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Effect of weed management practices on growth dynamics and productivity of rainfed pearl millet under conservation agriculture

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ABSTRACT

An experiment was conducted on rainfed pearl millet at ICAR- IARI, New during the *kharif* season of 2019, in a split-plot design with three replications. tillage practices, viz. Conventional tillage (CT), Zero tillage and Zero till Residue@ 3t/ha (ZT+R) were evaluated in the main plot and seven weed manag treatments, viz. weedy check, hand weeding (HW) at 30 and 50 days after s (DAS), atrazine @ 0.75 kg/ha(PE) *fb* 2,4-D @0.75kg/ha (PoE), atrazine @ 0.75 PE, atrazine @ 0.75 kg/ha PE *fb* tembotrione @ 0.05kg/ha PoE, atrazine @ 0.75 PE *fb* tembotrione @ 0.075kg/ha PoE, atrazine @0.75 kg/ha PE *fb* tembotric 0.10 kg/ha PoE. ZT+R 3t/ha resulted in enhanced growth attributes, and higher uptake which led to increased grain yield. Among weed control treatments, weeding (HW) twice at 30 and 50 DAS along with the integration of pre-emer application of atrazine 0.75kg/ha *fb* 2,4-D 0.75kg/ha PoE and tembotrione, kg/ha or 0.1 kg/ha PoE resulted in better growth attributes which signifi resulted in higher grain yield under rainfed conditions of semi-arid tropics.

Introduction

Pearl millet [*Pennisetum glaucum* (L.) R. Br. emend Stuntz] is an important crop of the arid and semi-arid climate of the world with a greater ability to withstand harsh environments. It is the sixth most important global cereal crop grown in the rainfed areas of India**.** In India, it forms a staple diet of the majority of poor farmers and is a multipurpose cereal crop for grain and green fodder for livestock. India is the largest producer of pearl millet covering marginal and sub-marginal land of rainfed areas. It is grown in an area of 7.41 million hectares with productivity of 1391kg/ha while a production estimate of 9.35 million tonnes (Directorates of millets development, 2021-22). However, the productivity of pearl millet is far less (1t/ha) than its potential (3t/ha) due to several constraints such as low and erratic availability of soil moisture, depleted soil fertility, and severe weed infestation. Tillage systems intensified with mechanization have played a crucial role to meet the growing demand for food grains for the burgeoning global population. But extreme tillage practices have many objectionable effects on soil and water such as the formation of hardpan due to soil compaction, advancing soil erosion, degradation of soil structure, reduction of soil organic matter, depleting soil properties and water holding capacity etc., resulting in low and unstable crop production (Bronick and Lal, 2005; Ramos *et al.,* 2011; López-Garrido *et al.,* 2012). Conservation agriculture offers an encouraging alternative to conventional agriculture and outperforms traditional tillage problems such as soil fertility decline, moisture stress, low and unstable crop yields and high cost of production. Weed stress increased in the early years of conservation agriculture implementation, by cause of eliminating tillage as a weed control mechanism. Being a warm rainy season crop, pearl

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millet encounters severe weed competition leading to a heavy reduction in grain yield. They emerge and compete with the crop for nutrients, moisture, light, and space, which can reduce yield by as much as 16-94% (Balyan *et al.,* 1993), 41% (Girase *et al.,* 2017), and 35% (Nibhoria *et al.,* 2021). The nutrient depletion by weeds in pearl millet is up to 61.8 kg N, 5.6 kg P and 57.6 kg K/ha (Ram *et al.,*2005). Under such occurrences, effective and economic weed management practices are of foremost importance to attain efficacious control of weeds in pearl millet crops and achieve their productive potential with better soil and crop management. Therefore, a study was carried out to assess the effect of weed management on growth dynamics and productivity of rainfed pearl millet under conservation agriculture.

