Pre and Post Emergence Application of Imazethapyr on N Uptake, Nodulation and Microbial Population of Chickpea Sown after Rice in Vertisols of C. G.

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A B S T R A C T

A field experiment was conducted at the Agronomy Research Farm of IGKV, Raipur, during the Rabi season of 2010-11 and 2011-12. Incorporation of tillage and weed management practices considerably improved the yield of chickpea in terms of N-uptake, number of nodules per plant and microbial activities of rice rhizosphere. Results indicated that, among the tillage management practices, higher N uptake, number of nodules and microbial activities were obtained with CT which was followed by MT and ZT. Among the various weed management practices, N-uptake and number of nodules were maximum under one HW at 20 DAS, followed by the treatments of POE application of imazethapyr @ 90 g ha-1 and POE imazethapyr @ 80 g ha-1, respectively. Whereas, microbial population, basal soil respiration and dehydrogenase enzyme activity of experimental field was significantly higher under weedy check plot, followed by one HW at 20 DAS and POE application of imazethapyr @ 90 g ha-1 during both the years.

Keywords
Imazethapyr, Nodulation, Chickpea, N Uptake, Microbial activities.

Introduction

Chickpea (Cicer arietinum L.) is an ancient crop and is grown in tropical, subtropical, and temperate regions of the country and in recent years. Chhattisgarh region is dominated by rice crop in rainy (kharif) season followed by cultivation of wheat, oilseed and pulses in winter (rabi) season. In Chhattisgarh, chickpea is cultivated in an area of about 3.20 Lakh ha with an average production of 2.12 Lakh tonnes and productivity of 663 kg ha-1. The average productivity of chickpea is still below one ton per hectare, which is considered low by any standards. As yield is a very complex character depending on number of component characters, the knowledge of the association between the yield and its components and among the components themselves is of immense practical value in making selections. In spite of the importance of this crop in our daily diet and in agricultural production system, the productivity of this crop is very low in India as well as in Chhattisgarh.

Weed competition is considered as one of the most important causes of low productivity and inferior quality of chickpea in Chhattisgarh. Considerable yield losses in...
chickpea recorded to the extent of 88 per cent if weeds are not controlled within critical growth period (Bhalla et al., 1998).

Appropriately selected herbicides may perform an important role in weed infestation reduction, increasing weeds resistance to herbicides, high cost and especially, negative effects of herbicides on environment have increased the need of non-chemical weed control in agro ecosystems (Augustin, 2003). Crop rotation, the tillage systems, application of agrochemicals and other agricultural practices affect the soil seed bank and weed flora (Marshall et al., 2003).

In an integrated approach, the development of cropping systems such as appropriate spatial arrangement and efficient tillage will help crops themselves to compete with weeds. Manipulation of cropping systems for the purpose of improving integrated weed management requires a good understanding of weed dynamics and influences of crop and soil-related factors on weed life cycles (Davis and Liebman, 2003). Weed flora have changed over the past century, with either increasing or decreasing species abundance depending on the management (Bagment, 2000).

Chickpea grown in succession with rice and soybean under irrigated condition infested heavily with weeds affected the growth and yield of chickpea. Crop losses of 90% are possible in weedy situations (Knights, 1991) and lack of registered post-emergence herbicides for broadleaf weeds reduces the options for weed management. Hand and mechanical weed control methods traditionally followed in the spring crop are not effective in winter sown chickpea besides being costly and uneconomical. Because of the sensitivity of chickpea to herbicides, most effective herbicides are pre-sowing and pre-emergence soil-acting chemicals and their efficacy is highly dependent on soil type, moisture, temperature and weed flora. Post-emergence herbicides, particularly those for broad-leaf weeds are few. There is a need to identify more effective herbicides with broader spectrum of weed control and wide adaptability. An integrated approach involving herbicides and cultural practices to improve crop competitiveness is needed to develop effective and economic control measure.

