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Post Emergence Application of Non-chemical Formulations on Yield and Economics in Irrigated Maize

Arunjith P* and P. Murali Arthanari
Department of Agronomy,
Tamil Nadu Agricultural University,
Coimbatore - 641 003, Tamil Nadu, India

Field experiment was conducted during *Kharif* 2017 at Tamil Nadu Agricultural University to assess the impact of post emergence application of non-chemical formulations on yield and economics in maize. Lower density and dry weight of all the three types of weeds *viz*., grasses, sedges and broad leaved weeds were recorded at 20 DAS in plots treated with vinegar 20%, followed by traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*). At later stage of observation hand weeding twice on 20 and 45 DAS recorded lower density and dry weight due to efficient removal of weeds manually. Among different non-chemical formulations higher grain and stover yield, net return and B: C ratio were obtained in post emergence application of vinegar 20% + hand weeding on 45 DAS followed by early post emergence application of traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS.

Key words: Weed flora, Weed dry weight, Maize, Non-chemical weed management, Grain yield, Net return

Maize (*Zea mays* L.) is a cereal grain having wider adaptability to varied agro-ecological condition. It is known as the "queen of cereals" due to its high yielding potential. But, normally its full yield potential is not achieved due to several reasons. Weeds are among them which reduce the crop yield drastically. Weed flora and weed density are two among the factors which decides the extent of yield loss due to weed infestation (Maqsood *et al*., 1999). Higher weed density and dry weight which occasioned competition of resources and finally results in lower grain yield (Takim, 2012). Weeds begin to germinate even after germination of maize due to incessant rains in *Kharif* season. Post emergence application of herbicides and mechanical way of controlling these weeds would cause adverse environmental effects when comes to their intensive use. Directed applications of non-chemical formulations are a possible way for controlling these unwanted plants which will also reduce the dependence on synthetic herbicides and their associated ecological impact. Care should be taken while spraying these non-chemical formulations due to their non-selective nature. Post emergence application of naturally occurring compounds and plant derived inputs having controlling effect are to be exploited. These will supress the weeds instead of their complete eradication. There are earlier reports of weed control using common salt (Tabin and Singh, 2008), vinegar (Ivany, 2010) as post emergent spray. Weed suppressing prospective by limonene, a volatile monoterpene (Vaid, 2015) in lemon and allelochemicals in *Terminalia chebula* (Manikandan and Rejula, 2008) are already conveyed by different workers. The present investigation aims at to assess the effect of post emergence application of non-chemical formulations on yield and economics in maize.

*Corresponding author's email: arunjithp0077@gmail.com

Material and Methods

The present study was conducted using maize hybrid COH (M) 6 at Eastern Block Farm, Department Farm Management, Tamil Nadu Agricultural University during *Kharif* 2017. The farm is located in Western Agro climatic zone of Tamil Nadu (11ºN latitude and 77ºE longitude) and 426.7 m above MSL. The experiment was laid in randomized block design with ten treatments and three replications. Spraying (early post emergence and post emergence) of non-chemical formulations as well as spraying followed by hand weeding was included in the treatments. Early post emergence (EPOE) applications were done at 2-6 leaf stage of weeds (15th day of sowing) and post emergence (POE) at 20th day of sowing using knapsack sprayer fitted with deflector type nozzle and hood to avoid direct contact of the spray fluid with crop plants (protected spray). The treatments consisted of EPOE 30% common salt (T_1), EPOE 30% common salt + hand weeding on 45 DAS (T2), POE vinegar 20% (T_3), POE vinegar 20% + hand weeding on 45 DAS (T_4), EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) (T_5), EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS (T6), EPOE traditional formulation @ 7.5 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) (T_7), EPOE traditional formulation @ 7.5 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS (T_8), hand weeding twice on 20 and 45 DAS (T_9) and weedy check (T_{10}). Traditional formulation was prepared by mixing 3 kg finely

grounded powder of dried fruits of *Terminalia chebula,* juice of ten numbers of lemon fruit in 10 litre of one month old cow urine. This was kept for 15 days under shade after covering with gunny bag. Regular stirring was also done. Before spraying the formulation was sieved using a muslin cloth.

