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Non-chemical weed management in maize: An innovative way of weed management

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Abstract
Maize (*Zea mays* L.) called as queen of cereals is the third important cereal crops grown all over the for food and also as cattle and poultry feed. Weeds grow profusely in maize fields in early stages and reduce crop yields drastically. Normally yield loss between 15-30% and in severe cases the yield losses more than 50% is observed in maize. Weeds are one of the main constraints in the crop production and repeated use of synthetic herbicides in heavy doses causes environment pollution which decline in the soil health and increases the number of herbicide resistant weeds. To reduce the chemical effect during consumption and to minimize the weeds through natural way an experiment was carried out with randomized block design with 9 treatments and 3 replications during summer at Maize Research Station, Vagarai. The treatments were T_1- Mulching with maize stover (@ 5 tons ha^{-1}), T_2- Mulching with sugarcane trash (@ 5 tons ha^{-1}), T_3- Cowpea (1:1 additive series) and incorporation with power weeder on 25-30 DAS, T_4- Sunnhemp broadcasting and incorporation with power weeder on 25-30 DAS, T_5- Cowpea (1:1 additive series) as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS, T_6- Sunnhemp broadcasting as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS, T_7- Power weeder twice on 20 and 40 DAS, T_8- Hand weeding twice on 20 and 40 DAS and T_9- Weedy check. Based on the experimental results, higher grain yield and stover yield, lower weed flora, weed density and total dry matter of weed was observed in mulching with sugarcane trash (@ 5 tons ha^{-1}) (T_2) followed by hand weeding twice on 20 and 40 DAS (T_8). While, the lowest yield and higher weed flora, weed density and total dry matter of weed was recorded in weedy check (T_9). In the study it was concluded that the treatment of mulching with sugarcane trash was effective for the control of weeds in maize.

Keywords: Weeds, synthetic herbicide, resistance, yield, weed flora

1. Introduction
Maize scientifically known as *Zea mays L.* is ranked as the third most important food grain globally followed by rice and wheat. This holds true not only on a global scale but also within India. Maize is renowned for its remarkable genetic yield potential, often hailed as the "Miracle crop" and the "Queen of cereals." It serves as a fundamental source of nutrition for humans. It acts as essential livestock feed and serves as a primary raw material in numerous industrial applications. It contains ample quantities of starch (28% to 80%), protein (10-15%), fat (about 5-6%), fiber (9-15%) and a significant array of vitamins and minerals. (Klopfenstei *et al.*, 2013) [11].

In India, maize accounts for approximately nine percent of the overall cereal production volume as reported during the India Maize Summit in 2016. Its cultivation spans across 9.86 million hectares of land, resulting in a total production of 31.51 million tons with an average productivity of 3.19 tons per hectare. In Tamil Nadu, maize is cultivated in an area of 0.40 million hectares with production of 2.72 million tons with an average yield of 6820 kg ha^{-1}.

In the early stages of growth, weeds pose a significant challenge to maize crop by competing for essential resources such as light, space, water and nutrients. This competition adversely affects the efficiency of photosynthesis, production of dry matter and the distribution of food resources within the maize plant, resulting in potential yield losses of up to 35%. At the same time, the continuous use of the same group of herbicides over a period of time on a same piece of land leads to ecological imbalance in terms of weed shift, herbicide resistance in weeds which lead to environmental pollutions. (Gnanavel and Natarajan, 2014; [7] Therefore, evolving effective weed management practices is essential to increase the production and productivity of maize.

Controlling of weeds in maize during the critical period assumes greater importance for realizing higher yield. Weeds must be controlled during the initial 4-6 weeks period. After that the canopy develops thick enough to smother the weeds**.** Weed infestation also exerts negative impacts on economy and causes environmental and health issues in terrestrial ecosystems (Lee *et al.*, 2017) [13]. Maize crop has a specific critical period during which weed control is necessary to reduce yield losses (Nadeem *et al*., 2019) [14].