Materials and Methods

A field experiment was conducted at ICAR-IARI, New Delhi, India during the *kharif* season of 2019 under a 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 31-36.5°C, 21.8-28°C, 33-98%, and 780 mm. The NPK status of soil were 0.03 kg/ha,12 kg/ha,175 kg/ha and OC content 0.34%. The experiment was laid out in a split-plot design having 21 treatment combinations with 3 replications. Three tillage practices: conventional tillage (CT), zero tillage (ZT), zero tillage with residue 3t/ha (ZT + R) were assigned to the main plot and sub-plots 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. In the previous *rabi* season, the barley crop was sown as a uniform crop and the residue@ 3t/ha was retained on the soil surface after sowing in the respective treatments of the experiments. 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. The 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. The remaining N (30 kg/ha) was applied in two equal splits at 25 and 50 DAS prior to rainfall as N might subject to leaching. Pre-emergence application of atrazine was done one day after sowing. The post-emergence herbicides, 2,4-D and tembotrione were applied 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. Nitrogen (N) content was estimated by the modified Kjeldahl method (Prasad *et al.* 2006), while P and K concentrations were determined using a sulfuric–nitric–perchloric acid digest (Prasad *et al*.2006). By multiplying the nitrogen content of grain by the factor 6.25, the protein content of grain was calculated (A.O.A.C., 1970). The growth attributes of the crop were recorded at 30 and 60 DAS, and yield at harvest using standard procedures.

Results and Discussion

Growth attributes

The most common grassy weed species identified in the experimental field were *Cynodon dactylon*, *Echinochloa colona*, *Dactyloctenium aegyptium*, *Digitaria sanguinalis*, *Bracharia ramose*, and *Bracharia eruciformis*. Only two species, *Cyperus rotundus* and *Cyperus iria*, were classified as sedges, whereas *Commelina benghalensis*, *Trianthema portulacastrum*, *Digeria arvensis*, *Amaranthus viridis*, and *Parthenium hysterophorus* were found to be dominant broadleaved weed species.The observation showed that zero tillage + residue 3t/ha (ZT+R) had a promising effect on growth parameters at 30 DAS and 60 DAS compared to zero tillage (ZT) and conventional tillage (CT) (Table 1).Plant height (66.1 and 252.1 cm), number of tillers (1.9 and 2.7cm), leaf area index (2.3 and 5.4), dry matter accumulation (186.8 and 696.1 cm) were all significantly higher in zero tillage + residue 3t/ha (ZT+R) followed by zero tillage (ZT) treatment with plant height (62.4 and 239.9cm), number of tillers (1.7 and 2.4 cm), leaf area index (2.2 and 4.8), dry matter accumulation (174.4 and 638.6 g/m^2) at 30 and 60 DAS respectively (Table 1).ZT + R 3t/ha enabled the crop plant to withstand minimal competition, resulting in improved crop growth and growth parameters. This can be attributed to the

allelopathic effect of barley residues by exuding gramine, hordenine, and phenolic compounds in ZT+R, which suppressed the weeds by forming a physical barrier and overall weed suppressive effects. There is an increase in the microporosity in zero tillage soils by increasing the storage pores (0.5-50mm) and the number of elongated pores (50-500mm) which consequently increased the available water for plants (Pagliai *et al.,*2006). Furthermore, the retention of crop residue raised the soil moisture which ultimately enhanced the growth and biomass production of crops both directly and indirectly by augmenting the bio-availability, and efficient utilization of applied and endemic nutrients (Singh *et al.,*2018). Among the weed management practices, growth parameters like plant height, number of tillers/m^2, leaf area index and dry matter accumulation at 30 DAS were registered as significantly higher than those of the treatments receiving the pre-emergence application of atrazine 0.75 kg/ha over rest of the treatments (Table 1). Plant height was recorded highest (66.4 cm) in atrazine@ 0.75kg/ha (PE) *fb* tembotrione @ 0.075 kg/ha (PoE) at 30 DAS, and at 60 DAS it recorded highest (251.8cm) in hand weeding (HW) at 30 and 50 DAS (Table 1).

