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Efficiency of Early Post Emergence Herbicide and Integrated Weed Management Methods in Soybean (*Glycine max*) and their Residual effect on Succeeding Crops

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ABSTRACT: *Field experiments was conducted to evaluate the efficacy of imazethapyr on weed control in soybean and its residual effect on succeeding crops. The experiment was replicated thrice in randomized block design with ten treatments comprised of imazethapyr 50 (T_1), 75 (T_2), 100 (T_3) and 200 (T_4) g/ha as early post-emergence (EPOE) was sprayed 15 days after sowing. All these treatments, were given with an earthing up on 45 DAS. oxyfluorfen 125 g/ha + hand weeding on 45 DAS (T_5), oxyfluorfen 125 g/ha + power weeding on 45 DAS (T_6) and Pendimethalin 750 g/ha + hand weeding on 45 DAS (T_7), Pendimethalin 750 g/ha + power weeding on 45 DAS (T_8) as pre-emergence (PE) were sprayed at 3 days after sowing (DAS), hand weedings at 25 and 45 days after sowing (T_9) and unweeded check (control) (T_{10}). Imazethapyr at 200 g/ha has decreased the biomass of all weeds significantly which was followed by imazethapyr 100 g/ha. Imazethapyr at 200 g/ha caused phytotoxicity to soybean during intial stages resulting in reduced soybean yield and yield attributes. Early post emergence application of imazethapyr 100 g/ha reduced the density of broadleaved and grassy weeds as well as dry weight than sedges and recorded higher weed control efficiency and maximum in all growth attributes and yield attributes viz no of pods/plant, seeds/pod, 100 seed weight and gave higher grain yield, lowest nutrient removal by weeds and maximum nutrient uptake by the crop when compared with pre-emergence application of pendimethalin and oxyfluorfen. The residues of imazethapyr at different doses did not influence germination, growth, yield of sunflower and pearl millet and was statistically at par with checks.*

Key Words: *Early Post Emergence, Growth, Nutrient uptake, Residual effect, Weed control, Yield.*

Soybean (*Glycine max* (L.) Merill) is a important oilseed crop that is widely grown as a valuable source of protein and oil for human nutrition in the world. Weed infestation is considered a persistent and complex constraints in soybean, as it influences soybean growth and development through competition for moisture, light, nutrients and space as well as through production of allelopathic compounds (Vollmann *et al.,* 2010). Weeds not only compete with soybean but also hamper operation of equipment, harbor crop pests such as insects and diseases and contaminated the harvested seed yield with foreign matter and weed seeds of different species. Unavailability of adequate laborers during peak period of weeding and difficulty in use of mechanical weeding in heavy soil due to rain creates problem for effective control of weeds in soybean crop. Weed management through the herbicidal application remains the only viable option under these situations. Application of herbicides a pre emergence for effective weed control in soybean are required to be used within very short period (2-3 DAS) of time after sowing. In monsoon season, if rain captures this critical period of application then pre emergence herbicide can not be used effectively to control the weeds in soybean.

This situation has necessitated the search of some early post-emergence herbicides for effective control of weeds in soybean crop. In view of above facts, an experiments was conducted to evaluate the bio-efficacy of early post emergence herbicides on weed control and seed yield of soybean.

MATERIALS AND METHODS

Field experiments were carried out at Agricultural Research Station (ARS), Bhavanisagar, located at Western Zone of Tamil Nadu 11°29"N latitude and 77 °08"E longitude with an altitude of 256 meters above

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mean sea level. The climate is subtropical with mean annual rainfall of 610 mm**.** The soil of the experimental field was clayey loam in texture, with the pH of 6.7, medium in organic carbon content 0.55%, low in available nitrogen (230 kg/ha), available phosphorus (20 kg/ha) and available potassium (268 kg/ha). Soybean variety 'CO (Soy) 3' was sown in 30 cm wide rows and fertilized with 20 kg N + 80 kg P + 40 kg K/ ha). The experiment was laid out in randomized block design with three replications. The treatments comprised of imazethapyr 50 (T_1), 75 (T_2), 100 (T_3) and 200 (T_4) g/ha as early post-emergence (EPOE) was sprayed 15 days after sowing. All these treatments, were given with an earthing up on 45 DAS. oxyfluorfen 125 g/ha + hand weeding on 45 DAS (T_5), oxyfluorfen 125 g/ha + power weeding on 45 DAS (T_6) and Pendimethalin 750 g/ha + hand weeding on 45 DAS (T_7), Pendimethalin 750 g/ha + power weeding on 45 DAS (T_8) as pre-emergence (PE) were sprayed at 3 days after sowing (DAS), hand weedings at 25 and 45 days after sowing (T_9) and unweeded check (control) (T_{10}). All the herbicides were applied by manually operated knapsack sprayer fitted with flat fan nozzle using spray volume of 500 litre/ha. Crop phytotoxicity was studied three days after spraying of herbicide adopted using standard method for post emergence herbicide. The data on weed density and dry weight were subjected to log (X + 2) transformation before statistical analysis to normalize their distribution. Data for individual years was pooled and statistically analyzed.

