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Bioefficacy of Imazthapyr on N Uptake, Nodulation and Microbial Population of Chickpea Sown after Soybean in Chhattisgarh Plains

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A B S T R A C T

A field investigation was carried out during the winter season of 2010-11 and 2011-12 at the Agronomy Research Farm of IGKV, Raipur, to evaluate the effect of tillage and weed management practices on chickpea crop. 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.

Introduction

Chickpea (*Cicer arietinum* L.) ranks as the third most important annual major food grain legume in the world after dry bean and peas (Singh and Saxena, 1999). Global chickpea area is 10.94 M ha with production of 8.59 M tones and productivity of 786 kg ha^{-1}. It is also known as gram or Chana. Chickpea belongs to the leguminoceae family and mostly grown in rabi season (Oct-Nov to Feb-March). In India, chickpea is cultivated on 6.93 M ha with production of 5.60 M tonnes (GOI, 2007). 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. 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. The yield and productivity of

chickpea is influenced by various production constraints such as biotic and abiotic factors. Biotic constraints wilt, dry root rot and blight are the major. Weed is a plant growing where it is not desirable, declines yield production and quality of crop plants and leads to higher cost in food production (Pandya *et al.,* 2005). Therefore, weed control is one of the most important aspects of crop production in agricultural systems. Weed control is usually done by different methods including tillage, which may have their effect on weed population affecting soil moisture or soil seed bank dynamics during pulverizing the soil seed bed preparation. Tillage and/or herbicides are used for weed control, but the degree of control achieved may vary widely depending on weed species present, soil type, climatic condition, crop grown, tillage method and cropping system (Unger *et al.,* 1999). Continuous cropping of grain cereals has been common practice in northern New South Wales. This form of cropping has resulted in a depletion of soil organic carbon and nitrogen and decreased crop yields, grain protein contents and financial returns to producers (Horn *et al.,* 1996). Pulse crops have been incorporated into a rotation to avoid these losses while providing a disease and pest break. Crop rotations, when well managed, can contribute greatly to reduce the weed infestation. In the Mediterranean region, chickpea is commonly grown in two-course or three-course rotations with cereals and fallow or summer crop (Saxena, 1987). 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. To date there is only one Post-emergence herbicide registered for broadleaf weed control in chickpea, i.e. Pyridate, but this chemical controls only a relatively narrow weed spectrum. Registered Pre-emergence herbicides are available, e.g. simazine plus prometryn, cyanazine and metribuzin but these are expensive and their residues may be associated with reductions in crop yield (Rummery *et al.,* 1996). Hence, it has the potential to control mixed weed flora when applied as pre and post-emergence. Performance of imazethapyr in chickpea as pre and post-emergence has yet not been assessed in chhattisgarh. Generally herbicides are not harmful when applied in recommended levels in soil (Selvamani and Sankaran,1993), but reports are there which envisaged that herbicidal application has adverse effect on bacterial, actinomycetes (Rajendran and Lourduraj, 1999) fungal population (Shukla, 1997). Different cultural techniques affect soil productivity, contrasting tillage practices have been shown to alter the chemical and microbial properties of soils, which is supposed to create a great impact on agricultural production (Ferreira *et al.,* 2000).

Maximum growth of different microorganisms was recorded under conventional-conventional tillage system, whereas minimum zero-zero tillage system. Pre-emergence herbicide suppressed the microbial population between 0 to 10 days after emergence of rice plant (DAE), whereas post emergence herbicide inhibited the microbial population for a period of 10 days between 20 to 30 DAE. In weedy check, the microbial population was found significantly higher over other weed management practices in most of the cases.

To begin the process of developing weed management system with new herbicide for chickpea, a great deal of information is required, and initially crop development strategies need to be modified, so that weeds are considered part of the agronomic strategies.