Table 1: Effect of weed management on growth attributes of CA based pearl millet

Treatments	Plant height (cm)		Number of tillers/m^2		LAI		DMA (g/m^2)	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Main plot: Tillage								
CT	60.0	229.7	1.7	2.2	2.1	4.7	167.3	617.6
ZT	62.4	239.9	1.7	2.4	2.2	4.8	174.7	638.6
ZT + R 3t/ha	66.1	252.1	1.9	2.7	2.3	5.4	186.8	696.1
SEm±	0.8	4.2	0.03	0.05	0.17	0.08	3.5	15.3
LSD (P≤0.05)	3.2	17.1	0.13	0.71	0.04	0.30	14.1	62.0
Sub-plot: Weed management								
W_1	53.1	205.3	1.5	1.8	1.9	4.6	138.0	559.5
W_2	57.8	251.8	1.5	2.7	2.03	5.2	141.4	701.1
W_3	66.0	248.0	1.9	2.6	2.19	5.1	191.7	667.2
W_4	64.6	236.9	1.8	2.4	2.21	4.8	188.8	635.6
W_5	65.6	246.0	1.8	2.6	2.14	5.0	192.2	663.0
W_6	66.4	251.0	1.8	2.6	2.14	5.0	190.7	669.0
W_7	64.3	245.1	1.8	2.6	2.18	5.0	190.8	661.5
SEm ±	1.2	5.4	0.04	0.08	0.06	0.1	4.3	14.5
LSD (P≤0.05)	3.4	15.6	0.11	0.24	0.18	0.4	12.6	41.6

LAI: Leaf area index DMA: Dry matter accumulation DAS: Days after sowing
CT: Conventional tillage ZT: Zero tillage ZT+R: Zero tillage + Residue
W_1: Weedy check W_2: Hand weeding at 30 and 50 DAS W_3:Pre-emergence(PE) application of Atrazine@ 0.75kg/ha *fb* post emergence (PoE) application of 2,4-D 0.75kg/ha W_4:PE application of Atrazine@ 0.75kg/ha W_5:PE application of atrazine@ 0.75kg/ha *fb* PoE application of tembotrione @ 0.05 kg/ha W_6: PE application of atrazine @ 0.75kg/ha *fb* PoE application of tembotrione @ 0.075 kg/ha W_7: PE application of atrazine @ 0.75kg/ha *fb* PoE application of tembotrione @ 0.10 kg/ha

Similarly, number of tillers were recorded highest (1.9/m^2) in atrazine@ 0.75kg/ha (PE) *fb* application of 2,4-D 0.75kg/ha (PoE) and at 60 DAS recorded highest number of tillers (2.7) in HW at 30 and 50 DAS. Atrazine@0.75kg/ha (PE) had a greater LAI at 30 DAS (2.2), and HW at 30 and 50 DAS had the greatest LAI (5.2) at 60 DAS. Dry matter accumulation (DMA) recorded higher (192.2 g/m^2) in atrazine@ 0.75kg/ha (PE) *fb* tembotrione @ 0.05 kg/ha (PoE) at 30 DAS, and HW at 30 and 60 DAS reported higher DMA (701.1) at 60 DAS. Pre-emergence application of atrazine 0.75 kg/ha effectively controlled early emerging broad-spectrum weed flora by inhibiting photosynthesis.

Growth parameters were markedly influenced by different weed management practices. The maximum growth parameters were noted under two hand weeding at 60 DAS, which was significantly higher over the rest of the treatments. This could be attributed to a lower dry weight of weeds which led to less weed competition during the critical crop-weed competition period (30 and 45 DAS) and thereby better growth of pearl millet crop by sufficient availability of resources. The next best treatments were atrazine 0.75 kg/ha (PE) *fb* 2,4-D 0.75 kg/ha (PoE), atrazine at 0.75 kg/ha (PE) *fb* tembotrione 0.05 kg/ ha (PoE), atrazine 0.75 kg/ha (PE) *fb* tembotrione 0.075 kg/ha (PoE) and atrazine 0.75 kg/ha (PE) *fb* tembotrione 0.10 kg/ha (PoE) and recorded on a par with each other.