The biomass of weeds was expressed in kg/ha. Weed control efficiency (WCE) was calculated in relation to total biomass by using the following formula:

$$WCE = \frac{X-Y}{X} \times 100$$

Where,

X = biomass of weeds in weedy plots Y= biomass of weeds in treated plots and expressed in per cent.

After the harvest of soybean, residual effect of treatments was studied by raising succeeding crops such as sunflower and pearl millet without disturbing the layout. The residual effect of treatments was assessed by recording the germination, plant height, dry matter production and yield of the succeeding crops. Economics was worked out on the basis of prevailing market prices.

RESULTS AND DISCUSSION

The experimental field was associated with various weed species. Most common weeds among grasses are *Dactyloctenium aegyptium, Arachne racemosa* and *Bracharia reptans and Boerhaavia diffusa, Digera arvensis, Parthenium hysterophorous* and *Trichodesma indicum* among broadleaved weeds and *Cyperus rotundus* is the only sedge weed.

Weed Density and Dry Weight

Application of imazethapyr exerted significant influence on the density (no/m^2) of weeds during both the year of experimentations. The pooled analysis showed at 20 DAHA, early post emergence (EPOE) application of imazethapyr at 200 g/ha followed by EPOE imazethapyr at 100 g/ha, recorded lower broad leaved weed and grassy density, except hand weeding twice. The reason might be due to the application of imazethapyr was selective against broadleaved weeds and grassy weeds and it controlled all major weeds like *Boerhaavia diffusa, Digera arvensis, Parthenium hysterophorous* and *Trichodesma indicum, Dactyloctenium aegyptium, Acrachne racemosa* and *Bracharia re*ptans during both the seasons (Table 1). Whereas at 40 DAHA, EPOE imazethapyr 200 g/ha was statistically on par with imazethapyr 100 g/ha and recorded lower density of grass, broad leaved weeds than hand weeding twice, its due to residual effect of herbicide have effective control of weeds. But it efficacy against sedges was almost low at all the rates. Obviously unweeded control resulted in higher grasses, sedge and broadleaved weed densities due to unchecked weed growth at all the growth stages of the crop (Table 2).These results are also in accordance with the findings of Glenn and Jorge (2005) who had reported that both PE and POE imazethapyr had better reduction in weed density. Among the herbicide application at 20 DAHA considerable reduction in total weed dry weight was recorded with the application of imazethapyr at 200 g/ha + earthing up on 45 DAS which was comparable with imazethapyr at 100 g/ha at later growth stages might be attributed to the lesser number of total weeds with lower biomass during the cropping period during both the season (Table 3). In these treatments, nearly 80 per cent reduction of weed dry weight was noticed over unweeded control. This corroborates with the findings of Lambade *et al.* (2008) who had reported that lower weed dry weight with herbicidal weed management in soybean due to lesser total weed density and higher weed control efficiency.

Weed Control Efficiency

Weed control efficiency (WCE) indicated the magnitude of effective reduction of weed dry weight

by weed control treatments over unweeded control. This was highly influenced by different weed control treatments. During both the seasons at 20 DAHA, all the weed control treatments recorded more than 50 per cent WCE, Hand weeding on 25 and 45 DAS(T_7) followed by EPOE application of imazethapyr @ 200 g/ha + earthing up on 45 DAS (T_4) , imazethapyr @ 100 g/ha + earthing up on 45 DAS (T_3) . More reduction of weed dry weight by reducing the weed density in these treatments might have resulted in higher WCE. At 40 DAHA with EPOE imazethapyr @ 200 g/ha + earthing up on 45 DAS (T_4) recorded higher WCE followed by hand weeding on 25 and 45 DAS , EPOE imazethapyr @ 100 g/ha earthing up on 45 DAS (T_3) (Table 3). It is in conformity with the experimental results of Vyas and Jain (2003) who had reported that post emergence application of imazethapyr @ 75 g/ha resulted in higher WCE might be due to lesser weed dry weight.

Growth Parameters

Growth attributes like plant height, dry matter production are the reflective processes of effective utilization of resources in a better crop productive environment. Conducive crop growth environment with a minimum stress due to biotic factors like lesser weed competition reflects further on better yield attributes of crops.

The pooled analysis of plant height, dry matter production during both the years showed a significantly marked variation across weed control treatments. EPOE imazethapyr @ 100 g/ha + earthing up on 45 DAS (T_3) registered taller plants followed by EPOE imazethapyr @ 200 g/ ha + earthing up on 45 DAS (T_4). Whereas, application of imazethapyr at 200 g/ha caused injury to soybean plants resulting in lesser plant height during initial stages and recovered at later growth stages (Table 4). Unweeded control resulted in shorter plants, obviously due to the effect of weeds at all stages of observation. Similarly, Basu and Sengupta (2012) observed that in soybean post emergence application of imazethapyr increased the plant height significantly.

Weed control treatments positively influenced the dry matter production of soybean at different growth stages. At 20 DAHA, EPOE imazethapyr @ 100 g/ha + earthing up on 45 DAS (T_3) recorded higher dry matter production of soybean. At subsequent stages, treatments with EPOE imazethapyr @ 200 g/ha + earthing up on 40 DAHA recorded higher DMP. The reason might be due to the better weed control resulted in favourable environment to have higher nutrient uptake reflected on higher leaf area index and better source sink relationship for accumulating higher dry matter (Table 4). This finding is in accordance Raghuwanshi (2005) who had recorded higher biomass of soybean with imazethapyr application. On the other hand, unweeded control recorded lower total dry matter due to severe weed competition at all the stages of crop growth.

