Table 2. Herbicides recommended for maize cultivation in India.

Herbicides	Dose/ha		Dilution in water (liter/ha)
	a.i.	Formulation	
Atrazine 50% WP	0.5-1 kg	1-2 kg	500-700
2,4-D Dimethyl Amine salt 58% SL	0.5 kg	0.86 ml	400-500
2,4-D Ethyl Ester 38 % EC (having 2,4-D acid 34 % w/w)	0.9 kg	2.65 L	400-450
Halosulfuron Methyl 75% WG	67.5	90 ml	375
Paraquat dichloride 24% SL [pre-plant (minimum tillage) before sowing]	0.2-0.5 kg	0.8-2.0 L	500
Paraquat dichloride 24% SL (Post-emergence directed inter row application at 2-3 leaf stage of weeds)	0.2-0.5 kg	0.8-2.0 L	500
Pyroxasulfone 85% w/w WG	127.5 g	150 ml	500
Tembotrione 34.4% SC	120 g	286 ml	500
Topramezone 336 g/l w/v SC	25.2 to 33.6 g a.i./ha + MSO adjuvant @ 2 ml/L of water	75 to 100 ml + MSO adjuvant @ 2 ml/L of Water	375
Mesotrione 2.27% w/w + Atrazine 22.7% w/w SC	875 g	3500 ml	500

Advantages of CA

The CA provides various visible and non-visible benefits over conventionally filled agriculture (Fig. 4).

CA and crop productivity, resource efficiency and profitability in maize systems

- CA gives up to 31% higher net returns with Rs 4300/ha lower production cost compared to conventional agriculture in different maize based cropping systems.
- Zero tillage (ZT) gives maximum maize system productivity with reduced irrigation water requirement by 40–65 ha-mm in different maize based cropping systems.
- It improved soil physical and biological health.

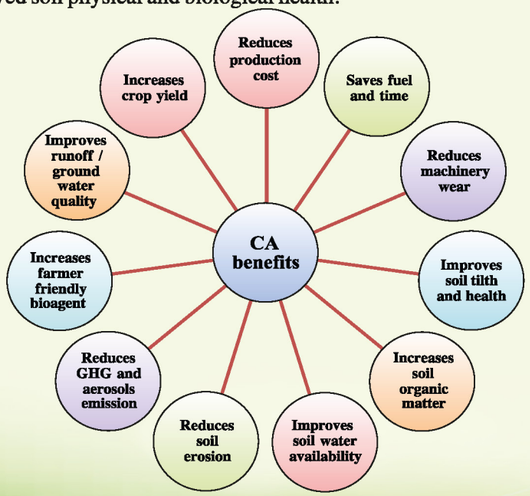

Fig. 4. Top 11 conservation agriculture benefits.

The major reasons behind yield gains in CA

Timely planting: Prohibition of primary and secondary tillage operation in CA advances crop planting by 15-20 days thus avoid heat/cold during reproductive stages and provide ideal growth environment throughout the crop life cycle.

Protection against abiotic stresses: Surface lying residues reduce soil moisture loss through evaporation and also enhance soil water holding capacity due to build up of organic carbon content. Hence, residue mulch extend the soil moisture availability and delay the occurrence of drought. CA in long run reduce soil hard pan and enhance water infiltertration rate and soil macro pores (biopores).

All these factors lead to drainage of excess water during heavy rainfall and protect the water logging sensitive crops from surface stagnant water. Residue mulch also protect the crop from heat stress. Presence of surface residue reduce canopy temperature because they maintain good soil moisture content that cause eavpo-transpiration cooling.

Soil health improvement: All the three components of CA improve soil physical, chemical and biological activities and provide ideal environment for root growth, water and nutrient extraction and other biological activities.

Table 3. Important do's and don'ts in CA

Farm operation	Do's	Don'ts
Land levelling and field layout	• Lesser area under furrow/bund/ channel. • Land should be levelled before going to CA. • More tilled soil should be sub-soiled to break hard pan.	• Undulating land surface
Tillage/mechanical manipulation	• Only for seeding and fertilizer placement by opening narrow slit.	• Opening
Crop establishment/ sowing	• By opening narrow slit for placing seed. • Covering of seed. • Closing of the opened furrow.	• The opening should not be
Residue application	• Anchored/standing residue for smooth seeding operations. • Spreading or uniform distribution of residue. • Atleast hard residue or any other part not used for animal and other competitive uses to be retain over surface.	• Residue removal Accumulation of residue at one place.
Weed management	• Herbicide based wed management. • Uprooting of hardy weeds. throughout season in initial year. • Prevention of seed setting. • Non-season weed control.	• No hand weeding with khurfi or by mechanical soil disturbance as this disturbance will bring more weed seed from below soil.

Compiled by: A.K. Singh, S.L. Jat, S.D. Bamboriya, D.M. Mahla, Seema Sepat, H.S. Jat

ICAR Indian Institute of Maize Research
Ludhiana, Punjab-141004, India
Fax: 91-161-2430038, Phone: +91-161-2440048, Email: director.maize@icar.gov.in

Conservation Agriculture in Maize Systems

A.K. Singh
S.L. Jat
S.D. Bamboriya
D.M. Mahala
Seema Sepat
H.S. Jat

ICAR - Indian Institute of Maize Research
Ludhiana-141004, Punjab

The soil sickness, fading organic carbon and decreasing input use efficiency are the major challenges for the sustainability of modern agriculture. It is further aggravated by the fast-changing climatic conditions having aberrant weather situation, which pose a serious threat to farming in the world and India in particular. The excessive tillage operation enhances the production cost and carbon oxidation and thus causes economic and soil health losses. The conservation agriculture (CA) based crop management practices are found effective for mitigating effects of climate change due to lesser greenhouse gas emissions compared to the conventional agriculture system. These practices also found effective for adaptation of the climate change effect due to favourable changes in soil health and microclimate modification.