Materials and Methods

The field trial was conducted to study the bioefficacy of imazethapyr on n uptake, nodulation and microbial population of chickpea sown after soybean in chhattisgarh plains during the winter seasons of 2010-11 and 2011-12 at the Research cum Instructional Farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.). 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 (T_1), minimum tillage (T_2) and zero tillage (T_3) in main plot and nine weed management practices as pendimethalin @ 1000 g ha^{-1} PE (W_1), imazethapyr @ 80 g ha^{-1} PE (W_2), imazethapyr @ 90 g ha^{-1} PE (W_3), imazethapyr @ 100 g ha^{-1} PE (W_4) at 2 DAS, imazethapyr @ 70 g ha^{-1} POE (W_5), imazethapyr @ 80 g ha^{-1} POE (W_6), imazethapyr @ 90 g ha^{-1} POE (W_7) at 20 DAS, one hand weeding at 20 DAS (W_8) and weedy check (W_9), in sub plots. The N, P, K through diamonium phosphate and muriate of potash were applied as basal at sowing of the crop. One protective irrigation gave at the time of sowing. 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 60^0C 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.

Nitrogen uptake by grain = N Concentration (%) in grain x Grain yield (kg ha^{-1}) / 100

Nitrogen uptake by stover = N Concentration (%) in stover x 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 was 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 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 for bacteria and Rose Bengal agar media (Martin, 1950) for fungi

were used, which were sterilized at 121^0C 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. 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).

Number of bacteria / fungi in 1gm soil =

$$\frac{\text{No. of CFU x Dilution}}{\text{Dry weight of 1 gm moist soil x aliquot taken}}$$

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°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 150 ml 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_2SO_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 CO2/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 as 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 37^0C 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 (kg ha^{-1})

The tillage and weed management practices significantly influenced the nitrogen uptake by crop and weeds in both the years. Among tillage management practices, maximum nitrogen uptake by crop and weeds was obtained under conventional tillage (51.41kg ha^{-1} nitrogen) and (35.69 kg ha^{-1} nitrogen) respectively, followed by minimum tillage (T_2) and zero tillage (T_3) respectively, in both the years. The improvement of soil physical properties, nutrient uptake and grain yield under conventional tillage has been reported by Tiwari (1997); Singh *et al.,* (1998); Pandey *et al.,* (2000); Rath *et al.,* (2000), Ray and Gupta (2001) and Sharma and Gangwar (2001). Creation of suitable condition for root growth and absorption of nutrients increased nutrient accumulation in grain and helped in increased uptake. Favourable effect of conventional tillage on nutrient absorption and translocation of chickpea has been also reported by Rath *et al.,* (2000).

Among the weed management practices, significant variation in N-uptake by crop and weeds was recorded. Nitrogen uptake by crop (57.94 kg ha^{-1} nitrogen) and lower by weeds (19.53 kg ha^{-1} nitrogen) was obtained under hand weeding followed by post-emergence application of imazethapyr over unweeded control plot. This might be due to lower weed competition in terms of dry matter of weeds which provides congenial environment for more availability of moisture and nutrient to crop and restrict removal of nutrients by weeds, which in turn lead to higher uptake of nutrients. The weed-free treatment had more nutrient uptake (N, P and K) in grain and stover 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. 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. Legumes are capable to fix atmospheric N through biological means (Vankessel *et al.,* 1985). This is possible because chickpea can increase the productivity both in terms of N saving from fertilizer source and build up soil fertility through biological source of N. Many studies revealed that nitrogenous compounds released mainly from the legume roots or on decomposition of the dead roots and nodule tissues could increase N supply (Ta and Faris, 1987; Ta *et al.,* 1989; Dubach &Russelle, 1994; Gill *et al.,* 2006) (Table 1).

Number of nodules plant^{-1}

Root nodulation pattern in chickpea was studied and the number of root nodules was counted at 20, 40 and 60 DAS. Nodules were small and elongate at initial stage of development and became bifurcate later on. The colour of nodule was light brown. The root nodules increased with the advancement of crop age upto 60 DAS. It was found that various tillage and weed management treatments exerted significant impact on number of nodules per plant mainly at 40 and 60 DAS. However, there was no significant impact of tillage and weed management on nodule formation at initial stage of crop i.e. at 20 DAS (Table 2).

Among the different tillage practices, conventional tillage was found to produce significantly greater number of nodules over minimum and zero tillage at 40 and 60 DAS.

Among the weed management treatments at 40 DAS, imazethapyr @ 90 g ha^{-1} POE (W_7) proved to be more effective in enhancing the number of nodules per plant as compared to other treatments. However, one hand weeding

at 20 DAS (W_8) was found more pronounced in producing number of nodules than herbicidal treatments at all the growth stages during both the years. Rest of the herbicidal treatments also produced significantly higher number of nodules than weedy check.