Data on weed density was estimated by using quadrat of size 0.5 m × 0.5 m in four places at random. The weed species were counted, pulled out and separated into grasses, sedges and broad leaved weeds and expressed as No. m^{-2}. The samples were air dried and then oven dried at 80ºC to attain a constant dry weight. Dry matter of weeds was expressed as g m^{-2}. The weed data were analysed after subjecting the original data to square root transformation (√X+0.5). The cobs harvested from net plot area of each treatment plot were sun dried, threshed, cleaned and grain yield was recorded at a moisture level of 14%. Stover yield was recorded from net plot area after the harvest of cobs by cutting close to ground level and leaving in the field for three days for sun drying. Both grain and stover yield were expressed in kg ha^{-1}. Net return (₹ ha^{-1}) and benefit-cost ratio (B: C ratio) were worked out based on total variable cost and returns.

Results and Discussion

Weed flora

The experimental site was infested with grasses (*Rottboellia cochinchinensis*, *Dactyloctenium aegyptium*, *Dinebra retroflexa*) followed by broad leaved weeds (*Digera arvensis*, *Corchorus olitorius*, *Trianthema portulacastrum*, *Acalypha lanceolata*) and sedges (*Cyperus rotundus*).

Table 1. Effect of post emergence application of non-chemical formulations on weed density (No. m^{-2}) at 20 DAS in maize

	Treatments	Grass	Sedge	BLW	Total
T_1	EPOE 30% common salt	8.82 (77.32)	1.58 (2.00)	6.58 (42.78)	11.07 (122.10)
T_2	EPOE 30% common salt + HW on 45 DAS	8.74 (75.99)	1.58 (2.00)	6.51 (41.95)	10.97 (119.94)
T_3	POE vinegar 20%	6.26 (38.67)	0.88 (0.33)	4.17 (16.89)	7.51 (55.89)
T_4	POE vinegar 20% + HW on 45 DAS	6.42 (40.67)	0.88 (0.33)	3.97 (15.33)	7.54 (56.33)
T_5	EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon + *T. chebula*)	7.76 (59.67)	1.22 (1.00)	5.95 (35.01)	9.81 (95.68)
T_6	EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon + *T. chebula*) + HW on 45 DAS	7.90 (62)	1.22 (1.00)	6.01 (35.67)	9.96 (98.67)
T_7	EPOE traditional formulation @ 7.5 l ha^{-1} (Cow urine + Lemon + *T. chebula*)	9.00 (80.77)	1.58 (2.00)	6.63 (43.57)	11.25 (126.34)
T_8	EPOE traditional formulation @ 7.5 l ha^{-1} (Cow urine + Lemon + *T. chebula*) + HW on 45 DAS	9.10 (82.40)	1.58 (2.00)	6.68 (44.31)	11.36 (128.71)
T_9	HW twice on 20 and 45 DAS	9.63 (92.33)	1.87 (3.00)	7.15 (50.67)	12.10 (146.00)
T_{10}	Weedy check	9.72 (94.00)	1.87 (3.00)	7.25 (52)	12.23 (149.00)
SEd		0.21	0.11	0.20	0.23
CD (0.05)		0.45	0.23	0.43	0.49

Figures in parenthesis are mean of original values; Data subjected to square root transformation

EPOE: Early post emergence application POE: Post emergence application DAS: Days after sowing HW: Hand weeding

Weed density

Traditional weed management methods had significant influence on weed flora and weed density at 20 and 45 DAS (Table 1 and Fig. 1).

Adoption of different traditional weed management methods had resulted in reduction of total weed density ranging from 2.01% to 62.48% at 20 DAS. Significantly lower and comparable density of weed morphological types (grasses, sedges and broad leaved weeds) and total weed density were observed in POE vinegar 20% and POE vinegar 20% + hand weeding on 45 DAS. Readily killing of weeds due to directed and contact application of vinegar caused reduction in weed density. This corroborates the results of Radhakrishnan *et al*. (2002). Post emergence application of vinegar 20% showed more reduction in density of broad leaved weeds (67.51% in T_3 and 70.51% in T_4) compared to grass weeds (58.86% in T_3 and 56.73% in T_4). Similar finding of more effectiveness in controlling broad leaved weeds due to vinegar application was also reported by Webber and Shrefler (2007).