**Materials and Methods**

A field experiment was conducted during rabi seasons of 2010-11 and 2011-12 at the Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh). The soil of experimental field was clayey in texture, low in nitrogen, medium in phosphorus and high in potassium contents with neutral pH. The experiment was laid out in Split Plot Design with three replications (Gomez and Gomez 1984). The treatments were divided into main and sub plots (tillage and weed management practices). Three tillage practices viz. conventional tillage (T1), minimum tillage (T2) and zero tillage (T3) in main plot Most mechanical weed control methods, such as hoeing, tillage, harrowing, torsion weeding, finger weeding and brush weeding, are used at very early weed growth stages (Singh, 2014; Kewat, 2014), and nine weed management practices as pendimethalin @ 1000 g ha\(^{-1}\) PE (W1), imazethapyr @ 80 g ha\(^{-1}\) PE (W2), imazethapyr @ 90 g ha\(^{-1}\) PE (W3), imazethapyr @ 100 g ha\(^{-1}\) PE (W4) at 2 DAS, imazethapyr @ 70 g ha\(^{-1}\) POE (W5), imazethapyr @ 80 g ha\(^{-1}\) POE (W6), imazethapyr @ 90 g ha\(^{-1}\) POE (W7) at 20 DAS, one hand weeding at 20 DAS (W8) and weedy check (W9), in sub plots. Removing weeds or patch of weeds by hand is often the most effective way to prevent that weed from spreading and therefore from becoming a
serious problem (Zimdhal, 2007). The N, P, K through diamonium phosphate and muriate of potash were applied as basal at sowing of the crop. Fertilizers alter the nutrient level in the agro-ecosystems and therefore they may directly affect weed population dynamics and crop weed competitions (Robert et al., 2004; Babu and Jain, 2012).

Strong effects can be observed by manipulating fertilizer timing, dosage, and placement in order to reduce weed interference in crops (Dubey, 2014). Placement of fertilizer significantly reduced the density and dry biomass of weed and produced higher grain yield than broadcast method of fertilizer application (Pandey et al., 2006; Lodha et al., 2010). One protective irrigation gave at the time of sowing.

Optimum time and number of irrigation reduces the density and weight of weeds (Das and Yaduraju, 2007; Verma, 2014). The chickpea variety JG-226 was sown as test crop in 2nd fortnight of November 2010 and 2011 and harvesting was done in 1st fortnight of March 2011 and 2012, respectively.

**Nitrogen uptake by crop and weeds**

The sample of crop and weeds grain and stover were dried in oven at 60°C till constant weight after sun drying. N content (%) was determined by Micro Kjeldahl method (Jackson, 1967). The nitrogen uptake was calculated for each treatment separately using the following formula.

\[
\text{Nitrogen uptake by grain} = \frac{\text{N Concentration} (%) \times \text{Grain yield (kg ha}^{-1})}{100}
\]

\[
\text{Nitrogen uptake by stover} = \frac{\text{N Concentration} (%) \times \text{Stover yield (kg ha}^{-1})}{100}
\]

The uptake of N was expressed in kg ha\(^{-1}\)

**Number of nodules plant\(^{-1}\)**

The number of nodules per plant were recorded at 20, 40 and 60 DAS. The roots removed from the 3 plants for root studies, were used to count the number of nodules. The nodules of each root were counted and mean value was noted as number of nodules plant\(^{-1}\).

**Microbial analysis**

**Population count study**

Bacterial and fungal population was counted by using serial dilution technique (Subba Rao, 1988). One gm of soil sample was suspended in 9 ml of sterile water in a dilution tube (Tuladhar, 1983) and shaken for 15 min. This constituted \(10^{-1}\) concentration. Using a fresh sterile pipette took 1 ml of this suspension and 9 ml sterile water was then added to get 10-2 dilution. The sequence was continued till a dilution of 10-7 was reached.

Different media was prepared for isolation of micro-organism. Thornton’s Asparagine Mannitol agar media (Thornton, 1922) for bacteria and Rose Bengal agar media (Martin, 1950) for fungi were used, which were sterilized at 121°C for 15 min. 1 ml of desired solution of freshly mixed suspension was transferred into the sterile petridish using sterile tip of micro-pipette. 10-3 to 10-5 dilutions for fungi and 10-5 to 10-7 dilutions for bacteria were used. Subsequently, about 15ml of partially cooled appropriate medium was poured into each plate and carefully swirl to thoroughly mix the contents (Plate 3b). After the media got solidified invert the plates and kept in an incubator at respective incubation temperature for different micro-organisms (28°C for fungi and 37°C for bacteria). After specified period of growth (48 hrs for bacteria and 96 hrs for fungi), colonies were counted and population was enumerated.
by using formula given by Schmidt and Caldwell, 1967.

\[
\text{Number of bacteria / fungi in 1gm soil = No. of CFU} \times \text{Dilution}
\]

\[
\text{Dry weight of 1 gm moist soil x aliquot taken}
\]

**Basal Soil Respiration study**

This study was conducted to know the respiration rate of microflora present in the crop rhizosphere soil. Basal soil respiration was calculated by measuring the CO\(_2\) evolution rates (Anderson, 1982). 100 g soil (oven dry basis) was taken in 1L conical flask. Then water is added to bring its moisture content to field capacity. 20 ml of 0.5N NaOH was taken in test tubes. The tubes were then hanged with the help of thread inside the conical flasks without touching the soil and kept the flasks air tight by rubber stoppers and note down the time. The flasks were kept in an incubator at 28\(^\circ\)C for about 20 hrs. After incubation test tubes were taken out from the flask and noted down the time to calculate the period of incubation from the time as noted down above. Immediately transferred the 0.5N NaOH solution from the test tube to a 150ml conical flask. Several washings of the tubes were done for complete transfer 5 ml of 3N BaCl\(_2\) solution and few drops of phenolphthalein indicator were added. Titrated the content with standard 0.5N H\(_2\)SO\(_4\) slowly until the pink colour just disappears. After getting the end point recorded the exact amount of acid required for titration.