Nutrient uptake and protein content

Nutrient depletion by weeds revealed that maximum N, P and K depletion was under CT, whereas lowest N, P and K depletion was observed in ZT+R 3t/ha (Table 2). This could be attributed to residues on the soil surface which acted as a physical barrier to resources for weeds growth and indirectly increased their predation in zero tillage by providing foraging and nesting habitat for predators, resulting in less weed infestation due to restricted germination, growth and development (Chauhan *et al.,* 2012; Den Hollander *et al.,*2007), ultimately low nutrient depletion by weeds. The exponential growth of weed in weedy check treatment resulted in higher uptake of N, P and K nutrients. On the contrary, the minimum depletion of N, P and K/ha was observed with atrazine 0.75 kg/ha (PE) *fb* tembotrione 0.10 kg/ha (PoE) that was closely accompanied by hand weeding at 30 and 50 DAS and atrazine 0.75 kg/ha (PE) *fb* tembotrione 0.075 kg/ha (PoE) treatments. Reduction in N, P and K depletion under corresponding treatments could be ascribed to effective control of broad-spectrum weeds by manual weeding and integration with herbicidal treatments, which increased the nutrient and water availability for crop plants. On the other hand, greater biomass of weeds accumulated under weedy checks interfere with crop growth development might be the only reason for higher nutrient depletion. The treatment with zero tillage + residue 3t/ha (ZT+R) was notably superior in total uptake of NPK by pearl millet when compared to both the tillage treatments (Table 2). The lowest N, P and K uptake was recorded under conventional tillage (CT). This may be due to more weed suppression under ZT + R 3t/ha, leading to much better weed control, ensuing higher nutrient content and total nutrient uptake by the crop due to increased yield of the crop. Ali *et al*.(2006) reported that the lowest values of soil organic matter, N, P and K were recorded in conventional till plots due to the inversion of topsoil during ploughing which shifts less fertile subsoil to the surface in addition to possible leaching. Among weed management practices, two hand weeding at 30 and 50 DAS reported the maximum uptake, which was found at par with atrazine 0.75 kg/ha (PE) *fb* 2,4-D 0.075 kg/ha (PoE). Increased N, P and K uptake might be ascribed to better weed control and higher yield production (Ramesh *et al.,* 2019; Ram *et al.,* 2005). ZT+R 3t/ha with hand weeding at 30 and 50 DAS recorded the highest protein yield followed by that under atrazine 0.75 kg/ha (PE) *fb* 2,4-D 0.075 kg/ha (PoE) (Table 2). As the protein in grain is a function of its N concentration, hence the higher concentration of N in grain under superior treatments seems to be the only reason for attaining higher protein content. The favourable effect of weed control using two hand weeding at 20 and 40 DAS and atrazine at 0.5 kg/ha + one hand weeding at 20 DAS on protein in pearl millet has also been reported by (Singh *et al.,* 2006; Das *et al.,*2013).

Grain yield

Grain yield was significantly more under ZT+R (2.40 t/ha) as compared to CT (2.08) and ZT-R (2.18 t/ha) (Table 2). Retention of barley residues had a

Table 2: Effect of weed management on protein content, NPK uptake and grain yield of CA based Pearl millet