Mulching is an important technology widely used in orchards and agricultural system to conserve soil moisture and improve weed control in row crops. Furthermore, mulching is also aimed at reducing soil erosion. Mulching is an important technique to suppress weed flora and improve crop yield. However, the role of different mulches in suppressing weed flora and improving the productivity of maize has to be reported for nonchemical weed management strategies.

2. Material and Methods

The experimental study was conducted in Maize Research Station, Vagarai (Lattitude -10.57º N, Longitude 77.56º E and the altitude of 254.4 m above sea level) in summer season in randomized block design (RBD) for weed management in maize crop by non-chemical ways. The average temperature is 25 ºC with maximum temperature and minimum temperature of 34 ºC and 24 ºC respectively. The maximum relative humidity was 68% and wind speed was 9.85 km/hr. The variety used for the study is CoH(M) 6. The following parameters were studied *viz*., weed flora, total weed density, total dry matter of weed, grain yield and straw yield of maize The treatment details are given below.

Treatment	Details
T_1	Mulching with maize stover (@ 5 tons ha^{-1})
T_2	Mulching with sugarcane trash (@ 5 tons ha^{-1})
T_3	Cowpea (1:1 additive series) and incorporation with power weeder on 25-30 DAS
T_4	Sunnhemp broadcasting and incorporation with power weeder on 25-30 DAS
T_5	Cowpea (1:1 additive series) as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS
T_6	Sunnhemp broadcasting as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS
T_7	Power weeder twice on 20 and 40 DAS
T_8	Hand weeding twice on 20 and 40 DAS
T_9	Weedy check

3. Result and discussion

3.1. Weed flora

The predominant weed flora in experimental field consist four species of grasses, one species of sedge and seven species of broad-leaved weeds. *Chloris barbata*, *Cynodon dactylon*, *Dactyloctenium aegyptium*, *Dinebra reftroflexa* in grasses *Cyperus rotundus* in sedges and *Parthenium hysterophorus*, *Trianthema portulacastrum*, *Portulaca oleracea*, *Tridax procumbens*, *Phyllanthus niruri*, *Cleome viscosa*, *Acalypha indica* in broad leaved weeds (Table 1). Hussain *et al*. (2022) [9] conducted an experiment and studied the impact of different mulching treatments on the productivity and concluded that highest suppression of weed flora was found in plastic mulch (PLM) and paper mulch.

3.2. Total weed density and dry matter of weed

The lowest total density of weeds were recorded during 20, 40 and 60 DAS, in mulching with sugarcane trash (@ 5 tons ha^{-1}) (T_2) as 25.33 no. m^{-2}, 20.00 no. m^{-2} and 18.00 no. m^{-2} on 20 DAS, 40 DAS and 60 DAS respectively and the hand weeding twice on 20 and 40 DAS (T_8) was found to be the next best treatment, the total density of weeds on 20 DAS, 40 DAS and 60 DAS are as follows 74.67 no. m^{-2}, 20.67 no. m^{-2} and 11.67 no. m^{-2}. While weedy check (T_9) recorded the higher total weed density during 20,40 and 60 DAS, (76.33 no. m^{-2},100.00 no. m^{-2},72.67 no. m^{-2} respectively). The details of the total weed density was represented in Table 2.

In the application of mulching with sugarcane trash (@ 5 tons ha^{-1} - T_2) reduced total dry weight of the weeds as 12.47 g. m^{-2}, 9.65 g. m^{-2} and 9.85 g. m^{-2} on 20 DAS, 40 DAS and 60 DAS were observed respectively. The next best treatment was hand weeding twice on 20 and 40 DAS (T_8) and the total dry weight of weeds on 20 DAS, 40 DAS and 60 DAS, was 50.01 g. m^{-2}, 12.95 g. m^{-2} and 5.91 g. m^{-2} respectively. The highest total dry weight weeds of 55.53 g. m^{-2}, 72.92 g. m^{-2}, and 51.94 g. m^{-2} was recorded in weedy check(T_9) on 20,40 and 60 DAS. (Table 3).

