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RESEARCH NOTE

Weed management with pre- and post-emergence herbicide in rainfed pearl millet under conservation agriculture

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ABSTRACT

In order to assess the impact of various tillage and weed management practices on the weed dynamics and productivity of rainfed pearl millet [*Pennisetum glaucum* (L.) R. Br] under conservation agriculture, an experiment was carried out in 2019–20 at ICAR–IARI, New Delhi. Adoption of zero tillage + barley residue retention 3 t/ha (ZT + R) increased the pearl millet grain yield by 9.17 and 13.3%, respectively over the zero tillage (ZT) and conventional tillage (CT). At 60 days after sowing (DAS), hand weeding (HW) had the highest weed control efficiency (78.3%). Pre-emergence application (PE) of atrazine 0.75 kg/ha *fb* post-emergence application (PoE) of 2,4-D 0.75 kg/ha was the next successful treatments (77.5%). With HW twice at 30 and 50 DAS, grain yield was considerably higher (2.53 t/ha), and atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75 kg/ha PoE recorded next highest yield (2.42 t/ha). Atrazine 0.75kg/ha PE *fb* 2,4-D 0.75 kg/ha PoE recorded significantly greater net returns (₹ 29201) and B:C (1.08).

Keywords: Barley residue, Herbicides, Pearl millet, Weed management, Zero tillage

Next to maize, rice, wheat, barley, and sorghum, pearl millet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz] is the sixth most significant cereal staple food crop in the world. As it is grown on 6.93 million hectares and contributes to 8.61 million tons of grain production with a productivity of 1.243 t/ha, India is the world's greatest producer of pearl millet (Directorate of Millets Development 2020). However, compared to its potential (3 t/ha), pearl millet yield in India is low (1.2 t/ha). Low yield is a result of a number of factors, including its growth in rainfed conditions combined with low fertility soils, the high prevalence of disease, severe weed infestation, and inadequate water management. One of the most important problems restricting the productivity of pearl millet is weed infestation. Weeds can deplete nutrients in Pearl millet up to 61.8 kg N, 5.6 kg P, and 57.6 kg K/ha (Ram *et al.* 2005). A key factor in reducing weed infestation is the use of various conservation agriculture (CA) practices under rainfed situations, as they aid in capturing and retaining moisture and so increases yield. Additionally, due to residue's ability to control weeds and the retention of residue under zero tillage, a greater visual negative effect on weeds may be seen. Weed infestation, on the other hand, is one of the main provocations in the early years of CA since it significantly reduces farm profitability and growth. Since weed ecology differs from that of conventional tillage, managing weeds is a difficult challenge in no-tillage farming. Under no-tillage, weed seeds are no longer dispersed throughout the soil profile but instead tend to gather on the soil surface, and weed communities gradually alter, especially in favour of perennial species (Streit *et al.* 2002). To achieve successful weed control in the pearl millet crops under these conditions, effective and affordable weed management practices are crucial. The goal of the current experiment was to assess the effect of different weed management and tillage practices on the performance of pearl millet in rainfed circumstances.

A field study was conducted at ICAR-IARI, New Delhi, India located at 28º 38' N, 77º 10' E, 228.6 m above the mean sea-level during the *Kharif* 2019 using split-plot design with three replications. The soil of the experimental field was sandy loam texture with 7.5 pH. During the crop duration (July-October), the mean minimum, maximum temperature, relative humidity, and total rainfall ranged from 31.0-36.5 ºC, 21.8-28.0 ºC, 33-98%, 780 mm. Main plot treatments consisted of three tillage practices: conventional tillage (CT), zero tillage (ZT), zero tillage with residue 3 t/ha (ZT + R) and sub-plots