Crop Phytotoxicity

The phytotoxic effect of imazethapyr was observed at higher doses viz., 200 g/ha (T_4). However, EPOE imazethapyr @ 200 g/ha (T_4) recorded slight crop damage (rating = 30) at 3 DAHA. At 7 DAHA, the effect was less (rating = 20) after 14 DAHA, the effect was negligible (rating = 10) and at 21 DAHA the soybean plants recovered from phytotoxicity and the symptoms were not evident after one or two irrigations.

Nutrient Uptake by Soybean

Quantity of nutrients uptake by crops is the reflection of crop biomass and nutrient content at each growth stage. The pooled data on nutrient uptake (N, P and K) by soybean has showed significant influenced on different weed control treatments due to imazethapyr application. EPOE application of imazethapyr @ 100 g/ha + earthing up on 45 DAS (T_3) for soybean resulted in higher plant dry matter and consequently higher N, P and K uptake by the plant. Lower dry weight and uptake of nutrients by weeds, in the weed control treatments eventually permitted the crop for more uptakes of nutrients owing to more availability. Obviously, unweeded control resulted in lesser dry matter in turn recorded the least nutrient uptake by soybean which might be due to maximum utilization of resources by weeds (Table 5 and 6). Ashok *et al.* (2009) reported that nitrogen uptake by soybean crop increased significantly with different weed control treatments when compared with weedy check.

Nutrient Removal by Weeds

Effective weed control by different methods provide a conducive environment for increased uptake of nutrients by crop with proportionate decrease in the depletion of nutrients by weeds. The pooled data on nutrient uptake (N, P and K) by weeds had significant influence by different weed control treatments. As far as nitrogen removal is concerned, during both the seasons EPOE application of imazethapyr @ 200 g/ ha + earthing up on 45 DAS recorded the lowest N removal at 20 and 40 DAHA (Table 7 and 8). This might be due to the lower weed density and dry

weight. This is in corroboration with the results of Jeyabal *et al.* (2001) observed that nutrient removal through weeds were less in weed control treatments than unweeded check. Similarly, the same trend was observed in P and K removal by weeds.

Yield Attributes

During both the seasons more number of pods and higher test weight were obtained with EPOE application of imazethapyr at 100 g/ha + earthing up on 45 DAS . It might be due to better control of weeds from earlier stage itself, followed by this treatment EPOE application of imazethapyr @ 200 g/ha + earthing up on 45 DAS recorded higher yield attributes against unweeded control which obviously experienced severe weed competition at all crop growth stages (Table 9). Similar reduction on number of pods per plant and test weight were recorded by

Chandel and Saxena (2001) due to competition offered by unchecked weeds in between crop plants in unweeded control soybean fields. Higher WCE of these treatments and less depletion of nutrients by weeds promoted the yield components of soybean.

Yield

The pooled analysis showed that EPOE application of imazethapyr @ 100 g/ha + earthing up on 45 DAS recorded higher grain yield. Better growth and physiological attributes coupled with yield attributes like pods per plant, seeds per pod and 100 grain weight as a result of lesser weed density and dry weight accounting for better WCE might be the reason for higher productivity (Table 10). Similar results were reported by Chandel and Saxena (2001),Where POE imazethapyr 100 g/ha was found to be effective in controlling weeds at various stages and also enhanced the grain yield to the tune of 51 per cent over control in soybean.

Higher stover yield of soybean was recorded with EPOE application of imazethapyr @ 200 g/ha + earthing up on 45 DAS (T_4) could be attributed to the reason that herbicide application might have killed the weeds from earlier stage and devoiding competition for crop growth. Comparatively taller plants with higher DMP could be attributed for lesser weed competition with EPOE imazethapyr 200 g/ha + earthing up on 45 DAS, which in turn might have favoured higher stover yield (Table 10). Results are in accordance with the findings of Khedkar *et al.* (2009) who have reported that POE application of imazethapyr plus imazamox recorded significantly higher stover yield.

The extent of yield reduction due to weed competition as assessed through weed index (WI) has evidently indicated the suppressing effect of imazethapyr @ 100 g/ha which had minimum weed competition and maximum grain yield (Table 10). The weed growth resulted in reduced vegetative growth and nutrient availability to the plants could be attributed for yield reduction in lesser doses of imazethapyr. This shows the importance of weed management for increasing dry matter production of soybean crop, thereby increasing the crop yield of soybean.

Economics

The effect of different treatments on economics showed that EPOE application of imazethapyr @ 100 g/ha had favourable influence on the economics. EPOE of imazethapyr at 100 g/ha recorded the highest gross return, net return and B:C ratio. Even though the cost of the treatment was higher with EPOE application of imazethapyr at 100 g/ha than the unweeded control. It was followed by application of imazethapyr at 200 g/ha. (Table 11) The increased additional income realized with these two treatments might be due to higher seed yield obtained due to the treatment efficiency which would have reduced the competition between weeds and crop for water and nutrients. Similar results were reported by Mukesh Kumar and Das (2008) that application of imazethapyr has better control over weeds and acquire highest benefit cost ratio and net returns.

