*Int.J.Curr.Microbiol.App.Sci* (2019) *8*(9): 1253-1264

International Journal of Current Microbiology and Applied Sciences
*ISSN: 2319-7706* **Volume 8 Number 09 (2019)**
Journal homepage: http://www.ijcmas.com

**Original Research Article** https://doi.org/10.20546/ijcmas.2019.809.144

# Changes in Soil Dehydrogenase Activity and Herbicide Efficiency Index as Influenced by Different Tillage and Weed Management Practices under Rice - Maize Cropping System

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**A B S T R A C T**

A field research was carried out during 2015-16 and 2016-17 at Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur. Fifteen treatment combinations (Five tillage and three weed management practices) were tested in split plot design with three replications. Soil dehydrogenase activity was not influenced significantly by different tillage practices alone and in combination of tillage and weed management practices. However, dehydrogenase activity was significantly influenced by weed management practices under rice maize cropping system both the years of study. Dehydrogenage activity was found higher due to application of oxadiargyl 90 g ha$^{-1}$ PE *fb* pinoxsulam 22.5 g ha$^{-1}$PoE over other herbicide combinations in rice. Maximum dehydrogenase activity was recorded under unweeded control. Among the herbicidal treatments; atrazine (1.0 kg ha$^{-1}$ PE) and halosulfuron (60 g ha$^{-1}$PoE) herbicides drastically reduced the dehydrogenase activity over unweeded control in maize. There was gradual increase in dehydrogenase activity with the advancement of days after application. The rate of increase was higher after 45 DAS/T under rice maize cropping system. After reaching to harvest stage of rice and maize all the herbicides were degraded and there residues become non toxic to the microbial activities. Maximum HEI recorded under oxadiargyl 90 g ha$^{-1}$ PE *fb* pinoxsulam 22.5 g ha$^{-1}$PoE in rice and atrazine 1.0 kg ha$^{-1}$ PE in maize.

**Keywords**

Dehydrogenase activity, HEI, Tillage, Weed Management

**Article Info**

***Accepted:***
15 August 2019
***Available Online:***
10 September 2019

## Introduction

Tillage systems influence biological properties of soil and have a major impact on soil productivity and sustainability. It alters the organic matter content in soil, which ultimately affects the microbial population and their activity. Conventional tillage practices may adversely affect long-term soil productivity due to erosion and loss of organic matter in soil (Carpenter *et al.*, 2003).Stable and sustainable soils are defined as those with high level of biological activity, high microbial diversity, and capability to release nutrients from soil organic matter (Friedel *et al.,* 2001). Higher soil microbial biomass and activity can directly affect crop nutrient availability. Thus, soil microflora is an effective indicator to predict overall fertility and productivity of a cropping system (Nair and Ngouajio, 2012). In zero tillage soils, the accumulation of crop residues on the soil surface resulted in enrichment of soil organic matter in the surface layer and as a consequence increased abundance of microorganisms (Mathew *et al.,* 2012). It has been shown that intensive tillage practices decrease microbial biomass by decreasing or reversing C accumulation and breaking down soil structure (Liang *et al.,* 2010).Govindan and Chinnusamy (2014) recorded that the total higher bacterial population in rice-based system under conservation agriculture. The addition of herbicides may cause qualitative and quantitative alterations in the soil microbial populations and their enzyme activities. Generally, herbicides are not harmful when applied at recommended rates (Selvamani and Sankaran, 1993) but some herbicides may affect non-target organisms including microorganisms.

Pre-emergence or post-emergence application of herbicides results in a large proportion of the herbicides accumulation in soil mainly on the top 0-15 cm depth. Latha and Gopal (2010) also reported that herbicides being biologically active compounds may adversely affect soil microorganisms and their activity that greatly contribute to the health and productivity of soils. Mishra and Das (2013) revealed that the application of pre and post-emergence herbicide reduced the biochemical activities in soil after its application (3 and 22 DAS, respectively) to 35 days of sowing of the crop, thereafter it became normalize due to degradation of applied herbicides. According to Samuel (2010) the dehydrogenase activity of a soil is thus the result of the activity of different microorganisms, which are an important component of the enzyme system of all microorganisms. It was found that no-tillage in comparison with conventional tillage resulted in significantly higher soil enzymatic activities in the 0-20 cm layer and in significantly lower activities in the deeper layers. However the soil DHA was recovered due to degradation of herbicide afterwards. Weed communities are floristically diverse in rice and maize field and usually comprises of both grassy and broad leaf weeds. Hence the use of herbicide that can simultaneously tackle both type of weeds, variable weed infestation levels under field condition and can alter herbicide efficacy. Looking to the above facts the present study was conducted to evaluate different method of tillage and different herbicides application on soil enzymatic activity and herbicide activity index in a rice-maize cropping system.