Soil respiration (mg of CO\(_2\)/h/100g soil) = \((B-V)\) NE/ hours of incubation

Where,

- \(B\) = Volume of acid (ml) needed for the blank.
- \(V\) = Volume of acid (ml) needed for the NaOH exposed to soil.

\(N\) = Normality of acid.

\(E\) = Equivalent weight, *i.e.* 22.

**Dehydrogenase activity**

The procedure to evaluate the dehydrogenase activity of soil described by Klein *et al.*, (1971). 1 gm air dried soil sample was taken in a 15 ml airtight screw capped test tube. 0.2 ml of 3\% TTC solution was added in each of the tubes to saturate the soil. 0.5 ml of distilled water was also 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. No air bubbles were formed that was ensured. The tubes were incubated at 37\(^\circ\)C for 24 hrs. Then 10 ml of methanol was added. Shake it vigorously and allowed to stand for 6 hrs. Clear pink coloured supernatant was withdrawn and readings were taken with a spectrophotometer. The amount of TPF formed was calculated from the standard curve drawn in the range of 10 mg to 90 mg TPF/ml.

**Results and Discussion**

**Nitrogen uptake by crop and weeds**

Data on quality parameters viz. nitrogen uptake table 2 indicated substantial variations due to tillage and weed management practices. The differences with respect to the nitrogen uptake were significant. Conventional tillage was found to contain maximum N uptake (by crop 29.66 kg ha\(^{-1}\) nitrogen and by weed 33.72 kg ha\(^{-1}\) nitrogen) and significantly higher than minimum and zero tillage during both the years. Hand weeding further excel all other treatments with respect to N uptake as it took maximum N uptake by crop (33.56 kg ha\(^{-1}\) nitrogen) and weeds (17.25 kg ha\(^{-1}\) nitrogen), which was significantly superior over pre-emergence and post-emergence herbicides (pendimethalin...
and imazethapyr) and weedy check plot. The weed-free treatment had more nitrogen uptake in grain and stalk than the weedy check during both the years. This was simply because of low shoot dry-matter production and low availability of these nutrients, as major amounts of nutrient were depleted by weeds. In weedy treatments, 37.5 kg N, 11.6 kg P and 38.3 kg K/ha were depleted in comparison to full-season weed-free conditions. The results are in conformity with the findings of Vengris et al., (1953), who reported vigorous growth and higher biomass of weeds resulted in more nutrient depletion.

### Number of nodules plant⁻¹

The tillage and weed management practices significantly influenced the number of nodules per plant at all the growth stages of chickpea crop except 20 DAS during both the years. Tillage practices enhanced the number of nodules per plant significantly in chickpea during all the stages of crop growth. Conventional tillage proved to be favourable for producing significantly greater number of root nodules and it was followed by minimum and zero tillage, in descending order, in both the years. The treatment of one hand weeding at 20 DAS (W8) superseded all the herbicidal treatments with respect to maximum nodulation, as it contains 10.56, 26.33 and 38.75 root nodules per plant at 20, 40, 60 DAS, respectively. Among the herbicidal treatments, imazethapyr @ 90 g ha⁻¹ POE (W7) produced significantly greater number of nodules per plant as compared to other treatments at all the growth stages during both the years. The treatments of imazethapyr @ 80 and 70 g ha⁻¹ as post-emergent were next, in order, and produced statistically greater number of nodules as compared to weedy check. Other herbicidal treatments also proved better than weedy check at all the growth stages under study during both the years (Table 3). Hand-weeding twice recorded the maximum number of nodules/plant. Ahlawat et al., (1985). All the weed-control treatments proved superior to the unweeded check treatment. Hand weeding at 25 and 45 days was found most promising. Malik et al., (1988) also reported similar results. Results indicated that inter-culture + hand weeding done at 20 and 40 DAS recorded significantly higher nodulation as compared to rest of the treatments except pendimethalin @ 0.75 kg/ha. Similar results were also reported by Singh and Singh (1998), wherein, they found the highest nodulation in hand weeded plot and the lowest in fluchloralin treated plot. These results are in agreement with the results of Rajput et al., (1998) who observed higher nodule weight under hand weeded and pendimethalin application over unweeded control in chickpea.

