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Efficacy of Sequential application of Herbicides on soybean growth and yield in north eastern transitional zone of Karnataka

Anand G Patil[1], A. S. Halepyati [2] AND B. M. Chittapur[3]
1.Department of NRM, College of Horticulture, Bidar, Karnataka, India
2. Department of Agronomy, College of Agriculture, Raichur, Karnataka, India
Email: kvkpatil@gmail.com

ABSTRACT
A field experiment was conducted at Agriculture Research Station, Janawada, Bidar during kharif seasons for two consecutive years (2014 and 2015) to study the efficacy of sequential application of herbicides on growth and yield of soybean (Glycine max L.) in north eastern transitional zone of Karnataka. The result revealed that among the different herbicide treatments in soybean the application of pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} fb imazethapyr 10 SL @ 75 g a.i. ha^{-1} in soybean crop recorded significantly higher seed yield (2456 kg ha^{-1}) due to higher growth parameters viz., plant height (51.44 cm), number of green leaves (18.42), number of branches (4.19), leaf area index (2.81), leaf area duration (75.10 days) and yield parameters at harvest viz., number of pods (52.85), pod weight per plant (25.06 g), seed yield per plant (35.24 g) and test weight (10.71 g). This was mainly due to lower weed density 0.5 m^{-2} (3.88) compared to other herbicide treatments respectively.
Key words: *efficacy, pendimethalin, imazethapyr, soybean*

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INTRODUCTION

Soybean (*Glycine max* L.) is the one of the important pulse cum oil seed crop among all the seed crops. It has been termed as miracle bean because of higher protein (40%) and oil (20%) content. It is richest, cheapest and easiest source of best quality protein and fats and having a multiplicity of uses as food and industrial products therefore it is called “Wonder crop”. In India it is cultivated in 12.20 m ha with annual production of 11.99 m t and productivity of 983 kg ha^{-1}. Karnataka contributes 0.23 m ha with a production of 0.25 lakh m t with productivity of 1129 kg ha^{-1} [1]. Soybean is one of the important oilseed cum pulse crops gaining popularity in north eastern transitional track of Karnataka during *kharif* season. Weed competition is one of the most important causes of yield reduction in soybean which is estimated to be 20-77 per cent depending on the weed species, their density and period of weed crop competition. The effective control of weeds can help in improving the productivity of soybean. The weed free maintenance up to 45 days after sowing resulted in 96 per cent increase in seed yield of soybean compared to uncontrolled weedy situations [2]. The effective and economical weed control in soybean on large scale is not possible through hand weeding or use of mechanical tools because of time and labour intensiveness and difficulty due to intermittent rains. The herbicides like alachlor, fluchloralin and pendimethalin which are recommended for weed control in soybean are being used by the farmers [3]. These herbicides have been quite effective on grasses and their continuous use has resulted in weed shift in some areas in favour of non-grassy weeds like *Cleome viscosa*,

Celosia argentea, Trianthema monogyna and *Commelina benghalensis,* which are highly competitive with soybean crop. Further, these herbicides proved ineffective against *Cyperus rotundus* and *Commelina benghalensis.* This could be due to immobility of herbicides from leaves to the tubers of *Cyperus rotundus*. Therefore, there is a need to have alternate herbicides which may provide wide spectrum of weed control to avoid weed shift and also possible development of herbicide resistance. The new herbicides namely; quizalofop-ethyl, Imazethapyr, chlorimuron-ethyl and fenoxyprop ethyl have been developed to control wide range of weeds in broad-leaved crops including soybean. Therefore the experiment was carried out to study the efficacy sequential application of different herbicides in soybean.