## Materials and Methods

The experiment was conducted at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur during 2015-16 and 2016-17. The field trial was arranged as split plot design with each plot consisted of 3.6 × 9.2 m. The treatment included (i) *i.e* CT (DSR) – CT (ii) *i.e* CT (DSR) – ZT (iii) *i.e* ZT (DSR) – ZT (iv) *i.e* CT (TPR) – ZT (v) *i.e* CT (TPR) – CT as main plot and three methods of weed management practices (i) oxadiargyl 90 g $ha^{-1}$ PE + pinoxsulam 22.5g $ha^{-1}$ PoE for rice and atrazine 1.0 kg $ha^{-1}$ PoE for maize (ii) pyrazosulfuron + pretilachlor 10 kg (G) $ha^{-1}$ PE + bispyribac 25g $ha^{-1}$PoE for rice and halosulfuron 60 g $ha^{-1}$ PoE for maize (iii) unweeded control as sub plots in split plot design with three replications. The soil was sandy loam in texture, neutral in reaction (pH 7.5), low in organic carbon (0.46 %), available nitrogen (220 kg $ha^{-1}$), and available phosphorus (22 kg $ha^{-1}$) contents and high in potassium (320 kg $ha^{-1}$).

## Dehydrogenase activity

Dehydrogenase is an indicator of overall microbial activity, because it occurs inter-cellularlly in all living microbial cells and is linked with microbial oxydoreduction processes (Quilchano and Maranon, 2002; Stepniewska and Wolinska, 2005).The procedure to evaluate the dehydrogenase activity by Klein *et al.,* (1971).

One gram air dried soil sample was taken in a 15 ml air-tight screw caped test tube. 0.2 ml of 3 per cent TTC was added in each of the tubes to saturate the soil 0.5 ml of distilled water was added in each tube. Gently tap the bottom of the tube to drive out all trapped oxygen so that a water seal was formed above the soil. Ensured that no air bubbles were formed. The tubes were incubated at 37 °C for 24 hours. Then 10 ml of methanol was added. Shake it vigorously and allowed to stand for 6 hours. Clear pink colored supernatant was withdrawn and reading was taken with a Spectrophotometer at (660 nanometer). The amount of triphenylformazan (TPF) solutions formed was calculated from the standard curve drawn in the range of 10 mg to 90 mg TPF/ML.

## Herbicide efficiency index (HEI)

It indicates the weed killing potential of different herbicide treatment and their phytotoxicity on the crop (Walia, 2003) and can be calculated as

$$HEI = \frac{Yt - Yc / Yc}{\frac{DMT}{DMC} \times 100}$$

Where,
Yt = Yield from treatment plot
Yc= Yield from control plot
DMT= Dry matter of weeds in treatment plot
DMC= Dry matter of weeds in control plot

## Results and Discussion

### Biological property

### Dehydrogenase activity (µg TPF $h^{-1}$ $g^{-1}$) under rice- maize cropping system

The DHA was not influenced significantly by tillage practices which was measured at 0, 15, 30, 45, 60 DAS/T and at harvest stages of rice and maize during both the years (Table 1 and 2). However, it was influenced significantly due to different weed management practices at 15, 30, 45, 60 DAS/T and at harvest of rice and maize during both the years. Maximum dehydrogenase activity found under unweeded control as compared to chemical treatments at all the stages of observation. Among the different herbicidal treatment the dehydrogenase activity was higher in application of oxadiargyl 90 g $ha^{-1}$ PE *fb*pinoxsulam 22.5 g $ha^{-1}$PoE over other herbicide combination in rice. Atrazine 1.0 kg $ha^{-1}$PE and halosulfuron 60 g $ha^{-1}$PoE drastically reduced the dehydrogenase activity over unweeded control in maize. There was gradual increase in dehydrogenase activity with the advancement of day after application. The rate of increase was higher after 45 DAS. The interaction effect of tillage and weed management on dehydrogenase activity was non- significant at any of the stage. There, was no significant variation in dehydrogenase activity among treatments prior to herbicide application. Whereas, it was observed that all the herbicides significantly inhibited the DHA after their application. The result is in agreement with the finding of Sebiomo *et al.*, (2011) who observed that the application of herbicides to the soils led to a significant drop in dehydrogenase activity with respect to unweeded control soil samples. Dehydrogenase is thought to be an indicator of overall microbial activity, because it occurs intercellularly in all living microbial cells and is linked with microbial oxydoreduction process (Quilchano and Maranon,2002). Stepniewska and Wolinska (2005) stated that specific kind of enzyme which play significant role in the biological oxidation of soil organic matter by transforming protons and electrons from substrates to acceptors. Soil dehydrogenase activity is considered to be a valuable parameter for assessing the side effects of herbicides treatments on the soil microbial biomass. At harvest both the herbicide treatments were at par which showed that by reaching to this stage all the herbicides degraded and there residuesbecome non-toxic to the microbial activities. This indicated that the different combination of pre-emergence and post-emergence are safe to uses.Suresh and Qureshi (2010) reported that application of herbicide reduced the activity of dehydrogenase enzyme. The decreases in enzymatic activity of dehydrogenase with increase in herbicidal concentration. There was an increase in the enzyme activity from the 30$^{th}$ day of application to the harvest stage in all the treatments. However, at later stages of the crop growth, there was a drastic increase in the activity of dehydrogenase enzyme in the plots treated with herbicides. So, the harmful effect of herbicides might have been reduced by microbial degradation at later stages of crop growth. Similar results were obtained by Shukla (1997).