Residual Effect of Herbicides on the Succeeding Crops

The germination percentage of the sunflower and pearlmillet has no significant difference among treatments. It is evident that there is no residual toxicity due to the application of herbicide imazethapyr, pendimethalin, oxyfluorfen at all the doses of the succeeding crops. Yield of sunflower and pearlmillet showed no distinct variation in succeeding crop due to different dose of herbicide imazethapyr. So, the various dose of imazethapyr tested in soybean had no adverse residual effect on the growth of the succeeding crop (Table 12). It is in conformity with the results by Bradley and Donald (2001) that application of imazethapyr as POE which had no residual effect on succeeding crops.

Thus, herbicidal weed control using early post-emergence imazethapyr 100 g/ha followed by earthing up on 45 DAS might be the best method to control majority of weeds for obtaining higher

Table 1
Effect of Weed Management on Groupwise Weed Density on Soybean on 20 DAHA

Treatments	*Grasses (no/m²)*			*BLW (no/m²)*			*Sedges (no/m²)*			*Total weed density (no/m²)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	7.48 (54.0)	13.11 (170.0)	10.68 (112.0)	7.48 (54.0)	5.74 (31.0)	6.67 (42.5)	5.48 (28.0)	6.40 (39.0)	5.96 (33.5)	11.75 (136.0)	15.56 (240.0)	13.78 (188.0)
T_2- EPOE imazethapyr at 75g / ha + E. up on 45 DAS	6.00 (34.0)	8.77 (75.0)	7.52 (54.5)	6.08 (35.0)	4.90 (22.0)	5.52 (28.5)	4.80 (21.0)	4.80 (21.0)	4.80 (21.0)	9.59 (90.0)	10.95 (118.0)	10.30 (104.0)
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	5.48 (28.00)	6.71 (43.0)	6.12 (35.50)	3.00 (7.0)	4.12 (15.0)	3.61 (11.0)	3.74 (12.0)	4.47 (18.0)	4.12 (15.0)	7.00 (47.0)	8.83 (76.0)	7.97 (61.5)
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	4.80 (21.0)	6.00 (34.0)	5.43 (27.5)	2.45 (4.0)	2.83 (6.0)	2.65 (5.0)	3.46 (10.0)	4.00 (14.0)	3.74 (12.0)	6.08 (35)	7.48 (54.0)	6.82 (44.5)
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	8.43 (69.0)	11.42 (128.4)	10.03 (98.7)	5.41 (27.3)	4.17 (15.4)	4.83 (21.3)	5.00 (23.0)	5.29 (26.0)	5.15 (24.5)	11.01 (119.3)	13.11 (169.8)	12.11 (144.6)
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	7.94 (61.0)	11.97 (141.3)	10.16 (101.2)	5.10 (24.0)	4.89 (21.9)	4.99 (22.9)	5.92 (33.0)	5.48 (28.0)	5.70 (30.5)	10.95 (118.0)	13.90 (191.2)	12.51 (154.6)
T_7 - PE pendimethalin at 750g /ha + HW on 45 DAS	7.07 (48.0)	9.90 (96.0)	8.60 (72.0)	5.10 (24.0)	5.66 (30.0)	5.39 (27.0)	5.10 (24.0)	4.69 (20.0)	4.90 (22.0)	9.90 (96.0)	12.17 (146.0)	11.09 (121.0)
T_8 - PE pendimethalin at 750g / ha + PW on 45 DAS	7.21 (50.0)	7.28 (51.0)	7.25 (50.5)	5.39 (27.0)	6.32 (38.0)	5.87 (32.5)	6.08 (35.0)	4.80 (21.0)	5.48 (28.0)	10.68 (112.0)	10.58 (110.0)	10.63 (111.0)
T_9 - HW on 25 & 45 DAS	3.16 (8.0)	3.61 (11.0)	3.39 (9.5)	3.00 (7.0)	2.45 (4.0)	2.74 (5.5)	3.16 (8.0)	3.61 (11.0)	3.39 (9.5)	5.00 (23.0)	5.29 (26.0)	5.15 (24.5)
T_{10} - Unweeded control	10.82 (115.0)	16.91 (284.0)	14.20 (199.5)	12.49 (154.0)	13.30 (175.0)	12.90 (164.5)	6.48 (40.0)	7.75 (58.0)	7.14 (49.0)	17.64 (309.0)	22.78 (517.0)	20.37 (413.0)
SEm ±	0.34	0.46	0.41	0.26	0.26	0.26	0.25	0.24	0.24	0.49	0.58	0.54
CD(P = 0.05)	0.73	1.00	0.88	0.56	0.56	0.57	0.53	0.52	0.52	1.04	1.25	1.15

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding, Figures in parenthesis are original values, Data subjected to log transformation (log(x+2))

Table 2
Effect of Weed Management on Groupwise Weed Density on Soybean on 40 DAHA