MATERIALS AND METHODS

The experiment was conduct at Agricultural Research Station, Janawada, Bidar to study the efficacy of weed management on soybean (*Glycine max* L.) in north eastern transitional zone of Karnataka during *kharif* 2014 and 2015. The land was ploughed once with mould-board plough and brought to fine tilth with two harrowing. The stubbles and weeds were collected and disposed off from the experimental area. At the time of sowing, the recommended dose of fertilizer for soybean is 40:80:25 kg N: P_2O_5: K_2O ha^{-1} was applied in the form of urea, diamonium phosphate (DAP) and muriate of potash as basal dose. The healthy seeds of soybean variety DSB-21 was treated with biofertilizer, mainly *Rhizobium* @ 20 g and PSB @ 20 g per kg seed and dried under shade. The recommended seed rate was used for sowing. The pre-emergence herbicides *viz.*, Pendimethalin 30 EC, Pendimethalin 38.7 CS and Oxyfluorfen 23.5 EC were sprayed uniformly one day after sowing of the crop. The pre-emergence application was made on the soil surface uniformly with minimum trampling. The post emergence herbicides *viz.*, Imazethapyr 10 SL, Quizalofop-p-ethyl 5 EC and Fenoxyprop-p-ethyl 5 EC were applied uniformly at 21 DAS as per the treatment. The soil was medium deep black, neutral in reaction. The experiment was laid out in randomized block design with the twelve treatment and three replications. In the treatment (T_{10}) one hand weeding (between 30-45 DAS) and two inter cultivations (30 and 45 DAS) were taken. The results have been discussed at the probability level of five per cent. The level of significance used in 'F' and 't' test were p=0.05. Critical difference values were calculated whenever the 'F' test was significant. The data was analyzed statistically for test of significance following the procedure described by Gomez and Gomez [4].

RESULTS AND DISCUSSIONS

The total weed population differed significantly due to different weed control treatments at all the growth stages (Table 1). The study indicated that the highest weed density was recorded in weedy check (8.15, 9.10, 9.22 and 9.43/0.5m^2 at 20, 40, 60 DAS and at harvest, respectively) and lowest with weed free check (0.71, 0.71, 0.71 and 0.71/ 0.5 m^2 at 20, 40, 60 DAS and at harvest). The effect of pre emergent herbicides was very effective at early stage and among the different weed control practices at 20 DAS, application of pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1}at 20 DAS + IC (35 DAS) was very effective in controlling all types of weeds (3.84/ 0.5 m^2) over weedy check. This was mainly due to effective control of weeds by pendimethalin as pre emergence besides use of imazethapyr as post emergence herbicide and one intercultivation carried out during critical period of crop growth. These results are in conformity with findings of Monsefi *et al.* [7], Sangeetha *et al.* [8] and Sangwan *et al.* [9]. However, from 40 DAS onwards the total weed count recorded with the application of pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (3.29, 3.61 and 3.88 at 40, 60 DAS and at harvest, respectively) was lower and it was followed by application of pendimethalin 30 EC @ 1 kg a.i. ha^{-1} + IC (30 and 45 DAS) + one HW (between 30-45 DAS) (3.38, 3.72 and 3.98 at 40, 60 DAS and at harvest, respectively), pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* quizalofop p ethyl @ 75 g a.i. ha^{-1}at 20 DAS + IC (35 DAS) (3.48, 3.71 and 4.09 at 40, 60 DAS and at harvest, respectively) and pendimethalin 38.7 CS@ 700 g a.i. ha^{-1} *fb* fenoxyprop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (3.50, 3.84 and 4.13 at 40, 60 DAS and at harvest, respectively) over weedy check (9.10, 9.22 and 9.43 at 40, 60 DAS and at harvest, respectively) indicating weed controlling efficiency of herbicides when applied in sequence. Similar results were also reported by Chandraker *et al.* [5]. Among the various herbicides used, T_{10}, T_1, T_3 and T_5 registered significantly lower weed count at 20 DAS. The

superiority of these treatments could be attributed to effective control of weeds by use of pre emergence herbicides and also post emergence herbicides. As a result of this number of grassy weeds, sedges and broad leaved weeds as well as total weeds were significantly lower in these treatments.