## Herbicide efficiency index (%) under rice-maize cropping system

Herbicide efficiency index computed at 20, 40, 60 DAS/T and at harvest is presented in Table 3 to 4 and depicted in Fig. 1.0 to 4.0. The data emphasized that maximum HEI was observed under CT (DSR) - CT followedby CT (DSR) - ZT at 20 DAS/T. At 40, 60 DAS/T and at harvest stage maximum HEI was observed under CT (TPR) - CT followed by CT (TPR) - ZT in both the years. Among weed management practices the highest HEI was recorded under oxadiargyl 90 g ha$^{-1}$ PE *fb* pinoxsulam 22.5 g ha$^{-1}$PoE at all the stages in both the years in rice. In case of maximum HEI was observed under CT (DSR) - CT at all the observational stages. Among weed management practices, the highest HEI was recorded under atrazine 1.0 kg ha$^{-1}$ PE.

However, least HEI was noticed under unweeded control at all the observational stages. HEI is a measure of level of performance of chemical substance. Here we have to study relationship between crop yields affected by dry matter of weeds.

More yield comparison to dry matter production of weeds represents more herbicide efficiency index. It means that herbicide more effective for weed control.

## System productivity (t ha$^{-1}$)

The data on system productivity are presented in Table 5. Significantly higher system productivity was found under combination of CT (TPR) - CT and ZT (DSR) - ZT with oxadiargyl 90 g ha$^{-1}$ PE *fb* pinoxsulam 22.5g ha$^{-1}$PoE in rice and atrazine 1.0 kg ha$^{-1}$ PE in maize, this was at par with the combination of CT (DSR) - CT with oxadiargyl 90 g ha$^{-1}$ PE *fb* pinoxsulam 22.5g ha$^{-1}$PoE in rice and atrazine 1.0 kg ha$^{-1}$ PE in maize, and other combinations of CT (TPR) - ZT with same herbicides. Oxadiargyl 90 g ha$^{-1}$ PE *fb* pinoxsulam 22.5g ha$^{-1}$ PoE recorded more DHA and HEI compared to pyrazosulfuron + pretilachlor 10 kg (G) ha$^{-1}$PE *fb* bispyribac-Na 25 g ha$^{-1}$PoE in rice. In case of maize atrazine 1.0 kg ha$^{-1}$ PE in initially stage but at later stage halosulfuron 60 g ha$^{-1}$ PoE found safe to augment DHA activity in soil and also gave higher HEI.

**Table.1**Dehydrogenase activity (μg TPF $h^{-1}$ $g^{-1}$) of rhizosphere soil at different growth stages in rice as influenced by tillage and weed management practices in rice under rice - maize cropping system