Treatments	*Grasses (no/m²)*			*BLW (no/m²)*			*Sedges (no/m²)*			*Total weed density (no/m²)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g / ha + E. up on 45 DAS	6.00 (34.0)	7.62 (56.0)	6.86 (45.0)	6.78 (44.0)	5.29 (26.0)	6.08 (35.0)	5.83 (32.0)	4.80 (21.0)	5.34 (26.5)	10.58 (110.0)	10.25 (103.0)	10.42 (106.5)
T_2- EPOE imazethapyr at 75 g / ha + E. up on 45 DAS	2.8 (36.0)	5.10 (24.0)	4.12 (15.0)	2.83 (6.0)	3.74 (12.0)	3.32 (9.0)	5.10 (24.0)	4.58 (19.0)	4.85 (21.5)	6.16 (36.0)	7.55 (55.0)	6.89 (45.5)
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	2.2 (43.0)	4.12 (15.0)	3.36 (9.0)	2.45 (4.0)	2.83 (6.0)	2.65 (5.0)	4.47 (18.0)	3.87 (13.0)	4.18 (15.5)	5.20 (25.0)	6.00 (340.0)	5.61 (29.5)
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	1.7 (31.0)	3.16 (8.0)	2.55 (4.5)	1.73 (1.0)	2.00 (2.0)	1.87 (1.5)	3.87 (13.0)	3.46 (10.0)	3.67 (11.5)	4.12 (15.0)	4.69 (20.0)	4.42 (17.5)
T_5 - PE oxyfluorfen at 125g/ ha + HW on 45 DAS	5.83 (32.0)	8.44 (69.3)	7.26 (50.7)	5.77 (31.3)	4.45 (17.8)	5.15 (24.5)	6.08 (35.0)	5.29 (26.0)	5.70 (30.5)	10.01 (98.3)	10.73 (113.1)	10.38 (105.7)
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	6.40 (39.0)	9.31 (84.7)	7.99 (61.9)	4.93 (22.3)	5.27 (25.9)	5.10 (24.0)	5.66 (30.0)	5.74 (31.0)	5.70 (30.5)	9.66 (91.3)	11.98 (141.5)	10.88 (116.4)
T_7 - PE pendimethalin at 750g/ ha + HW on 45 DAS	5.39 (27.0)	7.07 (48.0)	6.28 (37.5)	5.48 (28.0)	6.40 (39.0)	5.96 (33.5)	4.69 (20.0)	4.36 (17.0)	4.53 (18.5)	8.77 (75.0)	10.30 (104.0)	9.57 (89.5)
T_8 - PE pendimethalin at 750g/ ha + PW on 45 DAS	5.57 (29.0)	9.31 (84.7)	7.67 (56.9)	5.37 (26.9)	6.63 (41.9)	6.04 (34.4)	5.10 (24.0)	4.00 (14.0)	4.58 (19.0)	9.05 (79.9)	11.94 (140.68)	10.60 (110.3)
T_9 - HW on 25 & 45 DAS	6.08 (35.0)	4.90 (22.0)	5.52 (28.5)	3.74 (120.0)	4.24 (16.0)	4.00 (14.0)	4.24 (16.0)	4.58 (19.0)	4.42 (17.5)	8.06 (63.0)	7.68 (57.0.)	7.87 (60.0)
T_{10} - Unweeded control	9.17 (82.0)	14.53 (209.0)	12.14 (145.5)	12.92 (165.0)	15.39 (235.0)	14.21 (200.0)	7.62 (56.0)	7.94 (61.0)	7.78 (58.5)	17.46 (303.0)	22.52 (505.0)	20.15 (404.0)
SEm ±	0.27	0.38	0.33	0.26	0.28	0.28	0.26	0.24	0.25	0.44	0.53	0.49
CD(P = 0.05)	0.58	0.82	0.71	0.56	0.62	0.59	0.55	0.51	0.53	0.95	1.13	1.04

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding, Figures in parenthesis are original values, Data subjected to log transformation (log(x+2))

Table 3
Effect of Weed Management on Total Weed Dry Weight and Weed Control Efficiency on Soybean

