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Effect of different weed management practices on activity of enzymes in groundnut and soybean crops during *kharif* season

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Abstract
A field experiment was conducted at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad [Northern Transition Zone (Zone 8) of Karnataka] on medium black clay soil during two consecutive *kharif* seasons (2015 and 2016), to know effect of different weed management practices on activity of enzymes in of groundnut and soybean crops during *kharif* season. The experiment consisted of two Main Plot treatments (Groundnut-cv JL 24 and Soybean-DSb 21) and eleven Sub-Plot treatments [Weed management practices involving five pre-emergence herbicides, (Alachlor 50 % EC @ 3.00 l ai/ha, Pendimethalin 30 % EC @ 1.00 kg ai/ha, Butachlor 50 % EC @ 1.00 kg ai/ha, Pendimethalin 38.7 CS @ 750 g ai/ha and Oxyfluorfen 23.5 % EC @ 100 g ai/ha), four post-emergence herbicides (Propaquizafop 10 % EC @ 100 g ai/ha, Quizalofop ethyl 5 % EC @ 50 g ai/ha, Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha and Imazethapyr 10 % SL @ 100 g ai/ha), weed free control treatment and weedy check control treatment] and was laid out in Split Plot Design with three replications during two consecutive *kharif* seasons (2015 and 2016). Weed management practices had significant effect on dehydrogenase, phosphatase and urease enzymes activity in the soil at 15 days after sowing or 15 days after pre-emergence application of herbicides and 15 days after post-emergence application of herbicides in groundnut and soybean. Weed management practice involving post-emergence application of Imazethapyr 10 % SL @ 100 g ai/hain groundnut and soybean recorded significantly lower dehydrogenase, phosphatase and urease activity as compared to weedy check and weed free control plots.

Keywords: Dehydrogenase, phosphatase, urease and weed

Introduction
Soil enzymes are a group of enzymes which are usual inhabitants of soil and play an important role in maintaining soil ecology, physical and chemical properties, soil fertility and soil health. These enzymes fulfill the key biochemical functions in the overall process of organic matter decomposition in the soil system (Sinsabaugh *et al*., 1991) [25]. They are important in catalysing several vital reactions necessary for the life processes of micro-organisms in soils, stabilization of soil structure, decomposition of organic wastes, organic matter formation and nutrient cycling hence playing an important role in agriculture (Dick *et al.*, 1994 and Dick, 1997) [6, 7]. All soils contain a group of enzymes that determine soil metabolic processes (Mclaren, 1975) [19] which, in turn, depend on its physical, chemical, microbiological, and biochemical properties. The enzyme levels in soil systems vary in amounts, primarily due to the fact that each soil type has different amounts of organic matter content, composition, activity of its living organisms and intensity of biological processes. In practice, the biochemical reactions are brought about largely through the catalytic contribution of enzymes and variable substrates that serve as energy sources for microorganisms (Kiss *et al*., 1978) [17]. These enzymes may include dehydrogenase, phosphatase and urease released from plants (Miwa *et al*., 1937) [20], animals (Kanfer *et al.* 1974), organic compounds and microorganisms (James *et al*., 1991 and Richmond, 1991 and Shawale and Sadana, 1981) [15, 23, 24] and soils (Gupta *et al.*, 1993 and Ganeshamurthy *et al*., 1995) [14, 12].
The dehydrogenase enzyme activity is commonly used as an indicator of biological activity in soils (Burns, 1978) [26]. Dehydrogenase enzyme is often used as a measure of any disruption caused by pesticides (insecticides/fungicide/herbicide), trace elements or management practices to the soil (Reddy and Faza, 1989, Wilke, 1991 and Frank and Malkomes, 1993) [22, 30, 11], as well as a direct measure of soil microbial activity (Trevors, 1984 and Garcia and Hernandez, 1997) [29, 13]. It can also indicate the type and significance of pollution in soils. Higher the activities of dehydrogenases have been reported at low doses of pesticides and vis-a-versa (Baruah and Mishra, 1986) [2]. In soil ecosystems, phosphotases enzymes are believed to play critical roles in P cycles (Speir and Ross, 1978) [26]

as evidence shows that they are correlated to P stress and plant growth. Apart from being good indicators of soil fertility, phosphatase enzyme plays a key role in the soil system (Eivazi and Tabatabai, 1977 and Dick *et al*., 2000) [8, 10]. Urease enzyme is responsible for the hydrolysis of urea fertilizers applied to the soil into NH_3 and CO_3 with the concomitant rise in soil pH (Andrews *et al*., 1989 and Byrnes and Amberger, 1989) [1, 4]. Urease activity in soils is influenced by many factors which include cropping history, organic matter content of the soil, soil depth, soil amendments, heavy metals, pesticides and environmental factors such as temperature (Tabatabai, 1977 and Yang *et al*., 2006) [10, 31]. Therefore, field trial was conducted at the University of Agricultural Sciences, Dharwad during two consecutive years (2015 and 2016) to know effect of different weed management practices onactivity of enzymes in plots of groundnut and soybean crops during *kharif* season and plots of succeeding crops during *Rabi* season.