| Treatment | Dehydrogenase activity (μg TPF $h^{-1}$ $g^{-1}$ soil) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 DAS/T | | 15 DAS/T | | 30 DAS/T | | 45 DAS/T | | 60 DAS/T | | Harvest | |
| | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 | 2015 | 2016 |
| **Tillage practices** | | | | | | | | | | | | |
| **$T_1$: CT (DSR) - CT** | 35.52 | 36.59 | 23.99 | 24.91 | 22.84 | 23.56 | 33.41 | 34.60 | 39.44 | 40.66 | 34.42 | 35.80 |
| **$T_2$: CT (DSR) - ZT** | 35.49 | 36.51 | 23.83 | 24.86 | 22.63 | 23.28 | 33.27 | 34.50 | 39.29 | 40.50 | 34.16 | 35.39 |
| **$T_3$: ZT (DSR) - ZT** | 35.86 | 36.92 | 23.57 | 24.57 | 22.24 | 23.16 | 33.21 | 34.32 | 39.17 | 40.27 | 33.94 | 35.16 |
| **$T_4$: CT (TPR) - ZT** | 35.40 | 36.57 | 24.32 | 25.44 | 23.14 | 23.73 | 33.43 | 34.81 | 39.52 | 40.78 | 34.90 | 35.90 |
| **$T_5$: CT (TPR) - CT** | 35.43 | 36.53 | 24.13 | 25.09 | 23.21 | 23.88 | 33.83 | 34.79 | 39.73 | 40.82 | 34.57 | 35.88 |
| **SEm±** | **0.22** | **0.32** | **0.21** | **0.20** | **0.26** | **0.50** | **0.71** | **0.20** | **0.46** | **0.28** | **0.86** | **0.33** |
| **CD (P=0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Weed management** | | | | | | | | | | | | |
| **$W_1$: Oxadiargyl 90 g $ha^{-1}$ PE *fb* pinoxsulam 22.5 g $ha^{-1}$ PoE** | 35.53 | 36.62 | 12.98 | 13.37 | 11.44 | 12.04 | 18.49 | 19.51 | 27.45 | 28.20 | 34.07 | 35.07 |
| **$W_2$: Pyrazosulfuron + pretilachlor 10 kg (G) $ha^{-1}$PE *fb* bispyribac-Na 25 g $ha^{-1}$ PoE** | 35.41 | 36.47 | 11.82 | 12.18 | 10.65 | 10.28 | 17.92 | 18.85 | 25.44 | 26.32 | 33.13 | 34.63 |
| **$W_3$: Unweeded Control** | 35.68 | 36.78 | 47.11 | 49.37 | 47.35 | 48.24 | 55.88 | 56.46 | 59.41 | 60.29 | 38.00 | 39.17 |
| **SEm±** | **0.19** | **0.21** | **0.25** | **0.26** | **0.78** | **0.41** | **0.60** | **0.37** | **0.35** | **0.24** | **0.65** | **0.22** |
| **CD (P=0.05)** | **NS** | **NS** | **0.74** | **0.75** | **2.30** | **1.20** | **1.77** | **1.09** | **1.03** | **0.71** | **1.92** | **0.64** |
| **T×W** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**NS:** Non- significant,

**Table.2** Dehydrogenase activity (µg TPF $h^{-1}$ $g^{-1}$) of rhizosphere soil at different growth stages in maize as influenced by tillage and weed management practices in rice - maize cropping system

| Treatment | Dehydrogenase activity (µg TPF $h^{-1}$ $g^{-1}$ soil) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 DAS | | 15 DAS | | 30 DAS | | 45 DAS | | 60 DAS | | Harvest | |
| | 2015-16 | 2016-17 | 2015-16 | 2016-17 | 2015-16 | 2016-17 | 2015-16 | 2016-17 | 2015-16 | 2016-17 | 2015-16 | 2016-17 |
| **Tillage practices** | | | | | | | | | | | | |
| **$T_1$: CT (DSR) - CT** | 33.76 | 34.67 | 23.99 | 24.89 | 27.21 | 27.84 | 33.69 | 34.19 | 39.17 | 40.87 | 34.06 | 35.77 |
| **$T_2$: CT (DSR) - ZT** | 33.94 | 34.67 | 23.96 | 24.84 | 26.84 | 27.71 | 33.54 | 34.06 | 38.99 | 40.71 | 33.89 | 35.59 |
| **$T_3$: ZT (DSR) - ZT** | 34.03 | 34.82 | 23.66 | 24.53 | 26.58 | 27.49 | 33.32 | 33.69 | 38.79 | 40.48 | 33.67 | 35.37 |
| **$T_4$: CT (TPR) - ZT** | 34.29 | 34.57 | 24.56 | 25.43 | 27.80 | 28.13 | 34.28 | 34.64 | 38.79 | 41.46 | 34.64 | 36.36 |
| **$T_5$: CT (TPR) - CT** | 34.03 | 34.79 | 24.21 | 25.06 | 27.34 | 28.30 | 33.79 | 34.64 | 39.29 | 40.98 | 34.16 | 35.88 |
| **SEm±** | **0.33** | **0.42** | **0.35** | **0.17** | **0.62** | **0.57** | **0.35** | **0.57** | **0.47** | **0.43** | **0.65** | **0.37** |
| **CD (P=0.05)** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Weed management** | | | | | | | | | | | | |
| **$W_1$: Atrazine 1.0 kg $ha^{-1}$PE** | 33.94 | 34.65 | 12.30 | 12.43 | 12.33 | 12.51 | 17.27 | 17.19 | 25.77 | 26.17 | 31.29 | 32.55 |
| **$W_2$: Halosulfuron 60 g $ha^{-1}$PoE** | 33.57 | 34.20 | 12.00 | 12.36 | 11.95 | 12.11 | 18.01 | 18.36 | 27.37 | 28.06 | 32.47 | 34.16 |
| **$W_3$: Unweeded Control** | 34.52 | 35.25 | 48.92 | 51.07 | 55.79 | 57.20 | 65.89 | 67.18 | 70.87 | 72.47 | 38.49 | 40.67 |
| **SEm±** | **0.29** | **0.39** | **0.33** | **0.23** | **0.25** | **0.26** | **0.27** | **0.43** | **0.25** | **0.29** | **0.25** | **0.29** |
| **CD (P=0.05)** | **NS** | **NS** | **0.96** | **0.68** | **0.74** | **0.76** | **0.79** | **1.26** | **0.72** | **0.86** | **0.73** | **0.84** |
| **T×W** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

