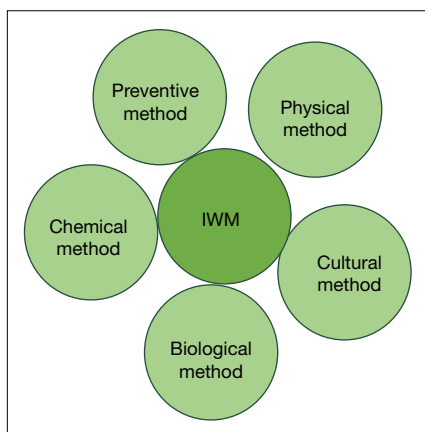
Integrated weed management in maize

To achieve desirable weed control in long run without adverse effect on environment with sustainable maize production, a multi-disciplinary approach is needed. Integrated weed management (IWM) utilizes a wide range of weed control measures *viz.* cultural, mechanical, biological and chemical methods to obtain economical weed control, minimizing weed interference with crop by maintain levels.

Prevention

Prevention is the first approach of IWM where weed seeds are prevented from introduction and multiplication at farm field. It can be done by:

- Use of clean and certified seeds to avoid weed multiplication along with maize seeds.
- Use of well decomposed FYM/compost to prevent the multiplication of weed seed bank in soil.
- Keep irrigation and channels farm path and surrounding area weed free.
- All farm implements must be used clean and grazing movement of cattle should be avoided from field-to-field.



Curative methods

The second approach in IWM is curative where emphasis is given to remove, smother or kill the weeds from further multiplication. It can be done by various methods described below.

Mechanical method

Mechanical weeding is the process of utilizing mechanical tools and equipment to physically eliminate or disrupt weeds in agricultural fields. This approach involves the



Fig. 2. Weed control in maize by mechanical inter-culture operations.

use of implements like hand hoe/*khurpi*, cultivators, harrows, rotary hoes, or specialized machinery specifically designed for weeding. These tools are employed to target and uproot weeds, primarily in the spaces between crop rows, with the aim of minimizing any potential harm to the cultivated plants. Hand weeding using hand hoe/*khurpi* and inter-row cultivation are commonly followed in maize.

- *Hand weeding*: Two hand weeding at 20-30 DAS or 30-45 DAS effectively minimizes weed population. However, manual weeding is uneconomical due to steep rise in wages which involves also lot of drudgery work.
- *Inter-row cultivation*: At the Knee-high stage of maize crop (approximately 30 days after sowing), weed control can be achieved by the use of cultivator or blade harrow in the inter-row spaces of the crop. Mechanical interventions should be avoided after the knee-high stage of the maize crop, as it can cause damage to the leaves.

Mechanical weeding indeed offers the advantage of root aeration, but the persistent rainfall during the *kharif* season poses a significant challenge as it saturates the soil, and sometimes delays inter-cultural operation in the field.

Cultural method

The cultural method of weed control encompasses a range of agronomic practices designed to manage weeds effectively. These

practices include legume inclusion, crop rotation, fertilizer and irrigation management, optimum sowing time, stale seed bed technique etc.

- **Legume inclusion:** Smother crop like soybean, mungbean, groundnut, cowpea sown as intercrop with maize significantly reduces weed density in maize. In addition, legumes are also beneficial as it add or transfer nitrogen to associated crop.
- **Fertilizer application:** Placement of fertilizers promotes vigorous growth of maize crop which can compete with weeds. Certain weeds, like lambsquarters, pigweeds, and quack grass, exhibit heightened growth and competitiveness in the presence of soluble nitrogen (N), particularly when the crop receives all its N fertilizer in a readily-available form during planting. However, by adopting alternative practices such as delayed or split-dose N applications, or preferably relying on slow-release nitrogen sources and rich soil organic matter for the majority of the crop's N requirements, these weeds can potentially be subdued in their competitive vigour.
- **Irrigation management:** Unlike sprinkler or flood irrigation, where water and nutrients are distributed more evenly across the entire field, drip irrigation supply water and nutrient near crop root zone. Consequently, the soil between the rows receives minimal moisture and nutrients, creating an unfavourable environment for weed proliferation. This restricted supply effectively hampers weed growth and helps maintain a weed-free zone between the crop rows. Subsurface drip irrigation, which minimizes soil surface wetting, plays a crucial role in inhibiting weed germination and growth. By limiting the availability of moisture to the soil surface, this irrigation method significantly curtails weed establishment.