Treatments	*Total weed dry weight (kg/ha)*						*Weed control efficiency (%)*					
	20 DAHA			*40 DAHA*			*20 DAHA*			*40 DAHA*		
	2008-09	*2009*	*Mean*	*2008-09*	*2009*	*Mean*	*2008-09*	*2009*	*Mean*	*2008-09*	*2009*	*Mean*
T_1 - EPOE imazethapyr at 50g / ha + E. up on 45 DAS	22.05 (484.0)	21.59 (464.1)	21.82 (474.2)	21.42 (457.0)	21.10 (443.1)	21.26 (450.1)	51.8	63.3	57.6	62.3	74.2	68.3
T_2- EPOE imazethapyr at 75 g / ha + E. up on 45 DAS	16.18 (259.9)	16.01 (254.3)	16.10 (257.1)	15.26 (230.9)	15.25 (230.5)	15.25 (230.7)	74.1	79.9	77.0	80.9	86.6	83.8
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	14.42 (205.9)	14.30 (202.6)	14.36 (204.3)	(166.9)	13.03 (167.7)	10.35 (167.3)	79.5	84.0	81.7	86.2	90.2	88.2
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	10.44 (107.0)	10.21 (102.2)	10.32 (104.6)	7.75 (58.0)	7.57 (55.3)	7.66 (56.7)	89.4	91.9	90.6	95.2	96.8	96.0
T_5 - PE oxyfluorfen at 125g/ ha + HW on 45 DAS	16.50 (270.3)	16.03 (254.9)	16.27 (262.6)	17.30 (297.2)	15.33 (233.0)	16.34 (265.1)	73.1	79.8	76.5	75.5	86.4	81.0
T_6 - PE oxyfluorfen at 125g/ ha + PW on 45 DAS	17.95 (320.1)	17.74 (312.8)	17.85 (316.5)	18.68 (346.9)	17.21 (294.4)	17.96 (320.5)	68.1	75.3	71.7	71.4	82.9	77.1
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	19.69 (385.5)	18.07 (324.6)	18.90 (355.1)	20.36 (412.4)	17.77 (313.6)	19.10 (363.0)	61.6	74.3	68.0	66.0	81.8	73.9
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	18.56 (342.3)	18.00 (321.9)	18.28 (332.2)	19.27 (369.2)	17.24 (295.0)	18.28 (332.1)	65.9	74.5	70.2	69.5	82.8	76.2
T_9 - HW on 25 & 45 DAS	9.99 (97.8)	11.07 (120.5)	10.54 (109.2)	11.47 (129.5)	10.57 (109.7)	12.03 (119.6)	90.3	90.5	90.4	89.3	93.6	91.5
T_{10} -Unweeded control	31.73 (1005)	35.58 (1264.2)	33.71 (1134.6)	34.84 (1211.9)	41.49 (1719.1)	38.31 (1465.5)	0.0	0.0	0.0	0.0	0.0	0.0
SEm ±	0.85	0.85	0.85	0.88	0.85	0.87	NA	NA		NA	NA	
CD(P = 0.05)	1.82	1.82	1.83	1.89	1.83	1.86						

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding, Figures in parenthesis are original values, Data subjected to log transformation (log(x+2), NA- Not analysed

Table 4
Effect of Weed Management on Growth Attributes of Soybean

Treatments	*Plant height (cm)*						*Dry matter production (kg/ha)*					
	20 DAHA			*40 DAHA*			*20 DAHA*			*40 DAHA*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50g/ ha + E. up on 45 DAS	37.0	36.3	36.7	63.8	69.0	66.4	580	611	596	1175	1206	1191
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	40.3	39.1	39.7	72.5	71.6	72.1	604	632	618	1344	1329	1337
T_3 - EPOE imazethapyr at 100g/ ha+ E. up on 45 DAS	42.0	41.7	42.2	74.4	74.2	74.3	856	763	810	1548	1430	1489
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	40.6	39.8	38.5	77.8	77.5	77.7	718	690	704	1847	1655	1751
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	37.8	36.1	37.0	60.6	68.5	64.6	589	618	604	1248	1385	1317
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	35.9	36.7	36.3	68.0	64.9	66.5	520	613	567	1203	1232	1218
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	36.1	35.2	33.0	66.5	63.7	65.1	573	623	598	1110	1320	1215
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	39.	35.1	37.3	62.4	66.1	64.3	540	598	569	1315	1216	1266
T_9 - HW on 25 & 45 DAS	41.4	41.4	38.3	50.0	56.4	53.2	533	564	549	996	1055	1026
T_{10}- Unweeded control	30.0	28.2	31.8	41.5	40.6	38.3	372	420	396	787	887	837
SEm ±	1.8	1.8	1.6	3.3	3.	3.3	30	31	31	65	65	65
CD(P = 0.05)	4.0	3.8	3.5	7.00	7.1	7.0	65	67	66	140	140	140

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding, Figures in parenthesis are original values, Data subjected to log transformation (log(x+2))

Table 5
Effect of Weed Management on Yield Attributes of Soybean

Treatments	*No of pods per plant*			*No of seeds per pod*			*100 seed weight (g)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	73.3	85.3	79.3	2.2	2.5	2.4	10.3	10.4	10.4
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	86.5	98.5	92.5	2.3	2.55	2.4	10.8	10.7	10.7
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	90.5	102.5	96.5	2.4	2.6	2.5	11.5	11.0	11.4
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	89.3	101.3	95.3	2.4	2.6	2.5	11.1	10.8	11.0
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	63.0	75	69.0	2.2	2.5	2.3	10.2	10.1	10.3
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	61.7	68.9	65.3	2.1	2.45	2.3	10.2	10.0	10.3
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	83.3	90.5	86.9	2.1	2.45	2.3	10.9	10.5	10.8
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	77.5	84.7	81.1	2.2	2.5	2.3	10.4	10.3	10.4
T_9 - HW on 25 & 45 DAS	61.0	68.2	64.6	2.2	2.5	2.3	9.8	10.2	9.9
T_{10} - Unweeded control	37.0	46.6	41.7	2.0	2.4	2.2	8.0	7.3	7.6
SEm ±	6.15	4.2	4.0	0.14	0.12	0.12	0.26	0.51	0.52
CD(*P* = 0.05)	13.2	9.07	8.6	NS	NS	NS	0.57	1.10	1.12