Material and methods

A field experiment was conducted at Main Agricultural Research Station (MARS) (15° 29′ 45″ N | 74° 59′ 19″ E | 700 m MSL), University of Agricultural Sciences, Dharwad (Karnataka) on medium black clay soil [Neutral pH (7.40 to 7.50), medium in available nitrogen and phosphorus (290.64 to 301.56 kg N/ha and 27.63 to 28.23 kg P_2O_5/ha, respectively), high in available potassium (384.37 to 386.32 kg K_2O/ha), medium in organic matter content (7.55 to 7.60 g/kg) and normal in salt content (0.25 dS/m)] during two consecutive years (2015and 2016) in *kharif*. The experiment consisted of two Main Plot treatments (Groundnut and Soybean) and eleven Sub-Plot treatments [Weed management practices involving five pre-emergence herbicides (Alachlor 50 % EC @ 3.00 l ai/ha, Pendimethalin 30 % EC @ 1.00 kg ai/ha, Butachlor 50 % EC @ 1.00 kg ai/ha, Pendimethalin 38.7 CS @ 750 g ai/ha and Oxyfluorfen 23.5 % EC @ 100 g ai/ha), four post-emergence herbicides (Propaquizafop 10 % EC @ 100 g ai/ha, Quizalofop ethyl 5 % EC @ 50 g ai/ha, Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha and Imazethapyr 10 % SL @ 100 g ai/ha), weed free control treatment and weedy check control treatment] and was laid out in Split Plot Design with three replications during two consecutive *kharif* seasons (2015 and 2016). The efficacy of different weed management practices on weed *control* (Weed bio-mass, weed control efficiency and weed index) in groundnut and soybean crops during *kharif* was assessed through the Split Plot Design. The enzyme activity of groundnut and soybean at eleven weed management practices during two consecutive *kharif* seasons (2015 and 2016) was assessed Randomised Complete Block Design (RCBD). Total rainfall received during the crop growth periods of groundnut and soybean was 252.0 mm (19 RD) and 296.6 mm (22 RD) and 369.2 mm (36 RD) and 369.2 mm (36 RD), respectively. Recommended rates of nitrogen, phosphorus and potassium (25 kg N, 75 kg P_2O_5 and 25 kg K_2O for groundnut and 40 kg N, 80 kg P_2O_5 and 25 kg K_2O for soybean) were applied to groundnut and soybean crops during *kharif* in the form of urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively The seeds of groundnut and soybean were sown at a distance of 10 cm in a furrows opened at 30 cm apart during last week of June and first week of July in 2015 and 2016 respectively. Pre emergence herbicides were applied immediately after sowing and post-emergence herbicides were applied 32 to 35 days after sowing. The enzymes activity was done by rhizosphere soil samples were collected from the randomly selected from each plot and analysed for enzymes activities. Ten grams of soil and 0.2 g $CaCO_3$ were thoroughly mixed and dispensed in test tubes. One ml of aqueous solution of 2, 3, 5-Triphenyl tetrazolium chloride (TTC) (3 %), one ml of glucose solution (1 %) and eight ml of distilled water were added. The tubes were stoppered with rubber cork and incubated at 30 ºC for 24 h. At the end of incubation, 10 ml methanol was added to the contents of the tube. The slurry was filtered through Whatman No. 50 filter paper. Rinsing of soil with one ml methanol was continued till the filtrate ran free of red colour. The filtrate was pooled and made up to 50 ml with methanol in a volumetric flask. The intensity of red colour was measured at 485 nm against methanol as blank using UV- VIS spectrophotometer. The concentration of TPF in soil samples were determined by referring to a standard curve prepared using graded concentration of TPF. The results were expressed as µg of triphenyl formazan (TPF) formed per g of soil per day. Phosphatase activity of the rhizosphere soil samples were determined by following the procedure of Evazi and Tabatabai (1979). One gram of soil sample was placed in 50 ml Erlenmeyer flask and 0.2 ml toluene was added followed by four ml of modified universal buffer (pH 7.5). One ml of para-nitro phenol phosphate solution made in modified universal buffer was added to the flasks and contents of the flasks were mixed by swirling for 2 minutes.