### Micro-flora studies

#### Bacterial population study

The result on total bacterial population on rhizosphere soil as affected by different tillage and weed management practices were recorded at definite interval and tabulated in table 1.

In rice-chickpea cropping sequence, the bacterial population study as affected by different tillage management practices, which indicated that tillage system did not impart any effect on bacterial population after harvest of the crop. Similar findings were also reported by Singh et al., (2007) who clearly mentioned that relatively higher availability of soil organic matter at lower soil profile under conventional tillage may be due to even distribution of crop residues and other nutrients throughout the plough zone. This may possibly account for observed higher counts of soil microflora at lower (7.5-15cm.) soil zone under conventional tillage than the
minimum tillage. Brady (1985) reported that tillage facilitates the aeration of soil hence the microbial population increases. Singh et al., (2007) also found higher microbial populations under conventional tillage system at lower soil depth (7.5-15 cm.). Janusauskaite et al., (2013) demonstrated that bacteria and fungi decreased in no tillage system by 25.5 and 22.7%, respectively in comparison to conventional tillage.

It can be concluded that conventional tillage system provides stimulating effects for microbial growth due to uniformly distributed residues in the arable layer and increases the rate of supplied oxygen to soil micro sites. The data related to total bacterial population in rice-chickpea cropping sequence revealed that among the different weed management practices, one hand weeding at 20 DAS was found effective to increase bacterial population superior over other treatments under study. These observations are in close agreement with Singh (1990) who reported that population of bacteria were affected with pre and post emergence application of herbicides and these adverse effects gradually reduced with passage of time. Sebiomo et al., (2010) who found that the herbicide treatments had significant effect on percent organic matter of the soils treated with herbicides, which reduced significantly as compared to control. The total bacterial population in rhizosphere soil of chickpea found significantly lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth period of crop.

| Treatments                        | Days after sowing | At harvest |
|-----------------------------------|-------------------|------------|
|                                   | 2010-2011 | 2011-2012 | Mean   | 2010-2011 | 2011-2012 | Mean   |
| **Main Plot: Tillage management** |         |           |        |           |           |        |
| T1: Conventional                  | 0.708     | 0.344     | 0.526  | 2.379     | 1.228     | 1.804  |
| T2: Minimum                       | 0.667     | 0.331     | 0.499  | 2.360     | 1.124     | 1.742  |
| T3: Zero                          | 0.582     | 0.328     | 0.455  | 2.355     | 1.015     | 1.685  |
| S Em + CD (P = 0.05)              | 0.043     | 0.005     | 0.030  | 0.060     |           |        |
| **Sub Plot: Weed management**     |         |           |        |           |           |        |
| W1: Pendimethalin @ 1000 g/ha PE  | 0.650     | 0.403     | 0.527  | 2.278     | 1.160     | 1.719  |
| W2: Imazethapyr @ 80 g/ha PE      | 0.654     | 0.463     | 0.559  | 2.331     | 1.183     | 1.757  |
| W3: Imazethapyr @ 90 g/ha PE      | 0.656     | 0.304     | 0.480  | 2.234     | 1.177     | 1.706  |
| W4: Imazethapyr @ 100 g/ha PE     | 0.650     | 0.250     | 0.450  | 2.178     | 1.161     | 1.670  |
| W5: Imazethapyr @ 70 g/ha POE     | 0.657     | 0.312     | 0.485  | 2.424     | 1.150     | 1.787  |
| W6: Imazethapyr @ 80 g/ha POE     | 0.659     | 0.176     | 0.418  | 2.314     | 0.998     | 1.656  |
| W7: Imazethapyr @ 90 g/ha POE     | 0.647     | 0.143     | 0.395  | 2.144     | 0.888     | 1.516  |
| W8: One hand weeding at 20 DAS    | 0.650     | 0.476     | 0.563  | 2.638     | 1.163     | 1.901  |
| W9: Weedy Check                   | 0.652     | 0.483     | 0.568  | 2.644     | 1.220     | 1.932  |
| S Em + CD (P = 0.05)              | 0.074     | 0.098     | 0.175  | 0.175     |           |        |

