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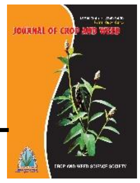

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Weed management impact on soil biological indicators in direct sown finger millet

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ABSTRACT

Soil organic carbon content and enzyme activity in soil are considered as the bio-indicators of soil fertility and soil health. Hence, to assess the impact of weed management practices on soil organic carbon content (SOC), dehydrogenase and urease enzyme activity in finger millet, a field experiment was conducted in randomized complete block design during summer season 2021 at Coconut Research Station, Balaramapuram with 12 treatments and three replications. Compared to un-weeded check, weed management resulted in significantly higher SOC, dehydrogenase and urease enzyme activity were recorded in weed management treatments indicating that the tested pre-emergence (PE) herbicides, pyrazosulfuron ethyl, bensulfuron ethyl + pretilachlor and oxyfluorfen, and the post emergence herbicides, bispyribac sodium and penoxsulam + cyhalofop butyl did not cause any inhibitory effect on soil biological indicators. Among the treatments, PE fb wheel hoe weeding (WHW) or penoxsulam + cyhalofop butyl 125 g ha^{-1} at 25 DAS resulted in higher SOC, dehydrogenase and urease enzyme activity compared to other treatments under study. Weed management treatments also had significant effect on weed biomass. At 40 DAS, hand weeding twice at 15 and 30 DAS recorded the lowest weed biomass (0.97 g m^{-1}); whereas at 60 DAS, PE pyrazosulfuron ethyl fb WHW at 25 DAS recorded the lowest weed biomass (32.40 g m^{-2}). Weed control efficiency also followed the same trend.

***Keywords*: Dehydrogenase activity, finger millet, organic carbon, herbicide and urease activity**

Soil organic carbon content (SOC) and activities of dehydrogenase and urease enzymes are the indicators of soil health. In all living microbial cells, the dehydrogenase enzyme is present as an intracellular enzyme and it represents the overall microbial activity in soil (Stepniewska and Wolinska, 2005). Whereas, urease, an extracellular enzyme, is involved in urea hydrolysis and breaking down of soil organic matter. Their measurements have been found to be a supreme tool for assessing the functionality of soils. Enzyme activity in soil can also be considered as a measure to explicate the effect of herbicide applications on the microbes in soil (Sebiomo *et al.*, 2011).

Among the different biological constrains in finger millet production, weeds were found to be the most important one. Weed infestation was severe during early growth stages due to slow initial growth and narrow leaf canopy of finger millet. Severe crop weed competition during initial growth stages results in heavy yield loss. Yathisha *et al*. (2020) reported a yield loss of 72.3 per cent in direct seeded finger millet. However, Mahapatra *et al*. (2021) reported a yield loss of 70 per cent.

Short communication

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The studies conducted over the past decades revealed that integrated weed management is the viable option for managing weeds in finger millet. Weed management practices was found to have an impact on soil health and microbial activity.

For weed management options to be sustainable, it should be safe to the crop and environment. Analysis of soil enzymes and SOC will provide the environmental impact of herbicides. Previous studies also reveal the significance of soil enzyme and SOC estimation in determining sustainability of weed management practices.

Mishra *et al*. (2013) found that compared to herbicide treated plots, un-weeded and hand weeded plots recorded significantly higher SOC. However, Brar *et al*. (2019) reported an increase in SOC in herbicide treated plots compared to un-weeded control plots in rice.

Dehydrogenase activity was remarkably increased by herbicidal application and the highest values were noted in lower doses, whereas the herbicides did not produce any effect on urease activity (Baruah and Mishra, 1986). Priya *et al*. (2017) observed that all the tested herbicides had inhibitory effects on the dehydrogenase activity, and the maximum dehydrogenase activity was recorded in weedy check and hand weeded treatment (122.70 and 114.68 µg TPF released g^{-1} soil). Filmon *et al*. (2021) revealed that the dehydrogenase enzyme activity of soil recovered in about 14 days- time following the application of oxyfluorfen @ 2 kg soil. Hence, the present research work was formulated to find out the effect of PE and POE herbicides, and wheel hoe weeding (WHW) on SOC, dehydrogenase and urease enzyme activity in direct sown finger millet.