The flasks were stoppered and incubated at 37 °C for one hour. After incubation, one ml of 0.5 M $CaCl_2$ and four ml of 0.5 M NaOH were added to the flask, swirled and filtered through Whatman No. 42 filter paper. The intensity of yellow colour developed was measured at 420 nm against the reagent blank using a spectrophotometer. Controls were maintained for each soil sample. The phosphatase activity in the soil samples was expressed as µg para nitro phenol formed per gram soil per hour with reference to the standard curve prepared by using graded concentrations of p-nitro phenol phosphate. Urease activity in the rhizosphere soil samples was determined by following the procedure of Tabatabai and Bremner (1972) [28]. Ten gram of soil samples were mixed with 1 ml toluene and 10 ml phosphate buffer and incubated at 30 ˚C for 24 h. After incubation, 15 ml 1N KCl was added and the contents filtered through Whatman No. 42. The filtrate volume was made up to 100 ml with distilled water. One ml of the extractant was taken and 2 ml of 10 per cent sodium tartarate, 0.5 ml Nesseler's reagent were added and incubated for 30 min and volume made up to 25 ml with distilled water. Colour (yellow) developed was read at 610 nm against blank (without urea solution) using a UV- VIS spectrophotometer. The results were expressed as µg NH_4-N per g soil per day.

Weed bio mass, weed control efficiency, weed index was recoded at 65 days after sowing and yield and yield parameters of groundnut and soybean was recorded at the time of harvest. The weed control efficiency (WCE) and weed index (WI) was calculated by using the following formulas.

1. Weed control efficiency (WCE) (%) in groundnut and soybean

$$\text{Weed control efficiency (\%)} = \frac{\text{Weed dry weight in unweeded control (g) - Weed dry weight in treatment (g)}}{\text{Weed dry weight in unweeded control (g)}} \times 100$$

II: Weed Index (WI)

$$\text{Weed index (\%)} = \frac{X - Y}{X} \times 100$$

Where,
X = Yield (Dry pod yield of groundnut / seed yield of soybean) (kg) from weed free plot
Y = Yield (Dry pod yield of groundnut / seed yield of soybean) (kg) from the treatment plot for which weed index is to be worked out.

Results and Discussion

Major weeds observed in the experimental field during *kharif* 2015 and 2016 were *Digitaria marginata* Link var. *fimbriate* Stap f., *Dinebraretroflexa* (Vahl.) Panz. *Setaria* spp., *Eleusine indica* Gaertn. *Echinochloa colona* (L.) Link, *Pannicum* spp. And *Cynodon dactylon* (L.) Pers among the annual grassy (monocots) weeds; *Commelina subulata* Roth. *Commelina benghalensis* L., *Euphorbiahirta* L., *Parthenium hysterophorus* L., *Sidaacuta* Burm. f., *Convolvulus arvensis* L., *Cyanotis cucullata* (Roth) Kunth, *Portulaca oleracea* L. *Mollugo pentaphylla, Corchorus olitorius, Phyllanthus niruri, Sonchusarvensis* L., *Lactucaserriola, P. hysterophorus* nd *Alternanthera sessilis* among the annual broad leaf weeds (dicots); and *Cyperus rotundus* among the sedges. Among the different weeds observed during periods of experimentation, *P. hysterophorus* was dominated the weed flora of groundnut and soybean.

Among the treatments which received pre-emergence herbicides (Alachlor 50 % EC @ 3.00 l ai/ha, Pendimethalin 30 % EC @ 1.00 kg ai/ha, Butachlor 50 % EC @ 1.00 kg ai/ha, Pendimethalin 38.7 % CS @ 750 g ai/ha, and Oxyfluorfen 23.5 % EC @ 100 g ai/ha) in groundnut and soybean, pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ hare corded lower weed bio-mass (27 kg/ha) at 65 DAS. Between different formulations of Pendimethalin, pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ harecorded lower weed bio-mass at 65 DAS (44 kg/ha) over pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha (50 kg/ha). In general all the pre-emergence herbicides were more effective in reducing weed bio-mass right from the emergence of groundnut and soybean crops. However, higher weed bio-mass was recorded with pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha as compared to pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha due to higher population of *P. hysterophorus*. Among the treatments which received different post-emergence herbicides (Quizalofop-ethyl 5 % EC @ 50g ai/ha, Propaquizafop 10 % EC @ 100g ai/ha, Fenoxaprop-p-Ethyl 9.3 % EC @ 100 g ai/ha and Imazethapyr 10 % SL @ 100 g ai/ha) in groundnut and soybean, post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha has recorded lower weed bio-mass (185 kg/ha) (Table 2).