- **Crop rotation:** Crop rotation is an integral component of an integrated weed management system, offering an efficient strategy to eliminate crop associated weeds. By incorporating this approach, farmers can alternate the use of herbicides with diverse modes of action, thereby preventing or delaying the onset of herbicide resistance.
- **Optimum sowing time:** Maize sowing in second fortnight of June with optimum seed rate of 20 kg/ha gives an edge over weeds.
- **Stale seed bed techniques:** Here, before sowing of maize, a light irrigation is given to stimulate the germination and growth of weeds. Thereafter, initial flush of weeds is removed either mechanically through shallow tillage or by chemical

means. By employing the stale seed bed technique, farmers can effectively reduce the weed seed bank, giving the crop a competitive advantage and reducing the need for subsequent weed control measures throughout the growing season.

- **Mulching:** Mulching is a crucial technology extensively employed in orchards and agricultural systems for soil and moisture conservation. Additionally, mulching plays a significant role in weed control, as it impedes weed germination and growth by limiting their access to sunlight. Both plastic mulch and crop residue mulch offer effective weed suppression by creating unfavourable conditions for weed growth, reducing weed competition, and promoting healthier crop development.

Table 2. Bioherbicide sources and target weeds species

Source	Target weeds	Phytotoxic effects
Plants		
<i>Achillea santolina</i> L.	<i>Medicago polymorpha</i> L.	Inhibit growth and changes in the metabolic process
<i>Brassica napus</i> L.	<i>Sorghum halepense</i> (L.) Pers.	Suppress germination and root length
<i>Carum carvi</i> L.	<i>Echinochloa crusgalli</i> (L.) P. Beauv.	Leaf lesions and biochemical changes in plant tissues
<i>Cymbopogon nardus</i> (L.) Rendle.	<i>Digitaria horizontalis</i> Willd., <i>Cenchrus echinatus</i> L.	Inhibit germination and plant development and reduce chlorophyll and protein content
<i>Parthenium hysterophorus</i> L.	<i>Echinochloa colona</i> (L.) Link., <i>Euphorbia hirta</i> L., <i>Ageratum conyzoides</i> L.	Seed germination, growth, and development
<i>Pinus densiflora</i> Sie bold & Zucc.	<i>Lolium multiflorum</i> Lam., <i>Digitaria sanguinalis</i> (L.) Scop.	Suppressed shoot and root growth
<i>Sinapis alba</i> L.	<i>Amaranthus powellii</i> S. Watson, <i>Setaria viridis</i> (L.) P. Beauv.	Reduced dry biomass
Fungi		
<i>Ascochyta agropyrina</i>	<i>Chenopodium album</i> L., <i>Cirsium arvense</i> (L.) Scop., <i>Mercurialis annua</i> L., <i>Sonchus oleraceus</i> L., <i>Setaria viridis</i> (L.)	Reduced root growth
<i>Fusarium fujikuroi</i>	<i>Cucumis sativus</i> L., <i>Sorghum bicolor</i> (L.) Moench.	Chlorosis, necrosis, and decrease in plant height and root length
<i>Lasiodiplodia pseudotheobromae</i>	<i>Solanum lycopersicum</i> L., <i>Amaranthus hybridus</i> L., <i>Echinochloa crusgalli</i>	Inhibited germ activity
Bacteria		
<i>Pseudomonas aeruginosa</i>	<i>Amaranthus hybridus</i> , <i>Solanum lycopersicum</i> , <i>Echinochloa crusgalli</i> , <i>Pennisetum purpureum</i> Schumach.	Inhibited seed germination, growth, and germ activity