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 6
Effect of Weed Management on Yield and Weed Index of Soybean

Treatments	*Grain yield (kg/ha)*			*Stover yield (kg/ha)*			*Weed index (%)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	1350	1387	1369	2281	2238	2260	-6.72	-12.40	-9.56
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	1315	1467	1391	2755	2386	2571	-3.95	-18.88	-11.42
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	1691	1645	1668	2511	2848	2604	-33.68	-33.31	-33.49
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	1533	1514	1524	2538	2669	2680	-21.19	-22.69	-21.94
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	1410	1304	1357	2530	2493	2512	-11.46	-5.67	-8.57
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	1298	1407	1353	2267	2596	2432	-2.61	-14.02	-8.31
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	1327	1481	1404	2109	2252	2181	-4.90	-20.02	-12.46
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	1305	1456	1381	2125	2419	2272	-3.16	-17.99	-10.58
T_9 - HW on 25 & 45 DAS	1265	1234	1250	2282	2029	2156	0.00	0.00	0.00
T_{10} - Unweeded control	738	833	786	1774	1473	1624	41.66	32.50	37.08
SEm ±	68	70	70	116	121	119	-	-	-
CD(P = 0.05)	147	151	150	250	260	255	-	-	-

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 7
Effect of Treatments on Nutrient Removal by Weeds on 20 DAHA

Treatments	*N (kg/ha)*			*P (kg/ha)*			*K (kg/ha)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	3.09	2.42	2.76	0.96	1.04	1.00	2.52	2.61	2.57
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	2.92	2.25	2.59	0.87	0.95	0.91	2.48	2.57	2.53
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	2.72	2.05	2.39	0.81	0.89	0.85	1.70	1.79	1.75
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	2.55	1.88	2.22	0.78	0.86	0.82	1.53	1.62	1.58
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	3.31	2.64	2.98	0.99	1.07	1.03	2.20	2.29	2.25
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	3.16	2.49	2.83	0.99	1.07	1.03	2.14	2.23	2.19
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	2.80	2.13	2.47	1.00	1.08	1.04	1.84	1.93	1.89
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	2.91	2.24	2.58	1.07	1.15	1.11	2.18	2.27	2.23
T_9 - HW on 25 & 45 DAS	3.05	2.38	2.72	2.18	2.26	2.22	2.14	2.23	2.19
T_{10} - Unweeded control	10.24	9.57	9.91	2.30	2.38	2.34	2.74	2.83	2.79
SEm ±	0.18	0.15	0.16	0.06	0.06	0.06	0.10	0.11	0.11
CD(P = 0.05)	0.38	0.32	0.35	0.13	0.14	0.13	0.22	0.23	0.23

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 8
Effect of Treatments on Nutrient Removal by Weeds on 40 DAHA

Treatments	*N (kg/ha)*			*P (kg/ha)*			*K (kg/ha)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	8.13	8.25	8.19	3.16	3.47	3.32	12.93	13.24	13.09
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	7.40	7.52	7.46	3.10	3.41	3.26	11.25	11.56	11.41
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	6.65	6.77	6.71	2.82	3.13	2.98	10.98	11.29	11.14
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	5.91	6.03	5.97	2.36	2.67	2.52	7.61	7.92	7.77
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	8.56	8.68	8.62	3.61	3.92	3.77	11.65	11.96	11.81
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	9.18	9.30	9.24	3.86	4.17	4.02	13.08	13.39	13.24
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	8.16	8.28	8.22	3.44	3.75	3.60	11.39	11.70	11.55
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	9.40	9.52	9.46	5.66	5.97	5.82	12.34	12.65	12.50
T_9 - HW on 25 & 45 DAS	10.71	10.83	10.77	8.42	8.73	8.58	13.25	13.56	13.41
T_{10} - Unweeded control	36.24	36.36	36.30	14.73	15.04	14.89	13.78	14.09	13.94
SEm ±	0.56	0.57	0.57	0.27	0.28	0.28	0.59	0.60	0.60
CD(P = 0.05)	1.21	1.23	1.22	0.58	0.61	0.59	1.26	1.29	1.28

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 9
Effect of Treatments on Nutrient Removal by Crop on 20 DAHA

Treatments	*N (kg/ha)*			*P (kg/ha)*			*K (kg/ha)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	3.96	3.27	3.62	1.72	1.39	1.56	3.22	3.19	3.21
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	4.08	3.39	3.74	1.81	1.48	1.65	3.35	3.32	3.34
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	4.51	3.82	4.17	1.95	1.62	1.79	3.59	3.56	3.58
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	4.45	3.76	4.11	1.9	1.57	1.74	3.45	3.42	3.44
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	3.92	3.23	3.58	1.56	1.23	1.40	3.29	3.26	3.28
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	3.83	3.14	3.49	1.51	1.18	1.35	3.12	3.09	3.11
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	3.89	3.2	3.55	1.65	1.32	1.49	2.95	3.03	2.99
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	3.41	2.72	3.07	1.45	1.12	1.29	3	3.08	3.04
T_9 - HW on 25 & 45 DAS	3.09	2.4	2.75	1.37	1.04	1.21	2.74	2.82	2.78
T_{10} - Unweeded control	2.62	1.93	2.28	1.22	0.89	1.06	2.04	2.12	2.08
SEm ±	0.192	0.158	0.18	0.081	0.065	0.07	0.156	0.157	0.16
CD(P = 0.05)	0.412	0.339	0.38	0.174	0.139	0.16	0.335	0.337	0.34