Weed control efficiency at 65 days after sowing differed significantly due to different weed control treatments. Among the treatments which received pre-emergence herbicides in groundnut and soybean, pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/harecorded higher weed control efficiency (97.96 and 98.40 % in groundnut and soybean respectively). Weed control efficiency in groundnut and soybean recorded with pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha, Butachlor 50 % EC @ 1.00 kg ai/ha, Pendimethalin 38.7 % CS @ 750 g ai/ha, and Oxyfluorfen 23.5 % EC @ 100 g ai/ha was 96.22 and 97.68, 97.19 and 97.64, 96.47 and 97.10, 97.86 and 97.28 in groundnut and soybean, respectively. Among the treatments which received post-emergence herbicides in groundnut and soybean, post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ harecorded higher weed control efficiency (82.88 and 92.61 %, respectively). Weed control efficiency in groundnut and soybean recorded with pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha, Butachlor 50 % EC @ 1.00 kg ai/ha, Pendimethalin 38.7 % CS @ 750 g ai/ha, and Oxyfluorfen 23.5 % EC @ 100 g ai/ha was 96.22 and 97.68, 97.19 and 97.64, 96.47 and 97.10, 97.86 and 97.28 in groundnut and soybean, respectively. Weed control efficiency in groundnut and soybean recorded with post-emergence application of Quizalofop-ethyl 5 % EC @ 50 g ai/ha, Propaquizafop 10 % EC @ 100 g ai/ha, Fenoxaprop-p-Ethyl 9.3 % @ 100 g ai/ha was 56.69 and 79.33 49.48 and 64.92, 54.03 and 73.92; 82.88 and 92.61 in groundnut and soybean, respectively. Higher weed control efficiency in groundnut and soybean crops was observed with pre-emergence herbicides application (96.22 to 97.93 and 97.10 to 98.40, respectively) as compared to post- emergence herbicides application (49.48 to 82.88 and 64.92 to 92.61, respectively) (Table 5).

Weed control treatments had significant effect on weed index at 65 days after sowing in groundnut and soybean (Table 5). Among the treatments which received pre-emergence herbicides in groundnut and soybean, pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha in groundnut and pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/hain soybean recorded lower weed index (4.97 and 7.96, respectively).Weed index in groundnut and soybean recorded with pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha, Butachlor 50 % EC @ 1.00 kg ai/ha, Pendimethalin 38.7 % CS @ 750 g ai/ha, and Oxyfluorfen 23.5 % EC @ 100 g ai/ha was 9.01 and 13.66, 5.46 and 14.78, 9.15 and 14.67, 6.75 and 14.72, respectively. Among the treatments which received post-emergence herbicides in groundnut and soybean, post-emergence application of Imazethapyr 10 % SL @ 100 g ai/harecorded higher weed index in groundnut and soybean (25.15 and 27.19 %, respectively). Weed index in groundnut and soybean recorded with post-emergence application of Quizalofop-ethyl 5 EC @ 50 g ai/ha, Propaquizafop 10 % EC @ 100 g ai/ha, Fenoxaprop-p-Ethyl 9.3 % @ 100 g ai/ha was 10.00 and 15.27, 10.71 and 8.61, 11.24 and 15.08, respectively (Table 5). Such differences in the weed index due to the application of pre-and post-emergence herbicides in groundnut and soybean were earlier noticed by Dubey and Gangwar (2012) [9], Pratap *et al.* (2014) and Malligawad *et al*. (2016) [18].

In the present investigation, the significant effect of weed control treatments on dehydrogenase activity was observed at 15 DAS/pre-emergence application of herbicides and 15 days after post-emergence application of herbicides in groundnut and soybean (Table 6 to Table 9). Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g/haingroundnut recorded significantly lower dehydrogenase activity (3.16 µg TPF formed/g soil/d) as compared to weedy check and weed free control treatments (4.12 and 4.10 µg TPF formed/g soil/d, respectively) while, pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha in soybean recorded significantly lower dehydrogenase activity (3.13 µg TPF formed/g soil/d) as compared to weedy check and weed free control treatments (4.25 and 4.18 µg TPF formed/g soil/d, respectively). Weed management practice involving post-emergence application of