**NS:** Non-significant

**Table.3** Herbicide efficiency index in rice as influenced by tillage and weed management practices in rice - maize cropping system

| Treatment | Herbicide efficiency index (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 DAS/T | | | 40 DAS/T | | | 60 DAS/T | | | At harvest | | |
| | 2015 | 2016 | Mean | 2015 | 2016 | Mean | 2015 | 2016 | Mean | 2015 | 2016 | Mean |
| **Tillage practices** | | | | | | | | | | | | |
| **$T_1$: CT (DSR) - CT** | 0.36 | 0.45 | 0.41 | 0.12 | 0.13 | 0.13 | 0.12 | 0.11 | 0.12 | 0.11 | 0.10 | 0.11 |
| **$T_2$: CT (DSR) - ZT** | 0.31 | 0.35 | 0.33 | 0.11 | 0.11 | 0.11 | 0.12 | 0.10 | 0.11 | 0.10 | 0.09 | 0.10 |
| **$T_3$: ZT (DSR) - ZT** | 0.25 | 0.34 | 0.30 | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.10 | 0.12 | 0.11 |
| **$T_4$: CT (TPR) - ZT** | 0.22 | 0.36 | 0.29 | 0.14 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.12 | 0.14 | 0.13 |
| **$T_5$: CT (TPR) - CT** | 0.23 | 0.40 | 0.32 | 0.15 | 0.16 | 0.16 | 0.15 | 0.14 | 0.15 | 0.13 | 0.14 | 0.14 |
| **Weed management** | | | | | | | | | | | | |
| **$W_1$: Oxadiargyl 90 g $ha^{-1}$ PE *fb* pinoxsulam 22.5 g $ha^{-1}$PoE** | 0.32 | 0.48 | 0.40 | 0.14 | 0.15 | 0.15 | 0.15 | 0.14 | 0.15 | 0.13 | 0.14 | 0.14 |
| **$W_2$: Pyrazosulfuron + pretilachlor 10 kg (G) $ha^{-1}$PE *fb* bispyribac-Na 25 g $ha^{-1}$PoE** | 0.22 | 0.28 | 0.25 | 0.10 | 0.11 | 0.11 | 0.11 | 0.10 | 0.11 | 0.09 | 0.10 | 0.10 |
| **$W_3$: Unweeded Control** | - | - | - | - | - | - | - | - | - | - | - | - |

**Table.4** Herbicide efficiency index in maize as influenced by tillage and weed management practices in - maize cropping system