At 60 DAS, number of nodules counted was significantly higher under all the treatments of weed management as compared to weedy check. Remarkable variation in number of nodules under the treatments of pre and post emergence application of herbicides was noted, where, all the doses of imazethapyr as post-emergence produced significantly higher number of nodules as compared to different doses of herbicides applied as pre-emergent. Though treatment of one hand weeding at 20 DAS produced significantly higher number of nodules than all the treatments except W_7 (Imazethapyr @ 90 g ha^{-1} POE) and W_6 (Imazethapyr @ 80 g ha^{-1} POE), respectively, during both the years.

Increased number of root nodules $plant^{-1}$ in above treatments might be due to the favourable microclimate after suppression of weeds near the root zone of chickpea crop. Higher nodulation fixed the atmospheric nitrogen which ultimately supported in higher crop growth of chickpea. Furthermore, nodules count in the above treatments might be due to greater infection of *Rhizobium* in the growing roots. The increased in nodule number probably due to increased aeration of *Rhizosphere* in soil condition. Effective nodules are the sites of symbiotic nitrogen fixation. Higher number of effective nodules is an indication that more atmospheric nitrogen fixation in the crop. So, more nitrogen fixation may be due to more numbers of nodule formations (Thompson, 1977).

Thus the higher growth and growth parameters was observed under the application of hand weeding at 20 DAS, this might be due to better control of weeds, which resulted in lower accumulation of dry matter of weeds, lower crop weed competition associated with better availability of moisture and nutrients to the crop. Photosynthetic food material synthesized in the plant gets deposited in the different plant parts leading to enlargement and development of plant tissues. This causes gradual increment in dry matter. This was also due to the result of luxuriant crop growth, as indicated by higher plant height, higher dry matter production and its accumulation in different plant parts *viz.,* stem, leaves, pods and seed. This could be attributed to better control of weeds in early growth stages of crop which provided the crop plants optimum environment to utilize growth resources efficiently resulting in better growth of crop. Singh (2010) also reported the similar results

Micro-flora studies

Bacterial Population count study

In soybean-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 Doran (1980) and 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.) (Table 3 and Plate 1).

Table.1 Nitrogen uptake by chickpea after harvest of soybean 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						
T_1 : Conventional	53.41	49.11	51.41	36.69	34.70	35.69
T_2 : Minimum	49.59	43.19	46.39	33.50	31.64	32.57
T_3 : Zero	43.29	38.69	40.99	32.92	29.73	31.33
S Em+	0.94	1.13		0.94	1.13	
CD (P = 0.05)	**3.71**	**4.43**		**3.71**	**4.43**	
Sub Plot: Weed management						
W_1: Pendimethalin @ 1000 g/ha PE	46.68	40.08	43.38	34.82	32.70	33.76
W_2: Imazethapyr @ 80 g/ha PE	42.29	37.72	40.01	35.94	33.83	34.89
W_3: Imazethapyr @ 90 g/ha PE	46.78	41.94	44.36	34.98	32.79	33.89
W_4: Imazethapyr @ 100 g/ha PE	49.41	45.43	47.42	33.98	32.01	32.99
W_5: Imazethapyr @ 70 g/ha POE	52.29	46.94	49.62	32.80	30.89	31.85
W_6: Imazethapyr @ 80 g/ha POE	54.91	49.27	52.09	31.99	30.08	31.04
W_7: Imazethapyr @ 90 g/ha POE	56.97	50.98	53.98	30.89	27.87	29.38
W_8: One hand weeding at 20 DAS	60.89	54.98	57.94	21.01	18.04	19.53
W_9: Weedy Check	28.65	25.60	27.13	52.95	50.03	51.49
S Em+	1.36	1.34		1.36	1.34	
CD (P = 0.05)	**3.86**	**3.81**		**3.86**	**3.81**	