Imazethapyr 10 % SL @ 100 g ai/hain groundnut and soybean recorded significantly lower dehydrogenase activity (4.14 µg TPF formed/g soil/d and 4.24 µg TPF formed/g soil/d, respectively) as compared to weedy check and weed free control treatments (5.63 and 5.39 µg TPF formed/g soil/d in groundnut and5.84 and 5.72 µg TPF formed/g soil/d in soybean, respectively).With respect to the soil phosphatase activity, weed control treatments had significant effect on phosphatase activity at 15 DAS/pre-emergence application of herbicides and at 15 days after post-emergence application of herbicides in groundnut and soybean. Among the different pre-emergence herbicides used in groundnut, the application of Pendimethalin 30 % EC @ 1.00 kg ai/harecorded significantly lower phosphatase activity (10.37 µg pNP formed/g soil/h) as compared to weedy check and weed free control treatments (11.82 and 11.44 µg TPF formed/g soil/d, respectively). Among the different pre-emergence herbicides used in soybean, the application of Butachlor 50 % EC @ 1.00 kg ai/harecorded significantly lower phosphatase activity (10.36 µg pNP formed/g soil/h) as compared to weedy check and weed free control treatments (12.01 and 11.74 µg pNP formed/g soil/h, respectively). Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/hain groundnut and soybean recorded significantly lower phosphatase activity (11.20 µg TPF formed/g soil/d and 10.38 µg pNP formed/g soil/h, respectively) as compared to weedy check and weed free control treatments (13.32 and 12.70 µg pNP formed/g soil/h, respectively in groundnut and 13.31 and 12.85 µg pNP formed/g soil/h, respectively in soybean).With respect to soil urease activity, the weed control treatments had significant effect on urease activity which was evident at 15 DAS/pre-emergence application of herbicides and at 15 days after post-emergence application of herbicides in groundnut and soybean. In the present investigation, pre-emergence application of both the formulations of Pendimethalin (30 % EC and 38.7 % CS)in groundnut recorded significantly lower urease activity(2.21 µg NH_4-N formed/g soil/d) as compared to weedy check and weed free control treatments (2.72 and 2.53 µg NH_4-N formed/g soil/d, respectively). Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha in soybean recorded significantly lowerurease activity (1.97 µg NH_4-N formed/g soil/d) as compared to weedy check and weed free control treatments (2.47 and 2.76 µg NH_4-N formed/g soil/d, respectively). Post-emergence application of Imazethapyr 10 % SL @ 100 g a.i/hain groundnut and soybean recorded significantly lower urease activity (2.40 µg TPF formed/g soil/d and 2.89 µg NH_4-N formed/g soil/d, respectively) as compared to weedy check and weed free control treatments (3.64 and 2.92 µg NH_4-N formed/g soil/d, respectively in groundnut and 3.07 and 3.06 µg NH_4-N formed/g soil/d, respectively in soybean).

Table 1: Total dry weight of weeds (kg ha^{-1}) at 65 days after sowing as influenced by weed management treatments (*kharif* 2015 and *kharif* 2016)

Treatments		Total dry weight of weeds (kg ha^{-1}) at 65 DAS							
		kharif 2015				*kharif* 2016			
		Groundnut		Soybean		Groundnut		Soybean	
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	(5.187)	27	(5.337)	34	(4.991)	25	(4.584)	22
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	(7.447)	60	(5.982)	39	(5.671)	32	(6.463)	45
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	(6.685)	47	(5.336)	31	(4.776)	23	(6.283)	40
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	(6.621)	48	(7.255)	54	(6.537)	43	(6.765)	51
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	(5.264)	30	(8.155)	66	(4.879)	23	(5.472)	33
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	(21.864)	482	(27.232)	751	(24.987)	625	(11.600)	138
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	(24.238)	587	(27.303)	745	(27.174)	756	(21.365)	517
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	(24.167)	585	(20.179)	426	(24.563)	614	(25.774)	665
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	(15.074)	291	(15.756)	260	(11.642)	149	(6.201)	38
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	(0.707)	0	(0.707)	0	(0.707)	0	(0.707)	0
T_{11}	Weedy check (No weed control)	(33.958)	1153	(48.197)	2402	(38.342)	1502	(39.767)	1582
Mean		13.747		15.585		14.042		12.271	
Comparing the two means of		S.Em±		LSD (p=0.05)		S.Em±		LSD (p=0.05)	
Crop (Groundnut and soybean)		1.68		10.24		0.43		2.60	
Weed control treatment		1.50		4.28		1.13		3.22	
Weed control measure at same crop (Groundnut and soybean)		2.12		6.05		1.59		4.56	
Crop (Groundnut and soybean) at same or different weed control treatment		3.07		8.77		1.09		3.12	

Figures in the parenthesis indicate the transformed $(x + 0.5)^{1/2}$ values, where x is weed count DAS: Days after sowing

Table 2: Weed biomass (total dry weight of weeds) as influenced by weed management treatments (POOLED)

Treatments		Total dry weight of weeds(kg ha^{-1})					
		Groundnut		Soybean		Mean	
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	(5.093)	26	(5.035)	28	(5.064)	27
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	(6.710)	46	(6.255)	42	(6.482)	44
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	(5.900)	35	(5.918)	36	(5.909)	36
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	(6.723)	46	(7.056)	53	(6.889)	50
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	(5.161)	27	(7.042)	50	(6.102)	39
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	(23.517)	553	(20.984)	445	(22.250)	499
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	(25.829)	672	(24.951)	631	(25.390)	652
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	(24.468)	600	(23.256)	546	(23.862)	573
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	(14.277)	220	(12.023)	149	(13.150)	185

T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	(0.707)	0	(0.707)	0	(0.707)	0
T_{11}	Weedy check (No weed control)	(36.329)	1328	(44.389)	1992	(40.359)	1660
Mean		14.063		14.329		14.197	
Comparing the two means of		S.Em±				LSD (p=0.05)	
Crop (Groundnut and soybean)		0.87				5.32	
Weed control treatment		0.91				2.60	
Weed control measure at same crop (Groundnut and soybean)		1.29				3.68	
Crop (Groundnut and soybean) at same or different weed control treatment		1.65				4.71	