The field study was carried out at Coconut Research Station, Balaramapuram during summer 2021-22 situated at 8° 22’ 52’’N and 77° 1’ 47’’ E, 9 m above MSL. The study area had warm and humid climate with average maximum temperature of 35.02°C and minimum temperature of 23.08°C, and the rainfall received during the field study was 129.8 mm. The soil was sandy loam with a pH of 5.19, of SOC 0.25%, soil available N of 275.96 kg ha^{-1}, soil available P of 17.23 kg ha^{-1} and soil available K of 324.8 kg ha^{-1}. The initial dehydrogenase and urease enzyme activity of soil were 58.08 µg TPF g^{-1} soil d^{-1} and 196.83 µg urea hydrolysed g^{-1} soil 4 h^{-1}, respectively.

Twelve treatments were laid out in randomized completely block design with three replications. The treatment details of the experiment with the abbreviations are given in Table 1. Pre-emergence herbicides and POE herbicides were sprayed using knapsack sprayer and crop protective herbicide applicator respectively at a spray fluid of 500 L ha^{-1}. Finger millet was grown in the inter-row spaces of mature coconut palms (60 years old) planted 7.6 m x 7.6 m spacing having 70 percent light transmission. Finger millet variety, PPR 2700 (Vakula) released from Agricultural Research Station, Perumalapalli, Andhra Pradesh was chosen for the study. The crop was fertilized with NPK @ 45: 22.5: 22.5 Kg ha^{-1} and FYM was applied @ 5 t ha^{-1} to all treatment plots as basal (KAU, 2016).

Composite soil sample was drawn from the experimental plots prior to experiment to analyse the SOC, dehydrogenase and urease enzyme activity. After the harvest also, composite soil samples were drawn from each treatment for analysing SOC. The soil was sieved through 0.2 mm sieve and SOC was determined by the rapid titration method (Walkley and Black,1934) and expressed in percentage. For enzyme assay, soil samples were collected from the rhizosphere region at 20 and 40 DAS and stored in a polythene bag. The analysis was completed within a week. Weed dry weight was determined by randomly placing the quadrat 0.5 m x 0.5 m at two locations in each treatment plot. Weeds were uprooted from the same area and the uprooted weeds were dried under shade for two days followed by oven drying at 65 °C until a constant weight was attained and was expressed in g m^{-2}. Weed control efficiency was worked out by the formula put forward by Mani and Gautham (1973). Data generated was statistically analysed using ANOVA (Cochran and Cox, 1965) and F test was used to test the significance. If the F value was found significant at 5 per cent probability, the critical difference (CD) was calculated.

Effect on SOC

Weed management markedly influenced the SOC of post-harvest soil. Among the treatments, T_4 resulted in the highest SOC (0.394%) which was on a par with T_6 and T_3. This might be due to higher microbial activity in the soil as evident from the data on dehydrogenase activity (Table 2) and also might be due to higher root biomass resulting from better control of weeds (Fig.1). Brar *et al*. (2019) also reported higher SOC in herbicide treated plots compared to non-herbicide treated plots. Compared to initial soil status, SOC was found to be higher in all the treatments except in T_8, T_9, T_{10}, and T_{12} (Table 1). Increase in SOC in the post-harvest soil was because of organic matter addition by the decay of leaves and roots. Compared to un-weeded check, weed management treatments recorded higher SOC due to better weed control which in turn provided a favourable environment for crop growth. Root exudation was regarded as the major component of below ground carbon allocation. Root exudation from the crop contributed to higher SOC in weed management treatments. Badri and Vivanco (2009) observed that the plants exuded about 20-40 per cent of photosynthetically fixed carbon as root exudates. Canarini *et al*. (2019) reported that root exudation was influenced by external stresses such as competition for nutrients and moisture. Severe crop weed competition for the resources, particularly nutrients and moisture, might have resulted in reduction in root exudation which ultimately led to low SOC in un-weeded check. Raj and Syriac (2015) also reported significantly higher SOC in weed management treatments compared to weedy check.

Effect on dehydrogenase and urease enzyme activity in soil

The soil dehydrogenase and urease enzyme activities are regarded as soil health bio-indicators. Dehydrogenase enzyme is an intracellular enzyme, its assay in soil indicated the microbial activity in soil (Watts *et al.,* 2010). Whereas, urease, an extracellular enzyme, is involved in urea hydrolysis and availability of N to the plants (Kocak, 2020). Reddy *et al*. (2011) revealed that estimation of urease enzyme activity provided an indication of soil biological activity. Dehydrogenase and urease enzyme activity in soil can also be considered as a measure to ascertain the effect of herbicides on microbial density in the soil (Sebiomo *et al.,* 2011).