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received seven weed management practices: weedy check(WC), hand weeding (HW) twice at 30 and 50 days after sowing (DAS), pre-emergence application (PE) of atrazine 0.75 kg/ha followed by (*fb*) post-emergence application (PoE) of 2,4-D 0.75 kg/ha at 30 DAS, atrazine 0.75 kg/ha PE, atrazine 0.75 kg/ha PE *fb* tembotrione 0.05 kg/ha PoE at 30 DAS, atrazine 0.75 kg/ha PE *fb* tembotrione 0.075 kg/ha PoE at 30 DAS, atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE at 30 DAS. For zero tillage + residue (ZT+R) treatment, the barley crop residue from the previous season was scattered 3 t/ha after sowing creating a residue cover thickness of 3-5 cm. Pearl millet (Pusa composite-443) was sown at the seed rate of 5 kg/ha at a spacing of 50 cm × 10 cm on 16th July 2019 in ZT and CT plots. Full dose of P_2O_5 (40 kg/ha), K_2O (40 kg/ha) and half dose of N (30 kg/ha) was applied as basal at the time of sowing. Remaining N (30 kg/ha) was applied in two equal splits at 25 and 50 DAS. Pre-emergence application of atrazine was done within 24 hours of sowing and post-emergence herbicides 2,4-D and tembotrione at 30 DAS. First hand weeding was done manually at 30 DAS in the respective plots of the treatments and the second HW was done at 50 DAS. Weed density and biomass (dry matter accumulation) was recorded at 60 DAS by using a quadrat of 0.5 x 0.5 m (0.25 m^2) size from the center of the plot. The entire weeds inside the quadrat were uprooted and cut close to the transition of root and shoot in each plot and collected for weed biomass. The samples were first dried in sun and then kept in an oven at 70 ± 2°C. The dried samples were weighed and expressed as biomass (g/m^2). The weed index (WI) and weed-control efficiency (WCE) were calculated by using formulae as suggested by Gill and Vijayakumar (1969), and Mani *et al.* (1973). Data on yield and economics were statistically analyzed as per the standard procedures.

Effect on weeds

The main weed species in the weedy check included *Dactyloctenium aegyptium* (21.9%), *Echinochloa colona* (18.1%) among grasses, *Trianthema portulacastrum* (17.9%) and *Commelina benghalensis* (16.7%) among broad-leaved weeds, as well as *Cyperus rotundus* (25.4%), a sedge (**Table 1**).

At 60 DAS, tillage and weed management practices resulted in significant changes in overall weed density and weed biomass. Zero tillage + residue (ZT+R) 3 t/ha produced the lowest density for all weed species at 60 DAS when compared to conventional tillage (CT) and zero tillage (ZT) (**Table 1**). The density of grassy weeds like *Dactyloctenium aegyptium* and *Echinochloa colona* was reduced by 28.9% and 22.5%, respectively, in response to the ZT+R treatment. Additionally, *Commelina benghalensis* and *Trianthema portulacastrum,* two broad-leaved weeds, had lower density compared to CT plots by 55.9% and 34%, respectively. The proportion of broad-leaved weeds was lower in ZT+R compared to ZT and CT. The most common sedge, *Cyperus rotundus*, saw a 32% reduction in ZT+R when compared to other tillage practices. Due to the prevention or lack of light provided by the residue layer on the soil surface, the reduction in weed density was attributed to weed suppression beginning with the early growth stage. Furthermore, strong allelopathic activity from barley residue by the release of phenolic compounds and alkaloids (hordenine, gramine) added to the effective reduction in weed density (Zinia *et al.* 2020). The lowest weed density was produced by hand weeding at 30 and 50

Table 1. Effect of weed management treatments on weed density at 60 DAS on CA-based pearl millet

Treatment	Weed density at 60 DAS (no./m^2)				
	Dactyloctenium aegyptium	*Echinochloa colona*	*Commelina benghalensis*	*Trianthema portulacastrum*	*Cyperus rotundus*
Tillage practice					
Conventional tillage	17.6	13.3	17.7	15.0	18.6
Zero tillage	12.9	11.7	11.6	12.4	15.3
Zero tillage + residue 3 t/ha	12.5	10.3	7.8	9.9	12.6
LSD (p=0.05)	1.44	0.69	1.58	1.86	1.46
Weed management					
Weedy check	37.6	30.97	28.6	30.6	43.4
Hand weeding at 30 and 50 DAS	7.2	4.83	6.4	7.0	8.13
Atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75kg/ha PoE	8.9	7.70	7.9	7.7	9.4
Atrazine 0.75 kg/ha PE	18.5	15.69	19.5	16.8	19.6
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.05 kg/ha PoE	9.4	7.81	8.2	8.9	9.5
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.075 kg/ha PoE	9.7	7.74	8.0	8.1	9.3
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE	8.9	7.60	7.7	7.7	9.1
LSD (p=0.05)	2.4	1.23	2.22	2.07	2.13

DAS: Days after sowing; PE: Pre-emergence; PoE: Post-emergence; *fb*= Followed by

DAS among the weed management practices (**Table 1**). This was made possible by hand weeding at 50 DAS, which allowed for the lowest weed infestation to be recorded at 60 DAS. In comparison to weedy check, the density of grassy weeds such *Dactyloctenium aegyptium* and *Echinochloa colona* was decreased by 80.9% and 84.5%, respectively. In comparison to weedy check treatment, the density of broad-leaved weeds *Commelina benghalensis* and *Trianthema portulacastrum* was decreased by 77.6% and 77.1%, respectively, and the density of the sedge *Cyperus rotundus* was decreased by 81.3%. Atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE and atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75 kg/ha PoE were the next-best treatments for lowering weed density at 60 DAS.