In this scenario, if alternate cropping system like maize-wheat or rice-maize in newer ecologies and traditional maize based cropping like maize-mustard or maize-chickpea or maize-oat or maize alone practised with CA based best management practices could lead to overall sustainability with lesser environmental footprints and improved soil health. Therefore, in this folder we discussed about CA in maize systems for sustainability in traditional and newer ecologies.

Principles of CA

The CA is the set of practices based on three cardinal principles of minimal soil disturbance, retention of residue as soil cover and profitable sustainable crop rotation.

A. **Minimal mechanical soil disturbance:** The mechanical disturbance of the soil is completely avoided expect for sowing purposes and also sowing implement or process must open soil minimally.

B. **Permanent covering of sufficient organic matter over the soil surface:** The minimal 30% coverage of the residue over the soil surface gives natural environment in the agro-ecosystems.

C. **Profitable sustainable crop rotation:** Cropping sequences and rotations that include legumes are desirable for CA based system. Inclusion of the diversified crops is key for success of the CA as well.

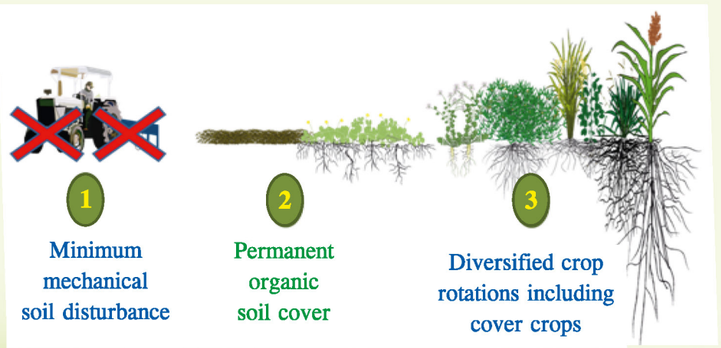

Fig. 1. Three basic principles of conservation agriculture.

CA in maize systems

Among different maize based cropping systems, maize-wheat ranks 1st and it is the 3rd most important cropping system after rice-wheat and rice-rice having 1.8 m ha area that contributes about 3% in the food grain production of India. Studies carried out at various soil and climate conditions under All India Coordinated Research Project on Cropping System revealed that compared to existing cropping systems, maize based cropping systems are better user of water and available resources at different locations. The research on CA in maize systems led to development of resource use efficient profitable cropping systems like maize-wheat-mungbean, maize-mustard –mungbean for IGP and other for various agro-ecologies (Table 1).

Table 1. The conservation agriculture based maize system for various agro-ecologies in India.

Agro-climatic region	Potential CA-based cropping system
Western Himalayan region	Maize-wheat
	Maize-oat
Eastern Himalayan region	Summer rice/maize-mustard
	Maize-maize-legumes
	Maize-french bean
	Maize-mustard
Lower Gangetic Plain region	Autumn rice-maize
	Jute-maize
Middle /Upper Gangetic Plain region	Maize-wheat-mungbean
Trans Gangetic Plain region	Maize-mustard-mungbean
	Maize-chickpea
Eastern plateau and hills region	Maize-wheat
	Maize-chickpea
Central plateau and hills region	Maize-wheat
	Maize-chickpea
Southern plateau and hills region	Rice-maize
	Maize-chickpea
East coast plain and hills region	Rice-maize-urdbean
West coast plain and hills region	Maize-pulses
	Rice-maize
Gujarat plains and hills region	Maize-wheat
	Maize-mustard
Western dry region	Maize-mustard
	Maize-chickpea
Island region	Rice-maize

Maize-wheat-mungbean: an efficient cropping system

- Advancing wheat planting
- Increased wheat duration
- Lesser water requirement to wheat
- Reduced terminal heat stress
- Enhanced wheat yield
- Timely planting of third crop of summer mungbean
- Increased mungbean yield
- Three crops with lesser water than rice

Maize-mustard-mungbean: More efficient MMM system

- Advancing mustard planting
- Increased mustard duration
- Reduced aphid infestation
- Enhanced mustard yield
- Timely planting of third crop of longer duration summer mungbean
- Increased mungbean yield
- Three crops with much lesser water than rice

Fig. 2. The conservation agriculture based maize systems

Cultivation practices in CA based maize systems

The adoption of the CA in maize systems needs focus on the following aspects of the cultivation:

Tillage and crop establishment: The adoption of the CA requires good seeding machinery and we have zero-till seed drill and happy seeders and their variation which suits for seeding of the most of crops in maize based cropping system. These machineries are also available for two wheel tractor. The hand operated machineries for small fields like star wheel seeders, punch planters, hand held corn planter are available. In very small fields, sticks may also be used for making whole for placing seed and fertilizer.

Fig. 3. (a) Hand seeding with stick, (b) Making marking by the tractor, (c) Star wheel planter and (d) Happy seeder.

Efficient weed management: The pre-emergence application of Atrazine followed by post emergence herbicide based weed management is available in maize (Table 2). Apply Tembotrione 42% SC @ 115 ml/acre or Topramezone 33.6% SC @ 30 g/acre or 2,4-D Amine 58% SL @ 350 ml/acre as post emergence herbicide at 20-35 days after sowing. There is good option available in maize for weed management.