Biological method

It includes use of living organisms for suppressing or controlling the weeds. Bioherbicides are composed of phytopathogenic microorganisms or microbial/plant derived phytotoxins that offer effective biological weed control and can be applied using similar methods to chemical herbicides. Such micro-organisms are known as bio-agents which prefer weeds for food intake. Biological methods are costly and lot of investment is required for screening for desirable predator in maize (Table 2).

Chemical method

Chemical weed management involves the application of herbicides, which are chemical substances developed to control or eradicate undesirable weeds. Use of herbicide is efficient, easily available and involves less cost. The herbicides commonly recommended for application in maize crop are listed in Table 3.

Precautions need to be taken care of during herbicide application:

It is important to use herbicides judiciously, following recommended dosage, application timing, and safety precautions to minimize potential negative impacts on the environment, non-target organisms, and human health.

- Avoid dehydration; consumption of adequate amount of drinking water should be done before start of herbicidal spray.
- Label instructions on herbicides should be followed for application doses and water volume.
- Do not use expiry products.
- Flat fan nozzle type sprayer should be selected for herbicide spray.
- Herbicide spray should be done in calm weather (no wind) during noon time. Avoid spraying under cloudy and rainy season.
- Need to wear protective gears such as hat, gloves eye and foot wear to avoid herbicide injury.
- Apply pre-emergence herbicide

Table 2. Herbicide recommendations in maize for effective weed control

Herbicide name	Trade name	Dose (kg/g a.i.)	Application time
Atrazine 50% WP	Atrataf, Solaro	1.0-1.5 kg/ha	Pre-emergence at 1-2 DAS; broad spectrum herbicide but basically a broad-leaved killer, early post-emergence application within 2 weeks after emergence in maize
Pyroxasulfon 85% WG	Zidua (BASF)	127 g/ha	Pre-emergence at 1-2 DAS; broader spectrum of control of small-seeded broadleaf weeds and grasses
Pendimethalin 30% EC	Stomp	1.0-1.5 litres/ha	Pre-emergence at 1-2 DAS; broad spectrum but basically a grass killer herbicide
Atrazine + Pendimethalin		0.75 + 0.75 kg/ha	Pre-emergence at 1-2 DAS; tank mix application controls a broad spectrum of weeds
Topramezone 33.6% SC	Tynzer (BASF)	25 g/ha	25-30 DAS; post-emergence control of tough broadleaf weeds and grasses
Tembotrione 42% SC	Laudis (BAYER)	112 g/acre	25-30 DAS; broad spectrum post-emergence herbicide for control of broad leaf and grassy weeds
Halosulfuron methyl 75% WG	Sempre (Dhanuka)	36 g/acre	25-30 DAS; post-emergence control of sedges and other weeds
Mesotrione 2.27% + Atrazine 22.7% SC	Calarisextra (SYNGENTA)	1400 ml/acre	25-30 DAS; pre-mix herbicide application control grass weeds and broad leaf weeds



Fig. 3. Weed control by tembotrione spray in maize at 30 DAS.

- when there is sufficient moisture in the soil.
- Do not disturb the soil after herbicide application.
- If pulse crop is to be raised as intercrop, do not use Atrazine. Spray Pendimethalin @ 0.75 kg/ha as pre-emergence within 1-3 days after sowing in maize.

SUMMARY

The presence of weeds in maize crops leads to a substantial reduction in yield due to competition for essential growth resources.

Minimizing competition from weeds is paramount for achieving optimal crop yield. Integrated weed management practices need to be followed in an appropriate manner during critical period of crop-weed competition. Adoption of integrated weed management practices may reduce herbicide usage while focusing on sustainable cultivation methods for a more promising future.

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