The biomass of grassy weeds like *Dactyloctenium aegyptium* and *Echinochloa colona* was considerably lower in the ZT+R 3t/ha plot than in the ZT and CT plots. Comparing ZT+R to the other tillage methods, *Commelina benghalensis* and *Trianthema portulacastrum* biomass decreased by 21.4% and 20.4%, respectively. For *Cyperus rotundus* biomass, a similar trend was also noted (**Table 2**). Hand weeding at 30 and 50 DAS recorded the lowest biomass of *Dactyloctenium aegyptium* and *Echinochloa colona*, followed by atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE and atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75 kg/ha PoE. *Commelina benghalensis*, *Trianthema portulacastrum* and *Cyperus rotundus* biomass was reduced effectively and equally by these treatments (**Table 2**). The decreased weed biomass and density may be attributable to the broad spectrum weed control attained by using herbicides at several stages of the crop's growth, including pre-emergence and post-emergence. Atrazine 0.75 kg/ha PE efficiently reduced weeds in the early stages, and 2,4-D 0.75 kg/ha or tembotrione 0.10 kg/ha PoE effectively controlled the weeds during the later stages. The efficacy of integration of pre- and post-emergence spraying in reducing weed density and biomass was reported earlier (Guggari and Mallappa 2017, Mishra *et al.* 2017).

The highest weed control efficiency (WCE) of 67.2% was achieved by zero tillage + residue (ZT+R) 3 t/ha, which was followed by zero tillage (61.3%) at 60 DAS (**Table 3**).Weed biomass indicated weed control treatments effectiveness. High weed control effectiveness with ZT + R 3 t/ha may be attributable to the lack of weed seed germination-friendly settings due to minimal soil disturbance and light interference from residue, as well as the depletion of weed seed through seed predation (Mirsky *et al.* 2010 and Kumar *et al.* 2013). Two hand weeding at 30 and 50 DAS was found to be the most effective weed management treatment, with a WCE of 78.3%. The next two most effective treatments were atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75 kg/ha PoE and atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE, with WCEs of 77.5 and 77.3%, respectively (**Table 3**). The broad-spectrum action and increased phytotoxic effects of pre- and post-emergence herbicides resulted in the higher WCE. Tembotrione caused complete chlorosis of all weeds, including grasses, sedges, and broad-leaved weeds. Weeds subsequently wilted and perished.

Zero tillage + residue 3 t/ha reported the lowest weed index (10.5%) based on weed biomass at 60 DAS, which was much lower than conventional tillage (19.9%). But no discernible difference between the weed index measured with that zero tillage +

Table 2. Effect of weed management treatments on weed biomass at 60 DAS on CA-based pearl millet

Treatment	Weed biomass at 60 DAS (g/m^2)				
	Dactyloctenium aegyptium	*Echinochloa colona*	*Commelina benghalensis*	*Trianthema portulacastrum*	*Cyperus rotundus*
Tillage practice					
Conventional tillage	9.2	33.0	8.4	6.4	18.6
Zero tillage	8.3	30.8	7.2	5.8	15.3
Zero tillage + residue 3 t/ha	7.8	29.6	6.6	5.1	12.6
LSD (p=0.05)	0.7	1.7	0.4	0.8	1.5
Weed management					
Weedy check	18.9	80.6	15.0	8.6	43.4
Hand weeding at 30 and 50 DAS	3.2	8.5	3.1	3.2	8.1
Atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75kg/ha PoE	5.1	17.2	5.9	5.1	9.4
Atrazine 0.75 kg/ha PE	10.7	57.4	8.7	7.7	19.6
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.05 kg/ha PoE	7.2	18.3	6.6	5.3	9.5
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.075 kg/ha PoE	7.0	18.0	6.3	5.2	9.3
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE	6.9	17.4	6.2	5.1	9.1
LSD (p=0.05)	1.0	2.2	0.6	1.1	2.1

DAS: Days after sowing; PE: Pre-emergence; PoE: Post-emergence; *fb*= Followed by

residue 3 t/ha and zero tillage were found. (**Table 3**). This was as a result of the application of barley crop residues under zero tillage, which creates a physical barrier with a residue thickness of 3-5 cm on the soil surface for light transmission and reduces crop weed competition, allowing the crop to better utilize the available resources, leading to higher crop yield and lower weed index. With atrazine at 0.75 kg/ha PE *fb* 2,4-D 0.75 kg/ha PoE, the lowest weed index was recorded among the weed management treatments, with a weed index of 4.3% as opposed to the highest of 33.4% seen under weedy check (**Table 3**) confirming Munde *et al.* (2012) and Das *et al.* (2013) in pearl millet.