Table.2 Number of nodules plant^{-1} of chickpea after the harvest of soybean 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	12.13	10.99	11.56	25.76	22.29	24.03	34.67	32.01	33.34
T_2 : Minimum	11.27	10.20	10.74	24.13	19.97	22.05	32.03	30.21	31.12
T_3 : Zero	10.87	9.63	10.25	22.02	18.24	20.63	29.90	28.32	29.11
S Em±	0.39	0.40		0.77	0.56		0.98	0.68	
CD (P = 0.05)	**NS**	**NS**		**3.04**	**2.21**		**3.84**	**2.69**	
Sub Plot: Weed management									
W_1 : Pendimethalin @ 1000 g/ha PE	11.47	10.04	10.76	20.80	17.95	19.38	26.93	25.64	26.29
W_2 : Imazethapyr @ 80 g/ha PE	10.62	9.42	10.02	20.53	16.06	18.30	25.16	24.76	24.96
W_3 : Imazethapyr @ 90 g/ha PE	11.02	9.82	10.42	21.73	19.66	20.70	28.71	26.89	27.80
W_4 : Imazethapyr @ 100 g/ha PE	11.10	9.90	10.50	23.40	20.76	22.08	31.73	28.98	30.36
W_5 : Imazethapyr @ 70 g/ha POE	11.16	10.21	10.69	26.33	22.29	24.31	32.71	30.87	31.79
W_6 : Imazethapyr @ 80 g/ha POE	11.22	10.39	10.81	27.53	22.47	25.00	38.76	35.29	37.03
W_7 : Imazethapyr @ 90 g/ha POE	11.52	10.65	11.09	29.33	23.08	26.21	40.09	37.62	38.86
W_8 : One hand weeding at 20 DAS	12.31	11.00	11.66	32.53	25.53	29.03	43.91	40.76	42.34
W_9 : Weedy Check	12.34	11.02	11.68	16.53	13.67	15.10	21.78	20.82	21.30
S Em±	0.64	0.65		1.12	0.73		1.36	0.89	
CD (P = 0.05)	**NS**	**NS**		**3.17**	**2.08**		**3.86**	**2.56**	

Table.3 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 sown after harvest of soybean

Treatments	Days after sowing					
	At Initial			At harvest		
	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean
Main Plot: Tillage management						
T_1 : Conventional	4.612	2.804	3.708	6.189	4.797	5.493
T_2 : Minimum	4.596	2.798	3.697	6.170	4.783	5.477
T_3 : Zero	4.539	2.144	3.342	6.120	4.133	5.127
S Em±	0.019	0.169		0.019	0.171	
CD (P = 0.05)	**NS**	**NS**		**NS**	**NS**	
Sub Plot: Weed management						
W_1 : Pendimethalin @ 1000 g/ha PE	4.470	2.732	3.601	6.192	4.666	5.429
W_2 : Imazethapyr @ 80 g/ha PE	4.484	2.859	3.672	6.484	4.859	5.672
W_3 : Imazethapyr @ 90 g/ha PE	4.487	2.622	3.555	6.247	4.622	5.435
W_4 : Imazethapyr @ 100 g/ha PE	4.491	2.566	3.529	6.191	4.566	5.379
W_5 : Imazethapyr @ 70 g/ha POE	4.557	2.532	3.545	6.157	4.532	5.345
W_6 : Imazethapyr @ 80 g/ha POE	4.557	1.812	3.185	5.437	3.812	4.625
W_7 : Imazethapyr @ 90 g/ha POE	4.650	1.736	3.193	5.327	3.702	4.515
W_8 : One hand weeding at 20 DAS	4.771	3.146	3.959	6.671	5.146	5.909
W_9 : Weedy Check	4.774	3.232	4.003	6.734	5.232	5.983
S Em±	0.177	0.185		0.177	0.185	
CD (P = 0.05)	**NS**	**NS**		**NS**	**NS**	

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 sown after harvest of soybean