Table 1. Effect of herbicides on weed biomass at different growth stages and weed index in soybean (2 year pooled data)

Treatments	Total weed count (No. 0.5 m^{-2})			
	20DAS	40DAS	60DAS	At harvest
T_1	3.84 (6.40)	3.29 (4.50)	3.61 (5.62)	3.88 (6.66)
T_2	4.97 (11.33)	4.39 (8.65)	4.68 (9.80)	4.83 (10.72)
T_3	3.92 (6.74)	3.48 (5.18)	3.71 (6.01)	4.09 (7.41)
T_4	4.82 (10.67)	4.41 (8.76)	4.60 (9.59)	4.79 (30.49)
T_5	4.00 (7.01)	3.50 (5.21)	3.84 (6.45)	4.13 (7.59)
T_6	4.77 (10.39)	4.45 (8.91)	4.62 (9.69)	4.76 (10.34)
T_7	6.07 (17.43)	5.60 (14.74)	5.87 (16.29)	6.09 (17.57)
T_8	6.17 (18.06)	5.79 (15.77)	6.07 (17.42)	6.26 (18.32)
T_9	6.09 (17.19)	5.79 (15.82)	6.12 (17.76)	6.24 (19.42)
T_{10}	4.00 (7.02)	3.38 (4.80)	3.72 (5.98)	3.98 (7.00)
T_{11}	8.15 (32.56)	9.10 (30.48)	9.22 (41.60)	9.43 (43.54)
T_{12}	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
S.Em.±	0.10	0.08	0.10	0.06
C.D. at 5%	0.31	0.26	0.29	0.20

Figures in the parentheses indicate the original value, data subjected for transformation using $\sqrt{x+0.5}$, where x is weed count

T_1: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* Imazethapyr @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_2: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Imazethapyr @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS) **T_3:** Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* Quizalofop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_4: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Quizalofop-p-ethyl @ 75g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_5: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* by Fenoxyprop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_6: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Fenoxyprop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_7: Imazethapyr @ 75 a.i. ha^{-1} (POE- 20 DAS) + IC (35 DAS),
T_8: Quizalofop-p-ethyl @ 75 a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS),
T_9: Fenoxyprop-p-ethyl @ 75a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS),
T_{10}: Pendimethalin @ 1 kg a.i. ha^{-1} (PRE)+ IC (30 & 45 DAS)+ one HW (between 30 to 45 DAS),
T_{11}: Weedy check
T_{12}: Weed free check

Table 2. Growth of soybean at different growth stages as influenced by weed management practices (2 year pooled data)

Treatment	Plant height (cm) at harvest	No. of green leaves at 60 DAS	No. of branches at harvest	LAI	LAD (30-60DAS)	Dry matter production (g $plant^{-1}$)
T_1	51.44	18.42	4.19	2.81	75.10	36.60
T_2	41.57	14.88	3.49	2.27	60.69	29.57
T_3	49.64	17.77	4.05	2.72	72.47	35.31
T_4	40.92	14.65	3.34	2.24	59.73	29.11
T_5	48.58	17.39	3.96	2.66	70.92	34.56
T_6	39.87	14.28	3.25	2.18	58.21	28.38
T_7	35.60	12.75	2.90	1.95	51.97	25.34
T_8	35.03	12.54	2.86	1.92	51.14	24.94
T_9	32.91	11.78	2.68	1.80	48.04	23.43
T_{10}	51.48	18.43	4.20	2.82	75.16	36.63
T_{11}	22.03	7.89	2.35	1.21	32.17	15.70
T_{12}	54.92	19.66	4.48	3.00	80.17	39.07
S.Em.±	1.05	0.37	0.07	0.05	1.54	0.75
C.D. at 5%	3.10	1.11	0.22	0.16	4.53	2.20

T_1: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* Imazethapyr @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_2: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Imazethapyr @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_3: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* Quizalofop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_4: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Quizalofop-p-ethyl @ 75g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)