Effect on grain yield

Compared to CT (2.08 t/ha) and ZT (2.18 t/ha), ZT+R produced a grain yield (2.40 t/ha) which was significantly higher (**Table 3**). Retaining barley residues had a synergistic impact on crop growth and yield characteristics, leading to a significantly larger grain production when compared to other practices. Reduced weed competition, improved and maintained soil moisture, control of soil temperature, and an increase in organic matter nutrients were all factors that contributed to an improvement in grain production with zero tillage + residue (Parameswari 2013). The best weed management treatment in terms of grain yield was hand weeding at 30 and 50 DAS, followed by atrazine 0.75 kg/ha (PE) *fb* 2,4-D 0.75 kg/ha (PoE) and atrazine 0.75 kg/ha (PE) *fb* tembotrione 0.075 or tembotrione 0.10 kg/ha (PoE) (**Table 3**). According to Sharma *et al.* (2018), applying tembotrione and atrazine together was significantly better than doing so separately because it resulted in significantly lower weed densities, dry weights, and weed index, higher weed control efficacy, and higher values for crop growth, yield attributes, and yield. The increase of the grain yield with HW twice at 30 and 50 DAS and a combination of pre- and post-emergence application of herbicides was due to effective control of broad-spectrum weeds, which is of prime importance to achieve a higher yield of pearl millet in rainfed conditions.

Economics

Due to the increased tillage intensity under the CT system, the cost of cultivation in CT ($32.3 \times 10^{3\;1}$ /ha) was greater than ZT and ZT + R. On the other hand, ZT and ZT+R had a reduced overall cost of cultivation (**Table 3**) confirming Gathala *et al.* (2011). Compared to herbicidal treatments, the cost of cultivation was higher with manual hand weeding twice at 30 and 50 DAS. The net return and net B:C ratio (0.73) under CT were lower than those in ZT+R (0.86) and ZT (0.74). Higher net returns are indicative of the benefits of ZT and ZT+R crop productivity and can be ascribed to lower cultivation costs when compared to the input costs of preparatory tillage and irrigation in CT. Higher net return in ZT+R have made up for the economic loss of agricultural residue returned. The atrazine 0.75 kg/ha PE *fb* 2,4-D kg/ha PoE yielded the highest net returns of $29.2 \times 10^{3\;1}$ /ha with a net B:C ratio of 1.08 among the weed management treatments (**Table 3**).

Therefore, it can be concluded that zero-tillage with barley residue retention was the most productive and effective way to cultivate rainfed pearl millet. Hand weeding twice at 30 and 50 DAS, and atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75 kg/ha or tembotrione 0.075, 0.10 kg/ha PoE can be used to effectively control weeds in rainfed pearl millet.

Table 3. Effects of weed management treatments on weed control efficiency, weed index, grain yield and economics of CA-based pearl millet

Treatment	Weed control efficiency (%)	Weed index (%)	Grain yield (t/ha)	Total cost of cultivation (x 10^3 ₹/ha)	Net return (x 10^3 ₹/ha)	B:C
Tillage practice						
Conventional tillage	59.9	19.9	2.08	32.3	20.3	0.73
Zero tillage	61.3	10.6	2.18	27.8	23.3	0.74
Zero tillage + Residue 3 t/ha	67.2	10.5	2.40	29.2	23.9	0.86
LSD (p=0.05)	1.51	2.6	0.18	-	2.2	0.06
Weed management						
Weedy check	0	33.4	1.65	26.2	11.9	0.49
Hand weeding at 30 and 50 DAS	78.3	0	2.53	33.6	23.3	0.68
Atrazine 0.75 kg/ha PE *fb* 2,4-D 0.75kg/ha PoE	77.5	4.3	2.42	28.9	29.2	1.08
Atrazine 0.75 kg/ha PE	53.3	14.7	2.09	27.0	21.3	0.77
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.05 kg/ha PoE	76.7	7.3	2.27	31.1	24.6	0.85
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.075 kg/ha PoE	76.8	4.6	2.33	30.5	24.7	0.83
Atrazine 0.75 kg/ha PE *fb* tembotrione 0.10 kg/ha PoE	77.3	7.2	2.29	30.7	22.5	0.74
LSD (p=0.05)	0.7	3.2	0.22	-	2.4	0.08

DAS: Days after sowing; PE: Pre-emergence; PoE: Post-emergence; *fb*= Followed by

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