Treatments	Days after sowing											
	10			30			50			At harvest		
	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean
Main Plot: Tillage management												
T_1 : Conventional	0.260	0.251	0.256	0.346	0.339	0.343	0.361	0.400	0.381	0.296	0.293	0.295
T_2 : Minimum	0.239	0.228	0.234	0.328	0.320	0.324	0.340	0.330	0.335	0.294	0.289	0.292
T_3 : Zero	0.217	0.210	0.214	0.307	0.300	0.304	0.319	0.310	0.315	0.285	0.283	0.284
S Em±	0.006	0.006		0.009	0.008		0.009	0.03		0.002	0.002	
CD (P = 0.05)	**0.020**	**0.030**		**0.03**	**0.03**		**NS**	**NS**		**NS**	**NS**	
Sub Plot: Weed management												
W_1 : Pendimethalin @ 1000 g/ha PE	0.160	0.146	0.153	0.337	0.334	0.336	0.405	0.399	0.402	0.215	0.211	0.213
W_2 : Imazethapyr @ 80 g/ha PE	0.174	0.158	0.166	0.344	0.336	0.340	0.414	0.403	0.409	0.221	0.218	0.220
W_3 : Imazethapyr @ 90 g/ha PE	0.158	0.151	0.155	0.336	0.330	0.333	0.400	0.393	0.397	0.218	0.214	0.216
W_4 : Imazethapyr @ 100 g/ha PE	0.155	0.148	0.152	0.331	0.327	0.329	0.389	0.379	0.384	0.214	0.212	0.213
W_5 : Imazethapyr @ 70 g/ha POE	0.305	0.300	0.303	0.301	0.292	0.297	0.204	0.239	0.222	0.304	0.301	0.303
W_6 : Imazethapyr @ 80 g/ha POE	0.296	0.293	0.295	0.295	0.285	0.290	0.203	0.240	0.222	0.300	0.298	0.299
W_7 : Imazethapyr @ 90 g/ha POE	0.389	0.287	0.338	0.286	0.275	0.281	0.205	0.241	0.223	0.299	0.296	0.298
W_8 : One hand weeding at 20 DAS	0.303	0.292	0.298	0.353	0.347	0.350	0.418	0.409	0.414	0.426	0.421	0.424
W_9 : Weedy Check	0.307	0.293	0.300	0.359	0.355	0.357	0.420	0.417	0.419	0.428	0.426	0.427
S Em±	0.009	0.009		0.013	0.013		0.014	0.030		0.004	0.004	0.004
CD (P = 0.05)	**0.030**	**0.030**		**0.04**	**0.04**		**0.04**	**0.08**		**NS**	**NS**	

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 sown after harvest of soybean

Treatments	Days after sowing											
	10			30			50			At harvest		
	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean	2010-2011	2011-2012	Mean
Main Plot: Tillage management												
T_1: Conventional	17.53	15.25	16.39	35.36	33.68	34.52	58.59	56.20	57.40	33.73	32.38	33.06
T_2: Minimum	15.55	13.24	14.40	33.34	31.65	32.50	56.78	54.23	55.51	32.31	31.14	31.73
T_3: Zero	13.52	11.26	12.39	31.3	29.63	30.47	55.18	52.40	53.79	30.33	29.13	29.73
S Em±	0.42	0.36		1.16	1.10		1.92	1.74		0.87	0.83	
CD (P = 0.05)	**1.65**	**1.41**		**4.57**	**4.32**		**NS**	**NS**		**NS**	**NS**	
Sub Plot: Weed management												
W_1 : Pendimethalin @ 1000 g/ha PE	13.27	11.22	12.25	29.16	27.23	28.20	76.43	73.17	74.80	32.87	31.90	32.39
W_2 : Imazethapyr @ 80 g/ha PE	14.36	11.82	13.09	31.19	29.84	30.52	79.73	76.06	77.90	35.12	34.09	34.61
W_3 : Imazethapyr @ 90 g/ha PE	13.63	10.29	11.96	28.54	26.17	27.36	75.07	72.36	73.72	32.97	31.78	32.38
W_4 : Imazethapyr @ 100 g/ha PE	12.36	9.73	11.05	26.36	24.21	25.29	72.36	69.32	70.84	31.83	31.07	31.45
W_5 : Imazethapyr @ 70 g/ha POE	17.20	15.20	16.20	14.14	12.92	13.53	12.43	11.21	11.82	28.94	28.06	28.50
W_6 : Imazethapyr @ 80 g/ha POE	17.23	15.24	16.24	12.14	11.67	11.91	11.14	9.48	10.31	26.12	24.94	25.53
W_7 : Imazethapyr @ 90 g/ha POE	17.21	15.25	16.23	9.04	9.36	9.20	7.97	8.16	8.07	25.16	24.09	24.63
W_8 : One hand weeding at 20 DAS	17.24	15.23	16.24	72.24	69.19	70.72	83.39	79.36	81.38	37.00	35.07	36.04
W_9 : Weedy Check	17.29	15.26	16.28	77.21	74.30	75.76	93.14	89.36	91.25	39.11	36.91	38.01
S Em±	0.66	0.57		1.74	1.66		2.92	2.73		1.34	1.29	
CD (P = 0.05)	**1.87**	**1.62**		**4.94**	**4.71**		**8.30**	**7.76**		**NS**	**NS**	