T_5: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* by Fenoxyprop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_6: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Fenoxyprop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_7: Imazethapyr @ 75 a.i. ha^{-1} (POE- 20 DAS) + IC (35 DAS),
T_8: Quizalofop-p-ethyl @ 75 a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS),
T_9: Fenoxyprop-p-ethyl @ 75a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS),
T_{10}: Pendimethalin @ 1 kg a.i. ha^{-1} (PRE)+ IC (30 & 45 DAS)+ one HW (between 30 to 45 DAS),
T_{11}: Weedy check
T_{12}: Weed free check

Table 3. Number of pods, pod weight, seed yield and hundred seed weight of soybean as influenced by weed management practices

Treatment	Number of pods (plant^{-1}) at 60 DAS	Number of pods (plant^{-1}) at harvest	Pod weight (g plant^{-1})	Seed yield (g plant^{-1})	Hundred seed weight (g)	Seed yield (kg ha^{-1})	Haulm Yield (kg ha^{-1})
T_1	24.58	52.85	25.06	35.24	10.71	2456	4888
T_2	19.87	42.72	20.25	28.48	10.40	1985	4345
T_3	23.73	51.01	24.18	34.01	10.53	2370	4763
T_4	19.55	42.04	19.94	28.03	10.98	1953	4316
T_5	23.22	49.92	23.66	33.28	10.68	2319	4697
T_6	19.05	40.96	19.44	27.31	10.91	1904	4225
T_7	17.01	36.57	17.35	24.38	10.68	1700	3900
T_8	16.74	35.99	17.08	23.99	10.68	1672	3854
T_9	15.72	33.81	16.05	22.54	10.24	1571	3636
T_{10}	24.60	52.90	25.09	35.26	10.84	2458	4914
T_{11}	10.53	22.63	14.06	15.09	10.21	1377	3265
T_{12}	26.17	56.26	28.09	37.51	11.19	2622	5006
S.Em.±	0.53	1.15	0.60	0.76	0.39	050	111
C.D. at 5%	1.57	3.37	1.76	2.25	NS	148	327

NS – Non significant
T_1: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* Imazethapyr @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_2: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Imazethapyr @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_3: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* Quizalofop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_4: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Quizalofop-p-ethyl @ 75g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_5: Pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} (PRE) *fb* by Fenoxyprop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_6: Oxyfluorfen @ 0.1 kg a.i. ha^{-1} (PRE) *fb* Fenoxyprop-p-ethyl @ 75 g a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS)
T_7: Imazethapyr @ 75 a.i. ha^{-1} (POE- 20 DAS) + IC (35 DAS),
T_8: Quizalofop-p-ethyl @ 75 a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS),
T_9: Fenoxyprop-p-ethyl @ 75a.i. ha^{-1} (POE-20 DAS) + IC (35 DAS),
T_{10}: Pendimethalin @ 1 kg a.i. ha^{-1} (PRE)+ IC (30 & 45 DAS)+ one HW (between 30 to 45 DAS),
T_{11}: Weedy check
T_{12}: Weed free check

The predominant attribute of growth would be the plant height which was responsible for producing more number of leaves and in turn leaf area for higher contribution to photosynthesis of the plant. At harvest, weed free check recorded 149.29 per cent increased plant height over weedy check. Lower plant height at harvest was recorded with weedy check (22.03 cm). While the treatments like application of pendimethalin 30 EC @ 1 kg a.i. ha^{-1} + IC (30 & 45 DAS) + HW (30-45 DAS) (51.48 cm) recorded on par plant height along with pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (51.44 cm), pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* quizalofop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (49.64 cm) and pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* fenoxyprop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (48.58 cm) have recorded higher but on par plant height, but significantly higher compared to weedy check (22.03 cm). Total number of branches was significantly higher with weed free check (4.48) when compared to weedy check (2.35) (Table 2). The unfavorable condition created by the weeds in case of weedy check might be the reason for lower number of branches whereas the uninterrupted availability of all the growth resources in weed free check resulted in more number of branches in weed free check. The possible reason for the more number of branches may be attributed to reduced crop weed competition and providing favorable

environment for growth of soybean at early growth stages. These results are in line with Chandraker *et al.* [5].