Table 1 Effect of tillage practices and weed control measures on total bacterial population (X 10^7 g^-1 soil) of rhizosphere soil at different growth stages of chickpea after harvest of rice
Table 2. Nitrogen uptake by chickpea after harvest of rice as influenced by different tillage and weed management practices

| Treatments                      | N Uptake (Kg ha⁻¹) |                      |                   |                      |                   |
|---------------------------------|---------------------|----------------------|-------------------|----------------------|-------------------|
|                                 | Crop                | weed                 |                   |                      |                   |
|                                 | 2010-2011 | 2011-2012 | Mean | 2010-2011 | 2011-2012 | Mean |
| Main Plot: Tillage management   |                      |                      |                   |                      |                   |
| T1: Conventional                | 31.17               | 28.14                | 29.66             | 34.98               | 32.45             | 33.72             |
| T2: Minimum                     | 28.61               | 25.59                | 27.10             | 33.02               | 29.88             | 31.45             |
| T3: Zero                        | 25.33               | 22.66                | 23.99             | 30.90               | 27.53             | 29.21             |
| S Em ± CD (P = 0.05)            | 0.94                | 0.94                 | 1.02              | 1.22                |                   |                   |
| Sub Plot: Weed management       |                      |                      |                   |                      |                   |
| W1: Pendimethalin @ 1000 g/ha PE| 26.83               | 24.48                | 25.66             | 31.09               | 29.46             | 30.28             |
| W2: Imazethapyr @ 80 g/ha PE    | 24.62               | 22.15                | 29.39             | 30.25               | 27.66             | 28.96             |
| W3: Imazethapyr @ 90 g/ha PE    | 26.47               | 23.79                | 25.13             | 32.37               | 29.67             | 31.02             |
| W4: Imazethapyr @ 100 g/ha PE   | 29.58               | 26.47                | 28.03             | 34.40               | 31.35             | 32.88             |
| W5: Imazethapyr @ 70 g/ha POE   | 30.48               | 27.36                | 28.92             | 35.74               | 32.46             | 34.10             |
| W6: Imazethapyr @ 80 g/ha POE   | 32.01               | 28.72                | 30.37             | 34.30               | 30.65             | 32.48             |
| W7: Imazethapyr @ 90 g/ha POE   | 33.22               | 29.72                | 31.47             | 33.65               | 28.74             | 31.19             |
| W8: One hand weeding at 20 DAS  | 35.52               | 31.59                | 33.56             | 18.12               | 16.38             | 17.25             |
| W9: Weedy Check                 | 16.58               | 14.90                | 15.74             | 46.77               | 43.20             | 44.99             |
| S Em ± CD (P = 0.05)            | 1.54                | 1.54                 | 1.42              | 1.46                |                   |                   |
|                                 | 4.37                | 4.37                 | 4.03              | 4.16                |                   |
**Table.3** Number of nodules plant$^{-1}$ of chickpea after the harvest of rice at different growth stages as influenced by Different tillage and weed management practices

| Treatments | 20 DAS | 40 DAS | 60 DAS |
|------------|--------|--------|--------|
|            | 2010-2011 | 2011-2012 | Mean | 2010-2011 | 2011-2012 | Mean | 2010-2011 | 2011-2012 | Mean |
| **Main Plot: Tillage management** | | | | | | | | | |
| T$_1$: Conventional | 11.06 | 9.08 | 10.07 | 23.41 | 20.26 | 21.84 | 32.24 | 30.09 | 31.17 |
| T$_2$: Minimum | 10.44 | 8.53 | 9.49 | 21.82 | 18.28 | 20.05 | 30.43 | 27.85 | 29.14 |
| T$_3$: Zero | 10.23 | 8.37 | 9.30 | 20.82 | 16.72 | 18.77 | 29.39 | 25.80 | 27.60 |
| S Em + CD (P = 0.05) | 0.37 | 0.35 | 0.59 | 0.51 | 0.64 | 0.97 |
| **Sub Plot: Weed management** | | | | | | | | | |
| W$_1$: Pendimethalin @ 1000 g/ha PE | 10.04 | 8.32 | 9.18 | 18.92 | 16.36 | 17.64 | 27.64 | 24.24 | 25.94 |
| W$_2$: Imazethapyr @ 80 g/ha PE | 8.58 | 7.86 | 8.22 | 18.68 | 14.65 | 16.67 | 26.49 | 22.64 | 24.57 |
| W$_3$: Imazethapyr @ 90 g/ha PE | 9.64 | 7.89 | 8.77 | 19.76 | 17.89 | 18.83 | 28.09 | 25.84 | 26.97 |
| W$_4$: Imazethapyr @ 100 g/ha PE | 10.02 | 8.30 | 9.16 | 21.26 | 18.89 | 20.08 | 30.04 | 28.56 | 29.30 |
| W$_5$: Imazethapyr @ 70 g/ha POE | 10.44 | 8.54 | 9.49 | 23.90 | 20.26 | 22.08 | 32.53 | 29.44 | 30.99 |
| W$_6$: Imazethapyr @ 80 g/ha POE | 11.06 | 9.12 | 10.09 | 24.98 | 20.81 | 22.90 | 34.76 | 32.61 | 33.69 |
| W$_7$: Imazethapyr @ 90 g/ha POE | 11.50 | 9.27 | 10.39 | 26.60 | 21.59 | 24.10 | 35.82 | 33.75 | 34.79 |
| W$_8$: One hand weeding at 20 DAS | 11.80 | 9.31 | 10.56 | 29.48 | 23.18 | 26.33 | 40.98 | 36.52 | 38.75 |
| W$_9$: Weedy Check | 12.12 | 9.34 | 10.73 | 14.58 | 12.51 | 13.55 | 19.82 | 17.60 | 18.71 |
| S Em + CD (P = 0.05) | 0.58 | 0.59 | 0.94 | 0.66 | 1.00 | 1.20 |
| **CD (P = 0.05)** | 1.65 | 1.68 | 2.67 | 1.87 | 2.84 | 3.41 |
**Table 4** Effect of tillage practices and weed control measures on Basal soil respiration (mg CO$_2$/h/100g soil) Of rhizosphere soil at different growth stages of chickpea after harvest of rice