Treatments	Protein content (%)	Weeds(kg/ha)			Crop(kg/ha)			Grain yield (t/ha)
		N	P	K	N	P	K	
Main plot: Tillage								
CT	11.3	12.3	1.4	10.7	37.6	13.7	21.3	2.08
ZT	11.5	10.7	1.2	9.3	40.0	14.7	22.8	2.18
ZT + R 3t/ha	11.8	7.7	0.9	6.7	45.5	17.1	24.8	2.40
SEm±	0.02	0.2	0.03	0.2	0.6	0.3	0.6	0.04
LSD (P≤0.05)	-	0.7	0.1	0.7	2.1	0.9	2.0	0.18
Sub-plot: Weed management								
W_1	11.2	28.2	3.2	24.8	29.5	10.9	18.0	1.65
W_2	11.8	5.9	0.6	5.1	46.7	17.4	24.0	2.53
W_3	11.6	6.1	0.7	5.3	44.5	16.8	23.3	2.42
W_4	11.2	13.4	1.5	11.6	37.8	13.6	20.7	2.09
W_5	11.5	6.2	0.7	5.4	42.2	15.1	22.2	2.27
W_6	11.6	6.0	0.7	5.3	43.4	16.0	23.0	2.33
W_7	11.7	5.7	0.6	5.0	42.9	16.2	23.8	2.29
SEm ±	0.02	0.15	0.02	0.2	0.7	0.3	0.5	0.07
LSD (P ≤0.05)	-	0.4	0.05	0.4	2.1	0.8	1.7	0.22

CT: Conventional tillage ZT: Zero tillage ZT+R: Zero tillage + Residue
W_1: Weedy check W_2: Hand weeding at 30 and 50 DAS W_3: Pre-emergence(PE) application of Atrazine@ 0.75kg/ha *fb* post emergence (PoE) application of 2,4-D 0.75kg/ha W_4:PE application of Atrazine@ 0.75kg/ha W_5:PE application of atrazine@ 0.75kg/ha *fb* PoE application of tembotrione @ 0.05 kg/ha W_6: PE application of atrazine @ 0.75kg/ha *fb* PoE application of tembotrione @ 0.075 kg/ha W_7: PE application of atrazine @ 0.75kg/ha *fb* PoE application of tembotrione @ 0.10 kg/ha

synergistic effect on crop growth by improving the soil's physical, chemical and biological environment. Residue retention amends aggregate stability, reduces soil erosion, and increases soil macrofauna, which augments soil aeration and water infiltration, thus enhancing soil productivity. Furthermore, it directly increases the input of organic matter and nutrients into the soil, in turn improving soil nutrient availability for crop growth (Zheng *et al*.,2014). Hand weeding (HW) at 30 and 50 DAS was the best weed management practice in regards to grain yield followed by atrazine @ 0.75 kg/ha (PE) *fb* 2,4-D @ 0.75 kg/ha (PoE) at 30 DAS and atrazine 0.75kg/ha PE *fb* tembotrione 0.075 kg/ha PoE. Pre-emergence application of atrazine @ 750 g/ha *fb* HW at 30 DAS resulted in higher growth parameters which could be ascribed to weed-free conditions for a longer period during the crop ontogeny increasingthe availability of growth resources to the crop (Mishra *et al.,*2017). Additionally, the superiority of the integration of herbicides on yield-attributing parameters was attributed to better weed suppression at all the growth stages of the crop by pre-emergence and post-emergence application of herbicides. Girase *et al*. (2017) noted that the highest grain yield of pearl millet was obtained with pre-emergence application of atrazine 0.5 kg/ha + 1 HW at 35 DAS. Sharma *et al*. (2018) reported that the combined application of tembotrione with atrazine was significantly superior to its sole application, which considerably reduced weed density, dry weight, weed index, higher weed control efficiency, and increased values of growth, and yield attributes and yield of the crop.

Conclusion

Zero tillage + residue (ZT+R) 3t/ha with the use of two hand weeding (HW) at 30 and 50 DAS and a combination of pre and post-emergence application of herbicides proved their superiority in increasing all crop growth, lowest nutrient removal by weeds,

highest nutrient uptake by crop which resulted in maximum productivity, which is of prime importance to achieve a higher yield of pearl millet under rainfed conditions of semi-arid tropics.

Conflict of interest

The authors declare that they have no conflict of interest.

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