Initial DHA value: 2010-11: 15.17 & 2011-12: 13.19

Plate.1 Study of microbial population in experimental soil

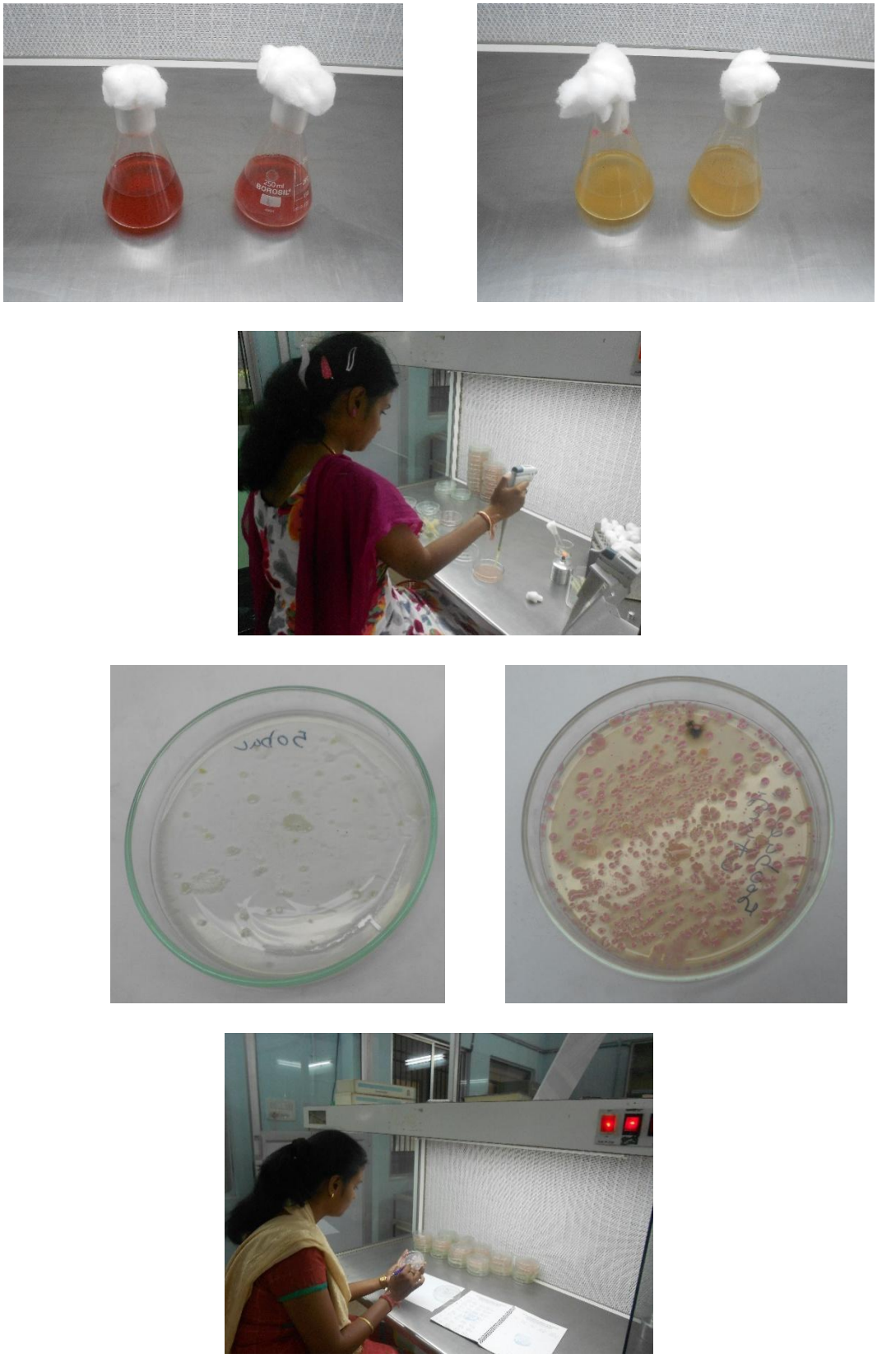
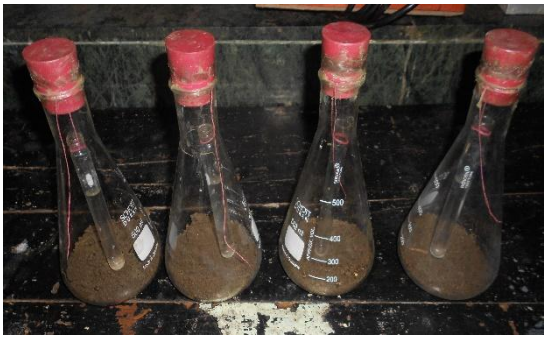