| Treatments                              | Days after sowing |                      |                      |                      |                      |                      |                      |                      |
|-----------------------------------------|-------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
|                                         | 10                | 30                   | 50                   | At harvest           |                      |                      |                      |                      |
|                                         | 2010-2011         | 2011-2012            | Mean                 | 2010-2011            | 2011-2012            | Mean                 | 2010-2011            | 2011-2012            | Mean                 |
| **Main Plot: Tillage management**       |                   |                      |                      |                      |                      |                      |                      |                      |                      |
| T$_1$: Conventional                     | 0.243             | 0.238                | 0.241                | 0.339                | 0.294                | 0.317                | 0.310                | 0.300                | 0.305                |
| T$_2$: Minimum                          | 0.226             | 0.221                | 0.224                | 0.319                | 0.288                | 0.304                | 0.296                | 0.286                | 0.291                |
| T$_3$: Zero                             | 0.208             | 0.202                | 0.205                | 0.299                | 0.276                | 0.288                | 0.277                | 0.267                | 0.272                |
| S Em + CD (P = 0.05)                    | 0.002             | 0.006                | 0.009                | 0.009                | 0.009                | NS                   | NS                   | 0.002                | 0.002                |
| **Sub Plot: Weed management**           |                   |                      |                      |                      |                      |                      |                      |                      |                      |
| W$_1$: Pendimethalin @ 1000 g/ha PE     | 0.151             | 0.139                | 0.145                | 0.329                | 0.295                | 0.312                | 0.404                | 0.394                | 0.399                |
| W$_2$: Imazethapyr @ 80 g/ha PE         | 0.165             | 0.151                | 0.158                | 0.335                | 0.300                | 0.318                | 0.411                | 0.399                | 0.405                |
| W$_3$: Imazethapyr @ 90 g/ha PE         | 0.149             | 0.144                | 0.147                | 0.328                | 0.293                | 0.311                | 0.399                | 0.389                | 0.394                |
| W$_4$: Imazethapyr @ 100 g/ha PE        | 0.146             | 0.141                | 0.144                | 0.321                | 0.290                | 0.306                | 0.387                | 0.375                | 0.381                |
| W$_5$: Imazethapyr @ 70 g/ha POE        | 0.299             | 0.288                | 0.294                | 0.296                | 0.263                | 0.280                | 0.195                | 0.194                | 0.195                |
| W$_6$: Imazethapyr @ 80 g/ha POE        | 0.293             | 0.281                | 0.287                | 0.288                | 0.256                | 0.272                | 0.194                | 0.185                | 0.190                |
| W$_7$: Imazethapyr @ 90 g/ha POE        | 0.233             | 0.271                | 0.252                | 0.281                | 0.250                | 0.266                | 0.196                | 0.184                | 0.190                |
| W$_8$: One hand weeding at 20 DAS       | 0.294             | 0.285                | 0.290                | 0.344                | 0.310                | 0.327                | 0.217                | 0.205                | 0.211                |
| W$_9$: Weedy Check                      | 0.298             | 0.286                | 0.292                | 0.349                | 0.318                | 0.334                | 0.244                | 0.233                | 0.239                |
| S Em + CD (P = 0.05)                    | 0.004             | 0.009                | 0.013                | 0.013                | 0.014                | 0.014                | 0.004                | 0.004                | 0.004                |

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**Table 5** Effect of tillage practices and weed control measures on Dehydrogenase activity (µg TPF/h/g soil) of rhizosphere soil at different growth stages of chickpea after harvest of rice.