Leaf area increased from 30 to 60 DAS. At 60 DAS, the pooled data revealed that application of pendimethalin 30 EC @ 1 kg a.i. ha^{-1} + IC (30 & 45 DAS) + HW (30-45 DAS) (8.45 dm^2 $plant^{-1}$) recorded on par leaf area along with pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (8.44 dm^2 $plant^{-1}$), pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* quizalofop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (8.15 dm^2 $plant^{-1}$) and pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* fenoxyprop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (7.97 dm^2 $plant^{-1}$). It is well known that the persistence of the assimilatory surface area is a prerequisite for prolonged photosynthetic activity and ultimately crop productivity. The leaf area indicates the photosynthetic area available for synthesis of food. Higher leaf area assimilates leads to higher dry matter thus increasing the growth attribute like plant height and inturn higher source to sink relationship. Similar findings were reported by Sureshkumar *et al.* [6].

Significant differences were observed with respect to seed yield of soybean due to different weed control treatments. In the present study, pooled data indicated that weed free check recorded significantly higher seed yield (2622 kg ha^{-1}) over weedy check (1377 kg ha^{-1}). The increase in yield was to the tune of 90.41 per cent. Among the different weed control treatments, significantly higher seed yield was recorded with the application of pendimethalin 30 EC 1kg a.i. ha^{-1} + IC (30 & 45 DAS) + HW (30-45 DAS) (2458 kg ha^{-1}) and sequential application of pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (2456 kg ha^{-1}), pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* quizalofop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (2370 kg ha^{-1}) and pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* fenoxyprop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (2319 kg ha^{-1}) recorded 69.28, 69.15 and 63.22 per cent increased yield over weedy check which were on par with each other and the same was attributed to better control of weeds and higher weed control efficiency when herbicides were applied in sequence. This gives the clear indication that, under scarcity of labour, use of sequential application of herbicide could be followed as an alternative method of weed control. Seed yield was closely associated with straw yield which followed similar trend. The above results are in accordance with the findings of Sureshkumar *et al.* [6].

This gives the clear indication that, under scarcity of labour, use of sequential application of herbicide could be followed as an alternative method of weed control. Seed yield was closely associated with straw yield which followed similar trend. The higher seed yield may be attributed to improved yield components *viz.,* number of pods $plant^{-1}$, pod weight $plant^{-1}$ and seed weight $plant^{-1}$. Application of pendimethalin 30 EC @ 1 kg a.i. ha^{-1} + IC (30 & 45 DAS) + HW (30-45 DAS) (52.90, 25.09 and 35.26 g, respectively) and sequential application pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (52.85, 25.06 and 35.24 g, respectively) and pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* quizalofop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (51.01, 24.18 and 34.01 g, respectively) and pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* fenoxyprop p ethyl @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) (49.92, 23.66 and 33.28 g, respectively) have recorded on par data of the above said yield contributing parameters which were attributed to on par seed yield among them (Table 3). Weedy check recorded lower number of pods (22.63) over weed free check (56.26), thus noticed substantially reduced seed yield. Increase in pod weight in these treatments accommodated higher seed weight. Weedy check showed lower seed weight (15.09 g) over weed free check (37.51 g). The results corroborate findings of Sureshkumar *et al.* [6] and Chandraker *et al.* [5].

The sequential application of pendimethalin 38.7 CS @ 700 g a.i. ha^{-1} *fb* imazethapyr @ 75 g a.i. ha^{-1} at 20 DAS + IC (35 DAS) was the effective weed management practice in reducing the weed biomass and increasing the yield of soybean under scarcity of labour.

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