The dehydrogenase and urease activity were markedly influenced by weed management at 20 and 40 DAS (Table 1). In general, at 20 and 40 DAS, both dehydrogenase and urease enzyme activity were higher in weed management treatments compared to un-weeded check. Reduction in weed population may provide a congenial environment for the activity of microorganisms which in turn resulted in higher enzyme activity. Koyama *et al.* (2013) concluded that increase in the availability of nutrients resulted in higher enzyme activity in soil. The treatment T_4 resulted in higher dehydrogenase enzyme activity (121.72µgTPF g^{-1} soil d^{-1}) at 20 DAS. However at 40 DAS, T_6 resulted in the highest dehydrogenase enzyme activity (72.15 µgTPFg^{-1} soil d^{-1}) and was statistically comparable with T_4. Significantly higher dehydrogenase and urease activity in the treatments PE pyrazosulfuron ethyl *fb* MW and PE pyrazosulfuron ethyl *fb* POE bispyribac sodium compared to un-weeded check was also pointed out by Ramalakshmi *et al*. (2017). Sinchana and Raj (2020) also reported significantly lower dehydrogenase enzyme activity in weedy check compared to other weed management treatments at 15 and 30 DAS in bush vegetable cowpea. Compared to 20 DAS, a decline in dehydrogenase enzyme activity was observed at 40 DAS. Sireesha *et al.* (2012) reported higher dehydrogenase activity from the day of application of oxyfluorfen to 30 days after application and thereafter a reduction in enzyme activity in the later stages in radish.

Table 1: Impact of weed management on SOC, dehydrogenase and urease enzyme activity in finger millet during summer 2021

Treatment	SOC of post-harvest soil (%)	Enzyme activity in soil: Dehydrogenase enzyme (µg TPF g^{-1} soil d^{-1}) 20 DAS	40 DAS	Urease enzyme (µg urea hydrolysed g^{-1} soil $4h^{-1}$) 20 DAS	40 DAS
T_1: Pre-emergence (PE) bensulfuron methyl + pretilachlor 495 g ha^{-1} (bensul +preti$_{495}$) *fb* Wheel hoe weeding (WHW)	0.310	84.48	42.41	148.54	125.12
T_2: PE bensul +preti$_{495}$ *fb* bispyribac sodium 20 gpha^{-1} (bispyri$_{20}$)	0.322	75.23	29.74	154.76	170.12
T_3: PE bensul +preti$_{495}$ *fb* penoxsulam+ cyhalofop butyl 125 g ha^{-1} (penox +cyhalo$_{125}$)	0.353	65.86	44.48	138.29	140.12
T_4: PE pyrazosulfuron ethyl 20 g ha^{-1} (pyrazo$_{20}$) *fb* WHW	0.394	121.72	65.43	170.12	174.88
T_5: PE pyrazo$_{20}$ *fb* bispyri$_{20}$	0.317	96.21	63.10	182.93	140.12
T_6: PE pyrazo$_{20}$ *fb* penox +cyhalo$_{125}$	0.390	98.62	72.15	187.32	140.85
T_7:PE oxyfluorfen 50 g ha^{-1}(oxy$_{50}$) *fb* WHW	0.252	92.07	33.36	165.36	144.51
T_8: PE oxy$_{50}$ *fb* bispyri$_{20}$	0.229	59.65	27.93	136.10	142.32
T_9: PE oxy$_{50}$ *fb* bispyri$_{20}$	0.245	72.41	36.21	172.68	133.90
T_{10}: WHW at 15 and 30 DAS	0.243	73.45	23.02	162.07	151.10
T_{11}: MW at 15 and 30 DAS	0.286	62.53	36.21	151.46	158.05
T_{12}: Un-weeded check	0.228	56.89	13.97	134.99	119.27
SEm (±)	**0.022**	**5.33**	**2.80**	**11.35**	**8.62**
LSD (0.05)	**0.070**	**15.72**	**8.25**	**33.51**	**24.45**

Note: *PE-pre-emergence, fb-followed by, WHW-wheel hoe weeding, MW-manual weeding, DAS-days after sowing; PE herbicides were sprayed on the day sowing, post emergence herbicides were applied on 25 DAS and WHW at 25 DAS except in* T_{10}