| Treatments                        | Days after sowing | At harvest |
|-----------------------------------|-------------------|------------|
|                                   | 10  | 30  | 50  |           |           |
|                                   | 2010-2011 | 2011-2012 | Mean | 2010-2011 | 2011-2012 | Mean | 2010-2011 | 2011-2012 | Mean |
| **Main Plot: Tillage management** |     |     |     |           |           |       |       |           |           |     |
| T<sub>1</sub>: Conventional       | 12.76 | 10.73 | 11.75 | 32.53 | 30.47 | 31.50 | 55.76 | 52.10 | 53.93 | 29.42 | 25.74 | 27.58 |
| T<sub>2</sub>: Minimum            | 10.74 | 8.71  | 9.73  | 30.56 | 28.44 | 29.50 | 53.54 | 50.21 | 51.88 | 28.31 | 25.66 | 26.99 |
| T<sub>3</sub>: Zero               | 8.77  | 6.72  | 7.75  | 28.56 | 26.46 | 27.51 | 52.87 | 49.10 | 50.99 | 26.25 | 24.52 | 25.39 |
| **S Em + CD (P = 0.05)**          | 0.28  | 0.22  | 1.08  | 1.01  | 1.66  | 0.84  | 0.81  | 0.31  |       |       |       |     |
|                                   | 1.09  | 0.87  | 4.24  | 3.97  |       |       |       |       |       |       |     |
| **Sub Plot: Weed management**     |     |     |     |           |           |       |       |           |           |     |
| W<sub>1</sub>: Pendimethalin @ 1000 g/ha PE | 9.34 | 7.17 | 8.26 | 26.45 | 24.21 | 25.33 | 72.15 | 68.93 | 70.54 | 29.06 | 29.02 | 29.04 |
| W<sub>2</sub>: Imazethapyr @ 80 g/ha PE | 10.36 | 8.34 | 9.35 | 27.42 | 25.32 | 26.37 | 75.09 | 71.84 | 73.47 | 30.96 | 28.15 | 29.56 |
| W<sub>3</sub>: Imazethapyr @ 90 g/ha PE | 8.03  | 6.16  | 7.10  | 25.31 | 23.14 | 24.23 | 71.53 | 66.69 | 69.11 | 28.88 | 25.98 | 27.43 |
| W<sub>4</sub>: Imazethapyr @ 100 g/ha PE | 8.00  | 6.09  | 7.05  | 23.47 | 21.27 | 22.37 | 68.17 | 60.83 | 64.50 | 27.89 | 25.02 | 26.46 |
| W<sub>5</sub>: Imazethapyr @ 70 g/ha POE | 12.20 | 10.12 | 11.16 | 12.14 | 10.10 | 11.12 | 11.14 | 9.21  | 10.18 | 25.08 | 22.44 | 23.76 |
| W<sub>6</sub>: Imazethapyr @ 80 g/ha POE | 12.22 | 10.16 | 11.19 | 10.06 | 9.34  | 9.70  | 9.61  | 8.49  | 9.05  | 22.03 | 19.28 | 20.66 |
| W<sub>7</sub>: Imazethapyr @ 90 g/ha POE | 12.21 | 10.15 | 11.18 | 8.14  | 7.21  | 7.68  | 7.75  | 6.36  | 7.06  | 21.14 | 18.93 | 20.04 |
| W<sub>8</sub>: One hand weeding at 20 DAS | 12.22 | 10.14 | 11.18 | 68.83 | 65.16 | 67.00 | 79.73 | 74.83 | 77.28 | 32.78 | 28.97 | 30.88 |
| W<sub>9</sub>: Weedy Check       | 12.22 | 10.15 | 11.19 | 73.13 | 70.36 | 71.75 | 91.31 | 87.03 | 89.17 | 34.11 | 30.01 | 32.06 |
| **S Em + CD (P = 0.05)**          | 0.46  | 0.38  | 1.62  | 1.53  | 2.65  | 1.38  | 2.02  |       | 1.25  | 0.54  |       |     |
|                                   | 1.32  | 1.08  | 4.62  | 4.36  | 7.53  | 3.91  |       |       |       |       |       |     |
Microbiological study (Basal soil respiration)

The observations on Basal Soil Respiration (BSR) as influenced by different tillage and weed management practices were recorded at definite intervals and the data tabulated in table 4.