Plate.2 Measurement of microbial respiration by basal soil respiration study

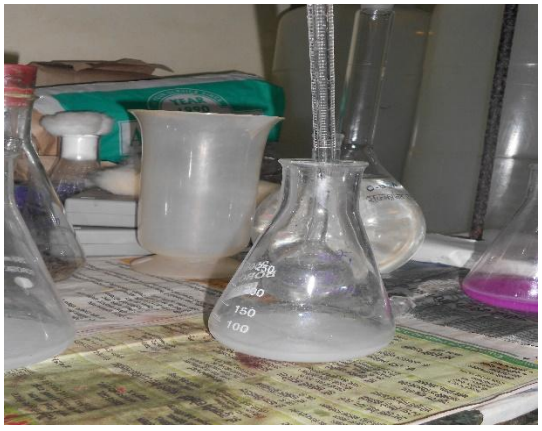
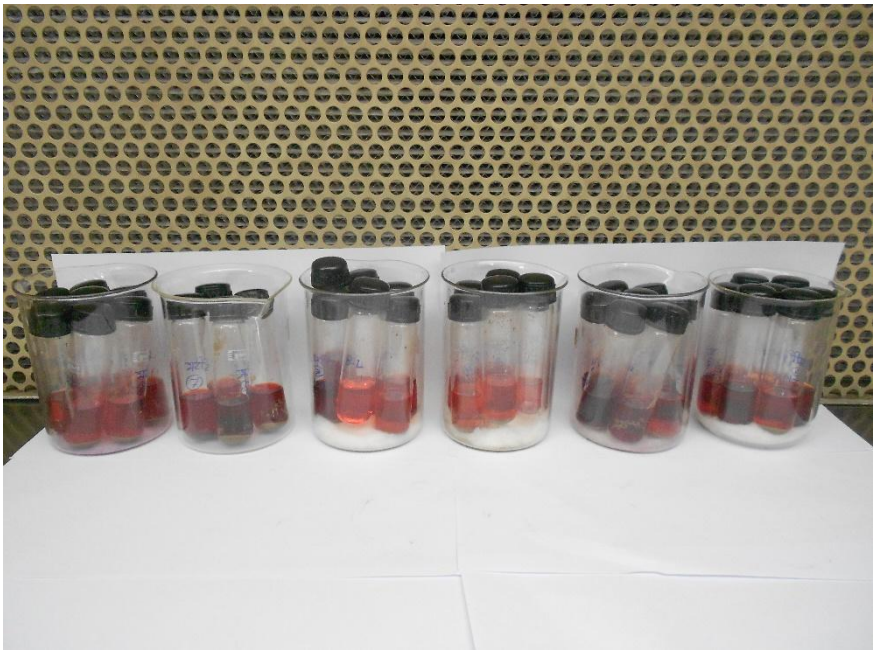



Plate.3 Dehydrogenase activity study



Variation in intensity of pink colour is an indicator of degree of dehydrogenase activity in soil

Plate.4 Study of herbicide degradation by measuring the dehydrogenase activity in soil

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 soybean-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. Kumar *et al.,* (1994) also revealed that the initial suppression of soil microflora upto 30 DAS of herbicide application recovered once again after 30 DAS. 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.

Microbiological study (Basal soil respiration)

In soybean-chickpea cropping sequence, it is revealed from the result that the BSR rate continuously increased from sowing of the crop upto 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. Luwayi *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 (Table 4 and Plate 2).

The data showed that there was an increase in BSR rate from 0 to 50 DAS followed by a decrease up to harvest stage in hand weeded and weedy check plots. Under soybean-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 data showed that in soybean-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 up to 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 exist. 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 (Table 5; Plate 3 and 4).

The data related to DHA in soybean-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.

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