This was followed by EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) and EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS which were on par with each other. The probable reason would be the seedling inhibition by allelochemicals especially phenolic acids present in the *Terminalia chebula* (Manikandan and

Rejula, 2008). Hand weeding twice and weedy check recorded higher and comparable density of all the weed morphological types and total weed density.

Range of decline in weed density was more at 45 DAS compared to observation made at 20 DAS. Hand weeding twice on 20 and 45 DAS conspicuously reduced the weed density at 45 DAS due to efficient removal of weeds manually (Fig. 1). Next lower density of weeds were noted in POE vinegar 20% + hand weeding on 45 DAS and POE vinegar 20% which were statistically on par with each other. Increase in density might be attributed to negligible residual activity of vinegar (Evans *et al*., 2009). Nevertheless to say higher density of weeds were noticed in weedy check due to undisturbed nature similar to the findings of Das *et al*. (2016).

Table 2. Effect of post emergence application of non-chemical formulations on weed dry weight (g m^{-2}) at 20 DAS in maize

	Treatments	Grass	Sedge	BLW	Total
T_1	EPOE 30% common salt	4.75 (22.16)	1.36 (1.34)	2.57 (6.15)	5.49 (29.65)
T_2	EPOE 30% common salt + HW on 45 DAS	4.74 (21.98)	1.36 (1.35)	2.51 (5.85)	5.45 (29.17)
T_3	POE vinegar 20%	1.91 (3.15)	0.82 (0.19)	1.45 (1.60)	2.33 (4.94)
T_4	POE vinegar 20% + HW on 45 DAS	1.87 (3.01)	0.81 (0.18)	1.45 (1.61)	2.30 (4.80)
T_5	EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon + *T. chebula*)	3.96 (15.30)	1.01 (0.52)	2.05 (3.74)	4.46 (19.56)
T_6	EPOE traditional formulation @ 10 l ha-1 (Cow urine + Lemon + *T. chebula*) + HW on 45 DAS	3.97 (15.43)	0.99 (0.49)	2.07 (3.82)	4.49 (19.74)
T_7	EPOE traditional formulation @ 7.5 l ha-1 (Cow urine + Lemon + *T. chebula*)	4.78 (22.35)	1.37 (1.37)	2.41 (5.30)	5.43 (29.02)
T_8	EPOE traditional formulation @ 7.5 l ha-1 (Cow urine + Lemon + *T. chebula*) + HW on 45 DAS	4.78 (22.42)	1.36 (1.35)	2.41 (5.33)	5.44 (29.10)
T_9	HW twice on 20 and 45 DAS	5.71 (32.17)	1.59 (2.02)	2.90 (7.90)	6.52 (42.09)
T_{10}	Weedy check	5.76 (32.72)	1.61 (2.10)	2.88 (7.94)	6.58 (42.76)
SEd		0.21	0.07	0.11	0.20
CD (0.05)		0.45	0.14	0.24	0.41

Figures in parenthesis are mean of original values; Data subjected to square root transformation

EPOE: Early post emergence application POE: Post emergence application DAS: Days after sowing HW: Hand weeding

Weed dry weight

The influence of post emergence application of non-chemical formulations was clearly observed on weed dry weight (Table 2). Weed dry weight was significantly reduced by more than 88 per cent under POE vinegar 20% + hand weeding on 45 DAS and POE vinegar 20% which were on par with each other at early stages of observation. This Superiority of vinegar 20% in controlling weeds has also been documented Curran *et al*. (2004). Cellular damage with lysis of cellular content might have caused reduction in dry weight of weeds as pointed by Evans *et al*. (2009). EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) and EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS were comparable for weed dry weight next to vinegar applied plots. Seedling inhibition of weeds by reduction in plumule and radicle length due to the presence of allelochemical principles in *Terminalia chebula* might be the probable reason for drop in dry weight.