| Treatment | Herbicide efficiency index (%) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 DAS | | | 40 DAS | | | 60 DAS | | | At harvest | | |
| | 2015-16 | 2016-17 | Mean | 2015-16 | 2016-17 | Mean | 2015-16 | 2016-17 | Mean | 2015-16 | 2016-17 | Mean |
| **Tillage practices** | | | | | | | | | | | | |
| **$T_1$: CT (DSR) - CT** | 0.55 | 0.57 | 0.56 | 0.53 | 0.61 | 0.57 | 0.43 | 0.48 | 0.46 | 0.41 | 0.49 | 0.45 |
| **$T_2$: CT (DSR) - ZT** | 0.27 | 0.22 | 0.25 | 0.36 | 0.31 | 0.34 | 0.29 | 0.25 | 0.27 | 0.28 | 0.24 | 0.26 |
| **$T_3$: ZT (DSR) - ZT** | 0.23 | 0.19 | 0.21 | 0.35 | 0.30 | 0.33 | 0.27 | 0.23 | 0.25 | 0.28 | 0.23 | 0.26 |
| **$T_4$: CT (TPR) – ZT** | 0.23 | 0.18 | 0.21 | 0.31 | 0.26 | 0.29 | 0.25 | 0.21 | 0.23 | 0.23 | 0.20 | 0.22 |
| **$T_5$: CT (TPR) – CT** | 0.36 | 0.37 | 0.37 | 0.37 | 0.43 | 0.40 | 0.31 | 0.35 | 0.33 | 0.29 | 0.35 | 0.32 |
| **Weed management** | | | | | | | | | | | | |
| **$W_1$: Atrazine 1.0 kg $ha^{-1}$PE** | 0.52 | 0.49 | 0.51 | 0.55 | 0.58 | 0.57 | 0.46 | 0.46 | 0.46 | 0.43 | 0.46 | 0.45 |
| **$W_2$: Halosulfuron 60 g $ha^{-1}$PoE** | 0.14 | 0.12 | 0.13 | 0.22 | 0.19 | 0.21 | 0.16 | 0.14 | 0.15 | 0.17 | 0.14 | 0.16 |
| **$W_3$: Unweeded Control** | - | - | - | - | - | - | - | - | - | - | - | - |

**Table.5** System productivity as influenced by the interaction of tillage and weed management practices in rice - maize cropping system. (Mean of 2015-16 and 2016-17)

| Treatment | System productivity(t ha$^{-1}$) | | | |
|---|---|---|---|---|
| | Weed management | | | |
| | **$W_1$:** Oxadiargyl 90 g ha$^{-1}$ PE *fb*pinoxsulam 22.5 g ha$^{-1}$ PoE in rice and atrazine 1.0 kg ha$^{-1}$ PE in maize | **W2:** Pyrazosulfuron + pretilachlor 10 kg (G) ha$^{-1}$ PE *fb*bispyribac - Na 25 g ha$^{-1}$ PoE in rice and halosulfuron 60 g ha$^{-1}$PoE in maize | **$W_3$:** Unweeded control | **Mean** |
| **Tillage practices** | | | | |
| **$T_1$: CT (DSR) - CT** | 9.27 | 7.90 | 3.77 | 6.98 |
| **$T_2$: CT (DSR) - ZT** | 8.93 | 7.69 | 3.31 | 6.64 |
| **$T_3$: ZT (DSR) - ZT** | 9.28 | 7.86 | 4.21 | 7.12 |
| **$T_4$: CT (TPR) - ZT** | 9.22 | 8.45 | 5.03 | 7.57 |
| **$T_5$: CT (TPR) - CT** | 9.28 | 8.38 | 5.20 | 7.62 |
| **Mean** | 9.19 | 8.06 | 4.30 | 7.18 |
| **T within W** | | | | |
| **SEm±** | | | | **0.14** |
| **CD (P=0.05)** | | | | **0.44** |
| **W within T** | | | | |
| **SEm±** | | | | **0.17** |
| **CD (P=0.05)** | | | | **0.51** |

**Fig.1** Herbicide efficiency index in rice as influenced by tillage practices in rice - maize cropping system at different time intervals (Mean of 2015 and 2016)