Ali *et al*. (2011) [1] reported that effective weed management increased the yield of maize crop by reducing the competition for weed, water, sunlight and nutrient. (Astif *et al*., 2020; Javed *et al*., 2020) [2, 10] and the results showed that all mulching treatments significantly affected weed growth, soil carbon and yield components of maize. Maximum soil organic matter and carbon contents were observed in wheat straw mulch. Lowest weed density and dry weight was observed in manual hoeing, transparent mulch and rice straw mulch respectively. They suggested that application of wheat straw mulch not only increased yield and soil organic matter content but also improve yield of maize.

3.3. Weed control efficiency

Weed control efficiency (WCE) was calculated at various crop growth stages and found highly influenced by weed management practices. Mulching with sugarcane trash (@ 5 tons ha^{-1}) (T_2) recorded the highest weed control efficiency (68.81% and 80.00% respectively) at 20 DAS and 40 DAS. Among the different weed management treatments were imposed hand weeding twice on 20 and 40 DAS (T_8) resulted the highest weed control efficiency of 83.94% at 60 DAS. Among the various treatments second least weed control efficiency (28.89%) was notified in mulching with maize stover (@ 5 tons ha^{-1}) (T_1) at 60 DAS. These findings specify that hand weeding at 20 and 40 DAS had better control of weeds at all crop growth stages which resulted in weed free, better weed control efficiency, and a conducive environment for the growth and development of Maize crop. These results are in line with (Table 4).

Table 1: Weed flora in experimental field

S. No.	Botanical Name	Common Name	Life cycle	Family
A. Grasses				
1.	*Chloris barbata*	Purple top Chloris	Annual	Poaceae
2.	*Cynodon dactylon* (L.)	Bermuda grass	Annual	Poaceae
3.	*Dactyloctenium aegyptium* (L.).	Crowfoot grass	Annual	Poaceae
4.	*Dinebra reftroflexa*	Viper grass	Annual	Poaceae
B. Sedges				
5.	*Cyperus rotundus* L.	Nut sedge	Perannial	Cyperaceae
C. Broadleaved weeds				
6.	*Parthenium hysterophorus* L.	Congress weed	Annual	Asteraaceae
7.	*Trianthema portulacastrum* L.	Horsepurslane, Giant pigweed	Annual	Aizoaceae
8.	*Portulaca oleracea*	Indian purslane	Annual	Portulacaceae
9.	*Tridax procumbens*	Tridox	Annual	Asreraceae
10.	*Phyllanthus niruri* L.	Gale of the wind	Annual	Phyllanthaceae
11.	*Cleome viscosa* L.	Tick weed	Annual	Cleomaceae
12.	*Acalypha indica* L.	Indian nettle	Annual	Euphorbiaceae

Table 2: Effect of non-chemical weed management practices on total weed density (no. m^{-2})

Treatments	20DAS	40DAS	60DAS
T_1 - Mulching with maize stover (@ 5 tons ha^{-1})	4.42 (57.33)	4.88 (70.00)	4.21 (51.67)
T_2 - Mulching with sugarcane trash (@ 5 tons ha^{-1})	2.99 (25.33)	2.64 (20.00)	2.53 (18.00)
T_3 - Cowpea (1:1 additive series) and incorporation with power weeder on 25-30 DAS	3.81 (42.00)	3.65 (38.67)	3.81 (42.00)
T_4 - Sunnhemp broadcasting and incorporation with power weeder on 25-30 DAS	4.01 (47.00)	3.73 (40.67)	3.88 (43.67)
T_5 - Cowpea (1:1 additive series) as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS	3.70 (41.33)	2.43 (18.67)	2.84 (22.67)
T_6 - Sunnhemp broadcasting as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS	4.06 (48.00)	3.89 (44.00)	4.16 (50.67)
T_7- Power weeder twice on 20 and 40 DAS	4.95 (72.00)	3.82 (42.67)	3.34 (32.00)
T_8- Hand weeding twice on 20 and 40 DAS	5.03 (74.67)	2.71 (20.67)	2.08 (11.67)
T_9- Weedy check	5.09 (76.33)	5.80 (100.00)	4.96 (72.67)
Sed	0.30	0.30	0.22
CD(p=0.05)	0.65	0.65	0.47