At later stages of observation (45 DAS) substantially lower dry weight of grasses, sedges, broad leaved weeds and hence the total dry weight were observed in hand weeding twice on 20 and 45 DAS because of preventing the generation of second flush of weeds. The total dry weight was only 26.33 g m^{-2} in plots hand weeded twice on 20 and 45 DAS compared to 442.07 g m^{-2} which was observed in weed check (Fig. 1). Next lower and comparable dry weight was observed with POE vinegar 20% + hand weeding on 45 DAS and POE vinegar 20%. The regrowth and new emergence of weeds might be the probable reason for increased dry weight in these plots applied with 20% vinegar as post emergence (Evans and Bellinder, 2009). Moderate dry weight was observed in EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) and EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS which were at par with each other. Considerably higher dry weight was observed in weedy check due to uncontrolled weed growth.

Yield

Hand weeding twice on 20 and 45 DAS and POE vinegar 20% + hand weeding on 45 DAS recorded significantly higher grain (7315 and 7214 kg ha^{-1}) and stover yield (10694 and 10403 kg ha^{-1}) which were comparable with each other (Table 3). This is in accordance with the findings of Evans and Bellinder (2009). Next best treatment in recording grain and

stover yield was EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS. This was the result of efficient weed control achieved with these weed management treatments due to the inhibitory effect of allelochemicals present in *Terminalia chebula*. The favourable condition created through the efficient weed management resulted in lesser weed competition between crop and weeds during the early stage of crop growth through reduced weed density and weed dry weight. The lower grain yield was noticed in weedy check due to high weed density and dry matter and severe crop weed competition resulting in poor source and sink development and poor yield components in the crop. These results were in conformity with the conclusion of Kurre *et al.*(2017).

Table 3. Effect of post emergence application of non-chemical formulations on yield and economics of maize

	Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Net return (₹ ha^{-1})*	B: C ratio*
T_1	EPOE 30% common salt	4202	6756	14590	1.28
T_2	EPOE 30% common salt + HW on 45 DAS	4940	7664	19309	1.33
T_3	POE vinegar 20%	5712	8608	36416	1.68
T_4	POE vinegar 20% + HW on 45 DAS	7214	10403	54738	1.93
T_5	EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon + *T. chebula*)	4224	6766	16945	1.34
T_6	EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon + *T. chebula*) + HW on 45 DAS	6546	9509	48057	1.88
T_7	EPOE traditional formulation @ 7.5 l ha^{-1} (Cow urine + Lemon + *T. chebula*)	4167	6737	16133	1.32
T_8	EPOE traditional formulation @ 7.5 l ha^{-1} (Cow urine + Lemon + *T. chebula*) + HW on 45 DAS	4986	7718	22108	1.39
T_9	HW twice on 20 and 45 DAS	7315	10694	46119	1.67
T_{10}	Weedy check	3415	5844	5594	1.12
SEd		302	401	-	-
CD (0.05)		635	842	-	-

EPOE: Early post emergence application POE: Post emergence application DAS: Days after sowing HW: Hand weeding *Data statistically not analysed

Economics

The field experiment indicated that maximum of net return (₹ 54738 ha^{-1}) and B: C ratio (1.93) were obtained in POE vinegar 20% + hand weeding on 45 DAS followed by EPOE traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) + hand weeding on 45 DAS. This might be due to increased grain yield and lower cost of cultivation. The B: C ratio was less in hand weeding twice on 20 and 45 DAS due to more labour cost involved in hand weeding. These were in accordance with the reports of Barla *et al.* (2016).

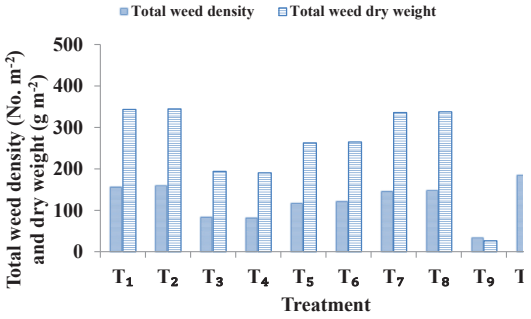

Fig. 1. Effect of post emergence application of non-chemical formulations on total weed density (No. m^{-2}) and dry weight (g m^{-2}) at 45 DAS

It can be concluded that post emergence application of vinegar 20% or early post emergence application of traditional formulation @ 10 l ha^{-1} (Cow urine + Lemon fruit + *Terminalia chebula*) along with hand weeding on 45 DAS were very effective for the control of broad spectrum of weeds and increased grain yield and economics of maize

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