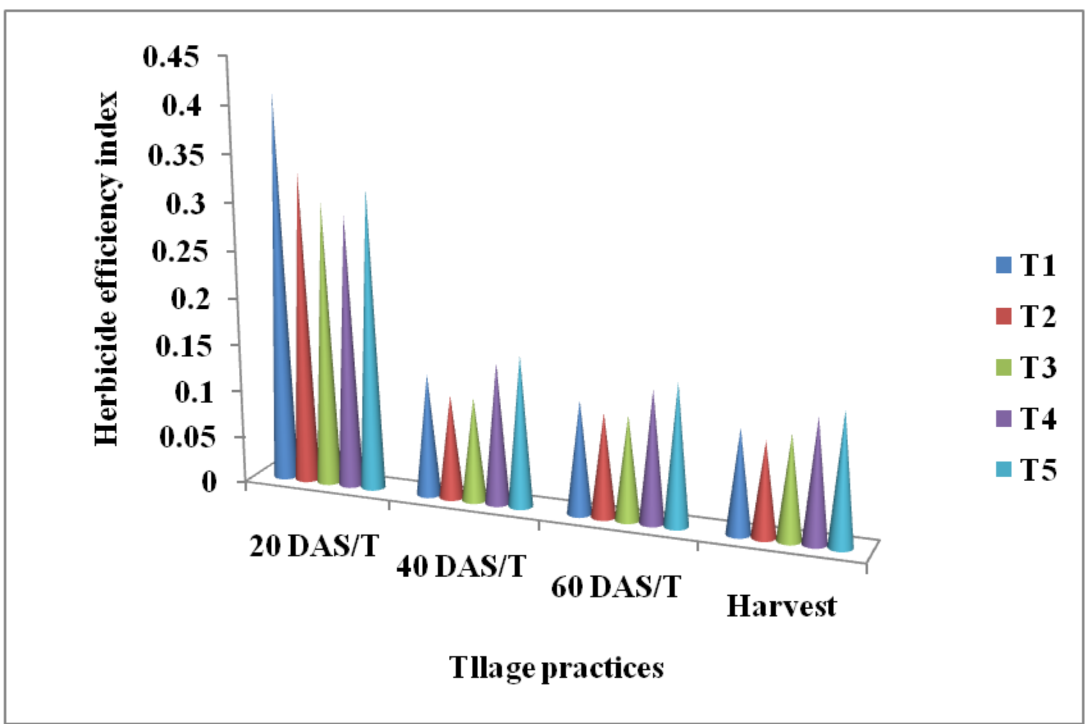


**Fig.2** Herbicide efficiency index in rice as influenced by weed management in rice - maize cropping system at different time intervals (Mean of 2015 and 2016)

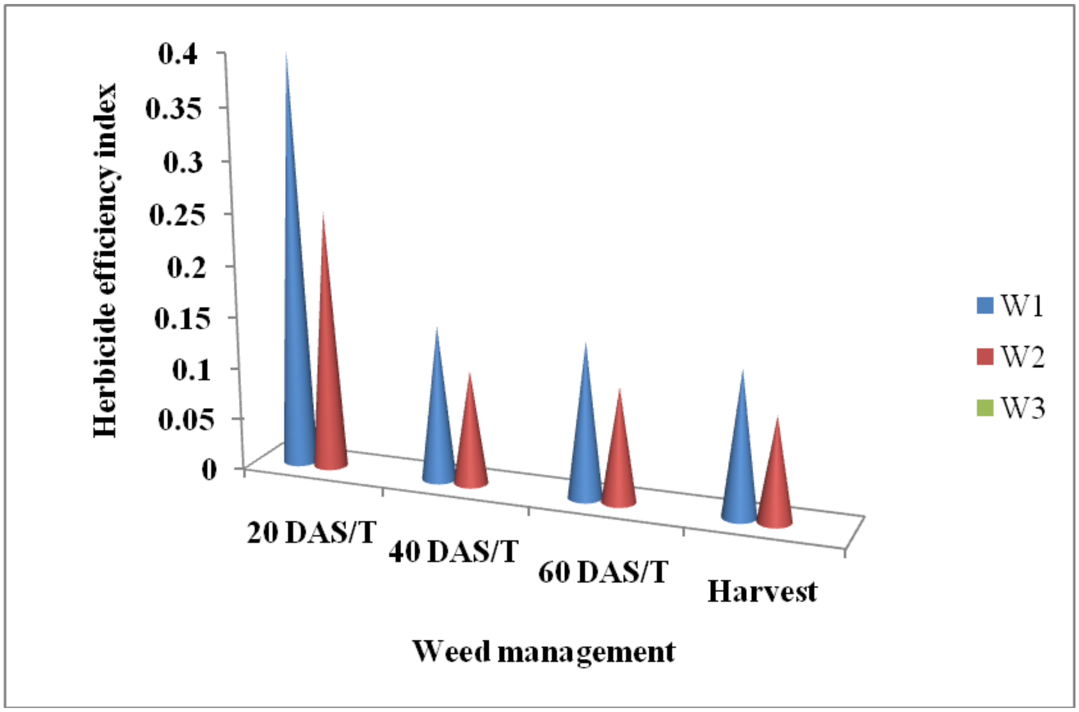



**Fig.3** Herbicide efficiency index in maize as influenced by tillage practices in rice - maize cropping system at different time intervals (Mean of 2015-16 and 2016-17)