Figures in the parenthesis indicate the transformed $(x + 0.5)^{1/2}$ values, where x is weed count DAS: Days after sowing POOLED: Mean of *kharif* 2015 and *kharif* 2016

Table 3: Weed control efficiency in groundnut and soybean at 65 days after sowing as influenced by weed management treatments (*kharif* 2015 and *kharif* 2016)

Treatments		Weed control efficiency (%) at 65 DAS							
		kharif 2015				*kharif* 2016			
		Groundnut		Soybean		Groundnut		Soybean	
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	(9.909)	97.68	(9.948)	98.46	(9.937)	98.24	(9.941)	98.33
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	(9.760)	94.77	(9.943)	98.37	(9.908)	97.67	(9.874)	97.00
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	(9.818)	95.91	(9.956)	98.62	(9.949)	98.48	(9.857)	96.67
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	(9.812)	95.79	(9.901)	97.54	(9.882)	97.15	(9.857)	96.67
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	(9.893)	97.38	(9.869)	96.89	(9.942)	98.34	(9.908)	97.67
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	(7.647)	58.21	(8.079)	65.33	(7.416)	55.18	(9.683)	93.33
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	(7.040)	49.06	(8.054)	64.84	(7.099)	49.90	(8.044)	65.00
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	(7.047)	49.27	(8.891)	79.16	(7.700)	58.80	(8.263)	68.67
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	(8.582)	74.96	(9.413)	88.21	(9.552)	90.79	(9.874)	97.00
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	(10.025)	100.00	(10.025)	100.00	(10.025)	100.00	(10.025)	100.00
T_{11}	Weedy check (No weed control)	(0.707)	0.00	(0.707)	41.90	(0.707)	0.00	(0.707)	0.00
Mean		8.204		8.617		8.374		8.730	
Comparing the two means of		S.Em±		LSD (p=0.05)		S.Em±		LSD (p=0.05)	
Crop (Groundnut and soybean)		0.06		0.35		0.14		0.84	
Weed control treatment		0.20		0.57		0.17		0.47	
Weed control measure at same crop (Groundnut and soybean)		0.28		0.81		0.23		0.67	
Crop (Groundnut and soybean) at same or different weed control treatment		0.21		0.61		0.34		0.98	

Figures in the parenthesis indicate the transformed $(x + 0.5)^{1/2}$ values, where x is weed count DAS: Days after sowing

Table 4: Weed index in groundnut and soybean as influenced by weed management treatments (*kharif* 2015 and *kharif* 2016)

Treatments		Weed index (WI)			
		kharif 2015		*kharif* 2016	
		Groundnut	Soybean	Groundnut	Soybean
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	3.26	8.00	6.68	7.92
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	8.27	20.41	9.75	6.91
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	7.26	19.01	3.66	10.56
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	7.39	12.27	10.90	17.06
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	10.82	16.86	2.68	12.59
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	9.64	17.84	10.35	12.70
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	11.55	16.11	9.86	1.11
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	11.25	18.47	11.23	11.69
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	31.24	31.75	19.06	22.63
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	0.00	0.00	0.00	0.00
T_{11}	Weedy check (No weed control)	15.08	26.32	26.71	20.33
Mean		10.525	17.004	10.080	11.227
Comparing the two means of		S.Em±	LSD (p=0.05)	S.Em±	LSD (p=0.05)
Crop (Groundnut and soybean)		3.15	19.15	3.81	23.18
Weed control treatment		3.05	8.71	3.05	8.72
Weed control measure at same crop (Groundnut and soybean)		4.31	12.32	4.32	12.34
Crop (Groundnut and soybean) at same or different weed control treatment		5.98	17.08	8.07	23.07

Figures in the parenthesis indicate the transformed $(x + 0.5)^{1/2}$ values, where x is weed count DAS: Days after sowing

Table 5: Weed control efficiency and weed index as influenced by weed management treatments (POOLED)