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 10
Effect of Treatments on Nutrient Removal by Crop on 40 DAHA

Treatments	*N (kg/ha)*			*P (kg/ha)*			*K (kg/ha)*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1- EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	18.24	17.55	17.90	2.79	2.46	2.63	21.7	21.71	21.73
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	18.44	17.75	18.10	2.91	2.58	2.75	22.9	22.91	22.93
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	20.49	19.8	20.15	3.18	2.85	3.02	26.2	26.16	26.18
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	20.78	20.09	20.44	3.21	2.88	3.05	27.6	27.58	27.60
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	18.68	17.99	18.34	2.26	1.93	2.10	20.1	20.07	20.09
T_6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	18.51	17.82	18.17	2.33	2.00	2.17	19.2	19.14	19.16
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	18.9	18.21	18.56	3.04	2.71	2.88	20.9	21.06	21.02
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	18.36	17.67	18.02	2.36	2.03	2.20	20.7	20.76	20.72
T_9 - HW on 25 & 45 DAS	17.09	16.4	16.75	1.98	1.65	1.82	20.	20.34	20.30
T_{10} - Unweeded control	10.9	10.21	10.56	2.41	2.08	2.25	16.9	17.01	16.97
SEm ±	0.929	0.89	0.91	0.132	0.12	0.12	1.09	1.095	1.09
CD(P = 0.05)	1.992	1.92	1.96	0.284	0.25	0.27	2.34	2.349	2.35

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 11
Effect of Treatments on Economics on Soybean

Treatments	*Cost of cultivation (x 103 ₹/ha)*	*Gross return (x 103 ₹/ha)*	*Net return (x 103 ₹/ha)*	*B:C ratio*
T1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	15.4	28.0	12.7	1.82
T2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	15.5	31.0	15.5	1.99
T3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	15.6	34.7	19.0	2.21
T4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	16.1	34.1	18.0	2.14
T5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	15.3	29.0	13.7	1.89
T6 - PE oxyfluorfen at 125 g/ ha + PW on 45 DAS	15.5	28.0	12.4	1.80
T7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	15.9	31.2	15.3	1.96
T8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	16.1	30.0	13.9	1.85
T9 - HW on 25 & 45 DAS	17.1	26.7	9.6	1.56
T10 - Unweeded control	13.6	19.6	6.0	1.43

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

Table 12
Effect of Treatments on Residual Effect of Succeeding Crop

Treatments	*Germination (%)*						*Yield (kg/ha)*					
	Sunflower			*Pearlmillet*			*Sunflower*			*Pearlmillet*		
	2008-09	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*	*2008-09*	*2009*	*mean*
T_1 - EPOE imazethapyr at 50 g/ ha + E. up on 45 DAS	95.50	90	92.75	88.70	86.33	87.52	955	911	933	625	622	623.50
T_2- EPOE imazethapyr at 75 g/ ha + E. up on 45 DAS	92.30	90.23	91.27	90.30	89.00	89.65	934	933	934	542	748	645.00
T_3 - EPOE imazethapyr at 100 g/ ha + E. up on 45 DAS	93.30	91.00	92.15	91.30	89.33	90.32	973	947	960	680	633	656.50
T_4 - EPOE imazethapyr at 200 g/ ha + E. up on 45 DAS	94.70	90.73	92.72	90.70	88.67	89.69	983	1003	993	710	781	745.50
T_5 - PE oxyfluorfen at 125 g/ ha + HW on 45 DAS	90.60	87.00	88.80	89.00	86.00	87.50	926	911	919	745	777	761.00
T_6 - PE oxyfluorfen at 125g/ ha + PW on 45 DAS	94.70	87.00	90.85	89.70	86.33	88.02	962	777	870	620	751	685.50
T_7- PE pendimethalin at 750 g/ ha + HW on 45 DAS	93.40	89.00	91.20	90.70	85.00	87.85	942	755	849	635	688	661.50
T_8 - PE pendimethalin at 750 g/ ha + PW on 45 DAS	94.20	87.33	90.77	92.40	87.33	89.87	954	788	871	658	737	697.50
T_9 - HW on 25 & 45 DAS	91.90	90.67	91.29	91.60	87.67	89.64	859	844	852	612	803	707.50
T_{10} -Unweeded control	93.70	90.66	92.18	90.80	86.67	88.74	889	800	845	635	788	711.50
SEm ±	4.6	2.3	4.52	4.5	2.1	4.41	46	133	45	32	127	34.56
CD(P = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

EPOE- Early post emergence, E.up- Earthing up, DAS-Days after sowing, DAHA- Days after herbicide application, PW-Power weeder, HW- Hand weeding

productivity of soybean and has no residual effect on succeeding crops.

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