Data in parentheses are$\sqrt{x}$+0.5transformed value DAS – Days After Sowing

Table 3: Effect of non- chemical weed management practices on total weed dry matter (g. m^{-2})

Treatments	20 DAS	40 DAS	60 DAS
T_1 - Mulching with maize stover (@ 5 tons ha^{-1})	3.57 (36.85)	3.97 (46.04)	3.40 (33.14)
T_2 - Mulching with sugarcane trash (@ 5 tons ha^{-1})	2.15 (12.47)	1.91 (9.65)	1.93 (9.85)
T_3 - Cowpea (1:1 additive series) and incorporation with power weeder on 25-30 DAS	3.01 (25.80)	2.82 (22.56)	3.14 (28.16)
T_4 - Sunnhemp broadcasting and incorporation with power weeder on 25-30 DAS	3.28 (31.03)	2.97 (25.31)	3.16 (28.56)
T_5 - Cowpea (1:1 additive series) as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS	3.10 (27.52)	2.14 (12.38)	2.17 (12.76)
T_6 - Sunnhemp broadcasting as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS	3.35 (32.38)	3.17 (28.71)	3.38 (32.77)
T_7- Power weeder twice on 20 and 40 DAS	4.20 (51.83)	3.15 (28.64)	2.68 (20.13)
T_8- Hand weeding twice on 20 and 40 DAS	4.14 (50.01)	2.09 (12.55)	1.56 (5.91)
T_9- Weedy check	4.28 (53.53)	4.98 (72.92)	4.21 n(51.94)
Sed	0.23	0.24	0.17
CD(p=0.05)	0.50	0.51	0.37

Data in parentheses are$\sqrt{x}$+0.5transformed value DAS-Days After Sowing

Table 4: Effect of non-chemical weed management practices on weed control efficiency

Treatments	WCE		
	20 DAS	40 DAS	60 DAS
T_1 - Mulching with maize stover (@ 5 tons ha^{-1})	24.89	30.00	28.89
T_2 - Mulching with sugarcane trash (@ 5 tons ha^{-1})	66.81	80.00	75.23
T_3 - Cowpea (1:1 additive series) and incorporation with power weeder on 25-30 DAS	44.98	61.33	42.20
T_4 - Sunnhemp broadcasting and incorporation with power weeder on 25-30 DAS	38.43	59.33	39.90
T_5 - Cowpea (1:1 additive series) as brown manuring through targeted application of ITK-based herbicide on 25-30 DAS	45.85	81.33	68.80
T_6 - Sunnhemp broadcasting as brown manuring through targeted application of ITK-based herbicide on	37.12	56.00	30.27

25-30 DAS			
T_7 - Power weeder twice on 20 and 40 DAS	5.67	57.33	55.96
T_8 - Hand weeding twice on 20 and 40 DAS	2.18	79.33	83.94
T_9 - Weedy check	-	-	-

DAS – Days After Sowing

4. Conclusion

Weeds due to their rapid growth, wider adaptability and survivability, dominate the crop growth and establishment. Although chemical weed control is vital tool for cost effective weed there are certain drawbacks in using synthetic chemicals as herbicides. Synthetic herbicide use is coming under closer examination as a result of public concern about food safety, negative environmental effects and herbicide resistance. The experimental result concluded that weed management in maize can be done by non-chemical method in economic way. The study concluded that eco-friendly weed management practice of mulching with sugarcane trash @ 5 tonnes per hectare was found to be economic in the control of weeds.

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Conflict of interest

The authors declare no conflict of interest.

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