Treatments		Weed control efficiency and weed index								
		Weed control efficiency (%)						Weed index		
		Groundnut		Soybean		Mean		Groundnut	Soybean	Mean
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai /ha	(9.923)	97.96	(9.945)	98.40	(9.934)	98.18	4.97	7.96	6.47
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	(9.834)	96.22	(9.909)	97.68	(9.871)	96.95	9.01	13.66	11.34
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	(9.884)	97.19	(9.906)	97.64	(9.895)	97.41	5.46	14.78	10.12
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	(9.847)	96.47	(9.879)	97.10	(9.863)	96.78	9.15	14.67	11.91
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	(9.917)	97.86	(9.888)	97.28	(9.903)	97.57	6.75	14.72	10.74
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	(7.531)	56.69	(8.881)	79.33	(8.206)	68.01	10.00	15.27	12.63
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	(7.069)	49.48	(8.049)	64.92	(7.559)	57.2	10.71	8.61	9.66
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	(7.373)	54.03	(8.577)	73.92	(7.975)	63.97	11.24	15.08	13.16
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	(9.067)	82.88	(9.643)	92.61	(9.355)	87.74	25.15	27.19	26.17
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	(10.025)	100.00	(10.025)	100.00	(10.025)	100	-	-	-
T_{11}	Weedy check (No weed control)	(0.707)	0.00	(0.707)	0.00	(0.707)	0.00	20.90	23.33	22.11
Mean		8.289		8.674		8.481		10.30	14.12	12.21
Comparing the two means of		S.Em±		LSD (p=0.05)				S.Em±	LSD (p=0.05)	
Crop (Groundnut and soybean)		0.09		0.56				2.71	16.49	
Weed control treatment		0.10		0.30				2.17	6.21	
Weed control measure at same crop (Groundnut and soybean)		0.15		0.42				3.07	8.79	
Crop (Groundnut and soybean) at same or different weed control treatment		0.23		0.65				5.37	15.34	

Figures in the parenthesis indicate the transformed $(x + 0.5)^{1/2}$ values, where x is weed count DAS: Days after sowing POOLED: Mean of *kharif* 2015 and *kharif* 2016

Table 6: Enzyme activities in soil of groundnut at 15 days after sowing/pre-emergence application as influenced by weed management treatments (*kharif* 2015, *kharif* 2016 and POOLED)

Treatments		After 15 days sowing/pre-emergence application								
		Dehydrogenase (µg TPF formed/g soil /g)			Phosphatase (µg pNP formed/g soil/h)			Urease (µg NH_4-N formed/g soil/g)		
		2015	2016	POOLED	2015	2016	POOLED	2015	2016	POOLED
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	3.35	3.32	3.33	10.61	10.62	10.62	2.13	2.38	2.25
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	3.31	3.26	3.29	10.17	10.58	10.37	2.05	2.37	2.21
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	3.21	3.31	3.26	10.48	10.41	10.45	2.42	2.45	2.43
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	3.25	3.35	3.30	10.73	10.36	10.55	2.28	2.14	2.21
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	3.10	3.21	3.16	10.48	10.38	10.43	2.28	2.23	2.26
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	3.69	3.78	3.73	10.90	10.93	10.92	2.64	2.30	2.47
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	3.97	3.62	3.80	10.88	11.23	11.06	2.55	2.21	2.38
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	3.77	3.66	3.71	10.78	11.25	11.02	2.64	2.60	2.62
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	3.88	3.91	3.89	10.83	10.44	10.64	2.09	2.25	2.17
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	4.09	4.12	4.10	11.75	11.89	11.82	2.67	2.76	2.72
T_{11}	Weedy check (No weed control)	4.06	4.18	4.12	11.27	11.61	11.44	2.51	2.54	2.53
Mean		3.61	3.61	3.61	10.81	10.88	10.85	2.39	2.38	2.39
S.Em±		0.114	0.129	0.080	0.259	0.182	0.174	0.190	0.126	0.113
LSD (p=0.05)		0.338	0.380	0.237	0.763	0.536	0.512	0.559	0.371	0.333

Table 7: Enzyme activities in soil of groundnut at 15 days after post-emergence application as influenced by weed management treatments (*kharif* 2015, *kharif* 2016 and POOLED)

Treatments		15 days after post-emergence application								
		Dehydrogenase (µg TPF formed/g soil/g)			Phosphatase (µg pNP formed/g soil/h)			Urease (µg NH_4-N formed/g soil/g)		
		2015	2016	POOLED	2015	2016	POOLED	2015	2016	POOLED
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	5.25	5.37	5.31	12.17	12.33	12.25	2.91	3.22	3.07
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	5.33	5.29	5.31	12.13	12.24	12.19	2.89	2.97	2.93
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	5.33	5.24	5.29	12.01	12.07	12.04	3.56	2.88	3.22
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	5.30	5.45	5.38	11.88	11.73	11.81	3.27	2.63	2.95
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	5.25	5.30	5.27	12.00	12.00	12.00	3.67	3.46	3.57
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	4.54	4.46	4.50	11.24	11.95	11.59	3.67	2.83	3.25
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	4.76	4.37	4.57	11.43	11.93	11.68	2.80	3.15	2.97
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	4.84	4.33	4.59	11.98	11.87	11.93	3.02	3.09	3.06
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	4.15	4.13	4.14	11.28	11.12	11.20	2.51	2.29	2.40
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	5.80	5.46	5.63	13.02	13.62	13.32	3.71	3.57	3.64
T_{11}	Weedy check (No weed control)	5.51	5.27	5.39	12.49	12.91	12.70	3.09	2.75	2.92
Mean		5.10	4.97	5.03	11.97	12.16	12.06	3.19	2.99	3.09
S.Em±		0.076	0.126	0.071	0.316	0.410	0.280	0.358	0.212	0.188
LSD (p=0.05)		0.223	0.370	0.210	0.934	1.210	0.827	1.057	0.626	0.553