Highest urease enzyme activity was noted in T_6 (187.32µg urea hydrolysed g^{-1} soil $4h^{-1}$) at 20 DAS and was comparable with T_9, T_4, T_7, T_{10} and T_2. At 40 DAS, T_4 noted the highest urease activity (174.88 µg urea hydrolyzed g^{-1} soil $4h^{-1}$) which was comparable with T_2, T_{11}, and T_{10}. At both 20 and 40 DAS, un-weeded check recorded the lowest urease enzyme activity. This might be due to reduction in the availability of substrates as a result of uncontrolled growth of weeds. Similar results were also reported by Sinchana and Raj (2020) in bush type vegetable cowpea. In general, at 40 DAS, a reduction in urease enzyme was observed compared to 20 DAS except in few treatments. This was because of higher organic matter content in soil at 20 DAS due to basal FYM addition. Organic sources provided carbon as the source of energy for the heterotrophs, hence an enhancement in SOC improves the microbial activity (Priyadarshani *et al.,* 2022). Increase in microbial population and the availability of substrates increased the activity of urease enzyme in soil (Raj *et al.,* 2015).

Effect on weeds

Weed management had remarkable impact on weed dry weight (Fig.1). At 40 DAS, significantly lower weed dry weight was observed in T_{11} which was followed by T_6 and T_6 was on par with T_4 and T_7. At 60 DAS, the lowest weed dry weight was observed in T_4. The percentage reduction in weed dry weight in weed management treatments compared to weedy check ranged from 82.0 to 98.9 per cent at 40 DAS and 18.6 to 91.8 per cent at 60 DAS, respectively. Weed control efficiency also varied with treatments (Fig 1.). Among the treatments, at 40 DAS, the highest WCE was observed in the treatment T_{11} (98.9%) followed by T_6 (98.4%) and T_4 (98.3%) and at 60 DAS, the highest WCE was noted in the treatment T_4 (91.8%).

CONCLUSION

Weed management practices markedly favoured the SOC and enzyme activity in soil. Higher SOC, dehydrogenase and urease enzyme activity were recorded in weed management treatments compared to un-weeded control. The tested herbicides as pre-emergence *viz.* pyrazosulfuron ethyl, bensulfuron methyl + pretilachlor and oxyfluorfen, and the post emergence herbicides *viz*., bispyribac sodium and penoxsulam + cyhalofop butyl did not have any harmful effect on soil biological indicators, indicating that the tested herbicides are environmentally safe. Among the treatments, the highest weed control efficiency was noted in the treatment, PE pyrazosulfuron ethyl *fb* WHW at 25 DAS.

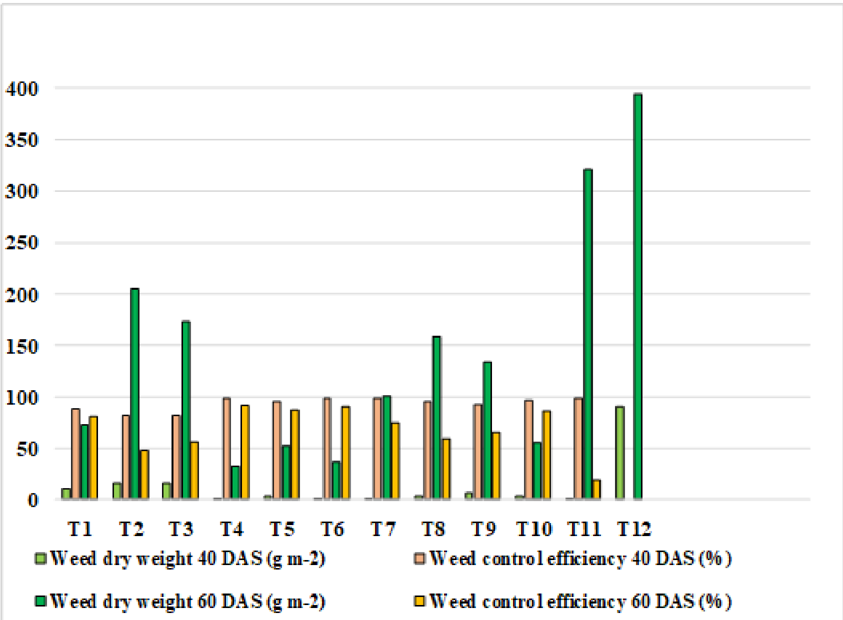

Fig.1. Effect of weed management on weed dry weight and weed control efficiency in finger millet during summer 2021

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