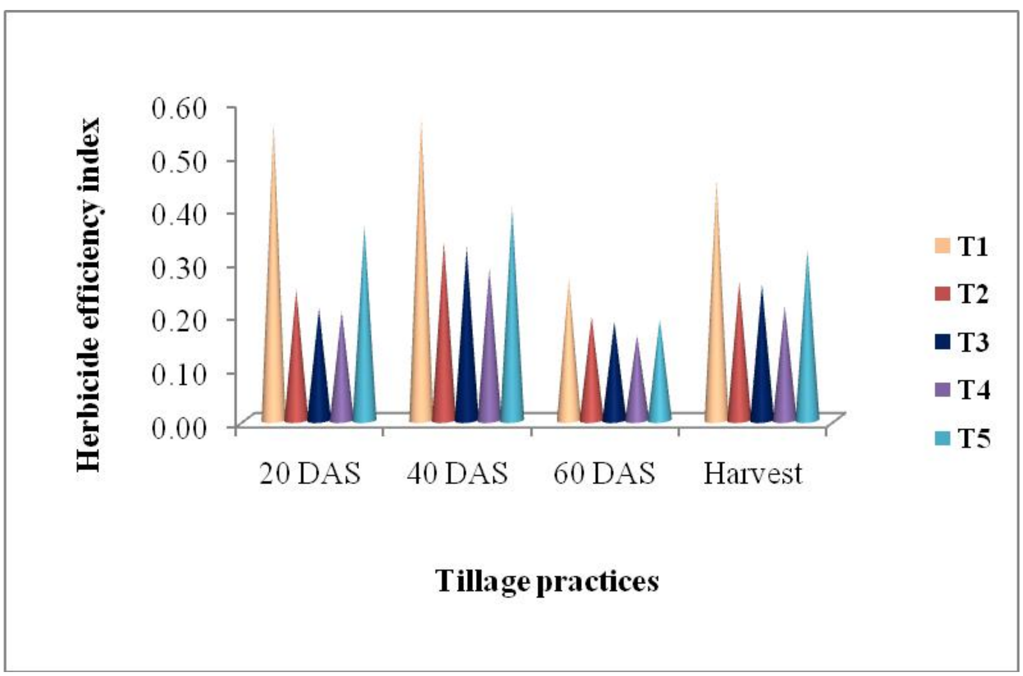
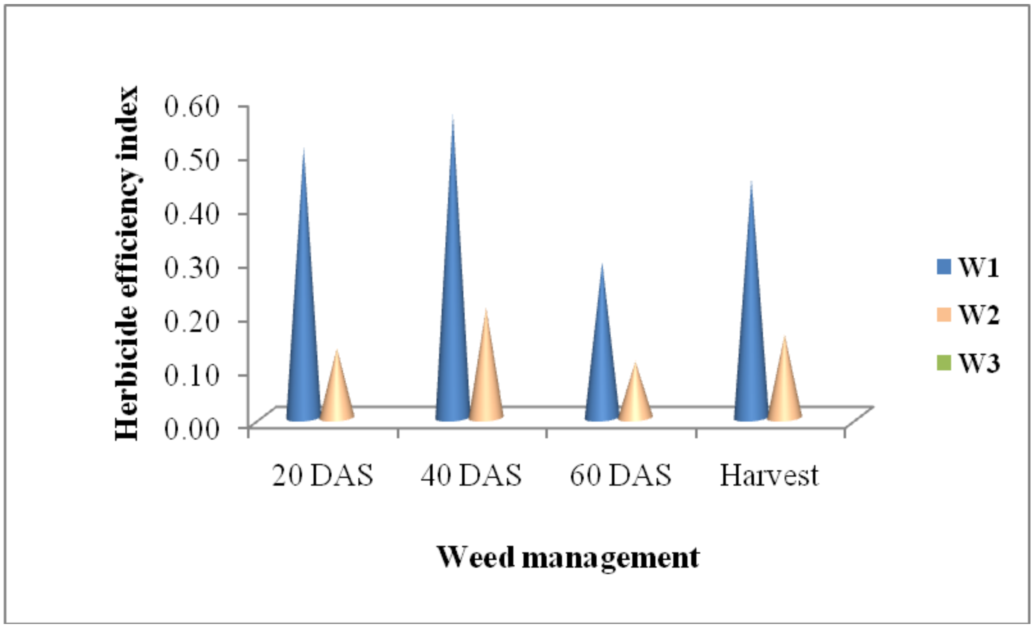


**Fig.4** Herbicide efficiency index in maize as influenced by weed management in rice - maize cropping system at different time intervals (Mean of 2015-16 and 2016-17)

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**How to cite this article:**

Sakshi Bajaj, Tapas Chowdhury, M. C. Bhambri, G. K. Shrivastava and Pandey, N. 2019. Changes in Soil Dehydrogenase Activity and Herbicide Efficiency Index as Influenced by Different Tillage and Weed Management Practices under Rice - Maize Cropping System. *Int.J.Curr.Microbiol.App.Sci.* 8(09): 1253-1264. doi: https://doi.org/10.20546/ijcmas.2019.809.144