Table 8: Enzyme activities in soil of soybean after 15 days sowing/pre-emergence application as influenced by weed management treatments (*Kharif* 2015-2016 and POOLED)

Treatments		After 15 days sowing/pre-emergence application								
		Dehydrogenase (µg TPF formed/g soil/g)			Phosphatase (µg pNP formed/g soil/h)			Urease (µg NH_4-N formed/g [1] soil/g)		
		2015	2016	POOLED	2015	2016	POOLED	2015	2016	POOLED
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	3.20	3.07	3.13	10.35	10.64	10.50	1.71	2.24	1.97
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	3.28	3.22	3.25	10.47	10.35	10.41	2.38	2.32	2.35
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	3.24	3.30	3.27	10.34	10.39	10.36	2.40	2.24	2.32
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	3.29	3.19	3.24	10.63	10.35	10.49	2.25	2.32	2.29
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	3.30	3.25	3.27	10.34	10.52	10.43	2.32	2.30	2.31
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	3.77	3.79	3.78	10.88	10.88	10.88	2.52	2.53	2.53
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	3.73	3.85	3.79	10.76	10.66	10.71	2.69	2.36	2.52
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	3.61	3.69	3.65	10.95	10.53	10.74	2.55	2.30	2.43
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	3.80	3.80	3.80	10.91	10.57	10.74	2.37	2.15	2.26
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	4.21	4.29	4.25	12.40	11.62	12.01	2.40	2.55	2.47
T_{11}	Weedy check (No weed control)	4.19	4.17	4.18	12.12	11.37	11.74	2.68	2.84	2.76
Mean		3.60	3.60	3.60	10.92	10.72	10.82	2.39	2.38	2.38
S.Em±		0.088	0.079	0.057	0.194	0.201	0.155	0.184	0.119	0.129
LSD (p=0.05)		0.259	0.232	0.168	0.574	0.594	0.458	0.544	0.350	0.380

Table 9: Enzyme activities in soil of soybean after 15 days post-emergence application as influenced by weed management treatments (*Kharif* 2015, *kharif* 2016 and POOLED)

Treatments		After 15 days sowing/post-emergence application								
		Dehydrogenase (µg TPF formed/g soil/g)			Phosphatase (µg pNP formed/g soil/h)			Urease (µg NH_4-N formed/g soil/g)		
		2015	2016	POOLED	2015	2016	POOLED	2015	2016	POOLED
T_1	Pre-emergence application of Alachlor 50 % EC @ 3.00 l ai/ha	5.28	5.08	5.18	11.72	11.58	11.65	2.90	2.71	2.80
T_2	Pre-emergence application of Pendimethalin 30 % EC @ 1.00 kg ai/ha	5.29	5.10	5.20	11.70	12.32	12.01	2.91	2.91	2.91
T_3	Pre-emergence application of Butachlor 50 % EC @ 1.00 kg ai/ha	5.31	5.23	5.27	11.96	12.01	11.99	2.87	2.87	2.87
T_4	Pre-emergence application of Pendimethalin 38.7 % CS @ 750 g ai/ha	5.37	5.41	5.39	11.38	11.77	11.58	2.88	2.88	2.88
T_5	Pre-emergence application of Oxyfluorfen 23.5 % EC @ 100 g ai/ha	5.40	5.34	5.37	11.87	12.26	12.07	2.94	2.94	2.94
T_6	Post-emergence application of Quizalofop ethyl 5 % EC @ 50 g ai/ha	4.80	4.89	4.84	11.83	11.46	11.65	2.96	2.96	2.96
T_7	Post-emergence application of Propaquizafop 10 % EC @ 100 g ai/ha	4.86	4.92	4.89	11.87	11.28	11.57	2.69	2.69	2.69
T_8	Post-emergence application of Fenoxaprop-p-ethyl 9.3 % EC @ 100 g ai/ha	4.89	4.78	4.84	11.67	11.25	11.46	2.79	2.79	2.79
T_9	Post-emergence application of Imazethapyr 10 % SL @ 100 g ai/ha	4.21	4.27	4.24	10.49	10.26	10.38	2.89	2.89	2.89
T_{10}	Weed free control (Situation based hand weeding and inter-cultivation)	5.63	6.05	5.84	13.34	13.27	13.31	3.07	3.07	3.07
T_{11}	Weedy check (No weed control)	5.51	5.93	5.72	13.01	12.70	12.85	3.06	3.06	3.06
Mean		5.14	5.18	5.16	11.89	11.83	11.86	2.91	2.89	2.90
S.Em±		0.082	0.173	0.084	0.372	0.523	0.377	0.186	0.197	0.190
LSD (p=0.05)		0.242	0.509	0.249	1.098	1.542	1.113	0.547	0.582	0.559

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