In rice-chickpea cropping sequence, it is revealed from the result that the BSR rate continuously increased from sowing of the crop to 50 DAS and there after narrowed down a little upto harvest. The respiration rate was found maximum in conventional tillage and minimum in zero tillage in all the growth stages of crop. Conventional tillage was found significantly superior over minimum and zero tillage at 10 DAS. However, it was found only significant over zero tillage at 30 DAS. From 50 DAS onwards non-significant variation was observed in BSR due to application of different tillage systems. This observation is a close proximity with Singh et al., (2007), who found at lower depth soil (7.5-15 cm) under conventional tillage were found to show significantly higher respiration rate at post germination stage of crop. Loudyi et al., (1999) also expressed similar views and mentioned that basal soil respiration is usually higher under conventional tillage than under zero tillage, resulting in higher specific respiration under conventional tillage than under zero tillage.

The data showed that there was an increase in BSR rate from 0 to 50 DAS followed by a decrease upto harvest stage in hand weeded and weedy check plots. Under rice-chickpea cropping sequence application of imazethapyr at different doses and pendimethalin @ 1000 g ha\(^{-1}\) significantly reduced the BSR rate soon after their application. The toxic effect of these chemicals was traced upto 10 DAS and there after a gradual increment BSR rate was noticed, which seems that the applied herbicides of pre-emergence stage started to degrade before 30 DAS. Higher dose of imazethapyr significantly reduced the BSR values over its lowest dose. However, effect of pendimethalin was found in between @ 80 and 90 g ha\(^{-1}\) dose of imazethapyr. The post-emergence application of imazethapyr exhibited its effect soon after its application and highest reduction in BSR rate was noticed at 50 DAS followed by 30 DAS. With the increasing doses of imazethapyr the BSR values had shown a decreasing trend at 50 DAS the post-emergence application of imazethapyr was found effective to reduce the BSR values in comparison to its application of pre-emergence stage. Sebiomo et al., (2010) who found that the herbicide treatments had significant effect on percent organic matter of the soils treated with herbicides, which reduced significantly as compared to control. The basal soil respiration in rhizosphere soil of chickpea found significantly lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth period of crop.

Biochemical study (dehydrogenase enzyme activity)

The result on Dehydrogenase activity (DA) as affected by different tillage and weed management practices were recorded at definite interval and tabulated in table 5.

The data showed that in rice-chickpea cropping sequence, there was an increase in dehydrogenase enzyme activity (DHA) in chickpea rhizosphere soil from 0 to 50 DAS followed by a decrease upto harvest was noticed in all the tillage practices. Effect of different tillage systems significantly varied upto 30 DAS and there after all the tillage practices found statistically equal. Highest DHA was observed in conventional tillage and lowest in zero tillage. Conventional tillage was found significantly superior over
minimum and zero tillage system at 10 DAS. However, it was only significant over zero tillage at 30 DAS. The above study indicated that effect of tillage existed upto 30 DAS and after that due to settlement of soil particles, all the tillage system found equal. This observation is a close agreement with Chowdhury et al., (2014), who concluded that in conventional tillage system. Ferreira et al., (2000) also reported relatively higher availability of soil organic matter at lower soil organic matter at lower soil profile under conventional tillage which may be due to even distribution of crop residues and other nutrients throughout the plough zone.

In soil enzymatic study it was found that the dehydrogenase activity was found significantly higher in conventional tillage treatments compared to other tillage treatments. The activity was found lowest under zero tillage treatment. Mijangos et al., (2005) also concluded that biological parameters have great value as early and sensitive indicator of change in soil properties induced by different soil management strategies.

The data related to DHA in rice-chickpea cropping sequence revealed that the pre-emergence application of pendimethalin and imazethapyr significantly reduced DHA soon after their application and their effect on DHA was visualized upto 10 DAS. From 30 DAS onwards the DHA was shown an increasing trend, which may be due to the degradation of applied herbicide after 10 DAS. When imazethapyr was applied at post-emergence stage its toxic effect was noticed upto 50 DAS after its application i.e. 20 DAS. It was also observed that the DHA reduced with the increasing doses of imazethapyr, when applied at pre and post emergence stage. Application of pendimethalin @ 1000 g ha$^{-1}$ had shown a value of DHA, which was intermediate between @ 80 and 90 g ha$^{-1}$, imazethapyr at pre-emergence level. One hand weeding practice was found significantly superior over herbicide applied plots in all the growing stages of crop except harvest stage.

Shukla and Mishra (1997) also reported similar type of result who found dehydrogenase activity tended to decrease on pre and post emergence application, but the end of the experimentation it recovered and even increased many folds. Sebiomo et al., (2010) who found that the herbicide treatments had significant effect on percent organic matter of the soils treated with herbicides, which reduced significantly as compared to control. The dehydrogenase enzyme activity in rhizosphere soil of chickpea found significantly lower in herbicide treated plots compared to hand weeded and weedy check plots in all the growth period of crop.

This might be due to available substrate and aerobic environment in soil ecosystem. Tripathi et al., (1993) also reported the similar results.

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