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Effect of weed management practices on weed dynamics and soybean productivity under mid hill zone of Himachal Pradesh

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Abstract
A field study was conducted during *kharif* of 2023 at Research farm, School of Agriculture, Abhilashi University, Mandi, Himachal Pradesh to evaluate the effect of weed management practices on weeds in soybean crop. The experiment was laid out in randomized block design (RBD) with three replications comprising of eight weed management treatments *viz*.- T_1= Weedy check, T_2= Weed free, T_3= Hand weeding at 25 & 45 DAS, T_4= Fluchloralin @1.0 kg a.i. ha^{-1} (PE), T_5= Pendimethalin @1.5 kg a.i. ha^{-1} (PE), T_6= Imazethapyr @100 g a.i. ha^{-1} (PE), T_7= Quizalofop-ethyl @50 g a.i. ha^{-1} (PoE) and T_8= Pendimethalin @0.75 g a.i. ha^{-1} + Imazethapyr @75 g a.i. ha^{-1} (PE). Application of weed free treatment (T_2) recorded significantly minimum count and dry matter of total weeds at 30, 60 and 90 DAS stage of soybean crop, which was significantly superior than all the other treatments at all the growth stages. The maximum weed control efficiency at every stage of soybean crop was also noted under treatment T_2. However, among the different herbicides, the application of Pendimethalin @0.75 kg a.i. ha^{-1}+ Imazethapyr @75 g a.i. ha^{-1} (PE) found the minimumcount and dry matter of total weeds and higher weed control efficiency at all stages of soybean crop. Whereas, the maximum count of total weeds, dry matter of total weeds and lowest weed control efficiency at 30, 60 and 90 DAS stages of soybean crop were observed under weedy check treatment (T_1) during field study.

Keywords: Soybean, weed management, herbicides, pendimethalin and imazethapyr

Introduction
In India, oilseed crops constitute the second largest agricultural produce, next to food grains and these are the important source of our national economy. The oil and economic end product of oilseed crops is an integral part of human diet. Besides dietary needs, the vegetable edible oil has numerous industrial, medical and therapeutic uses too.

Soybean [*Glycine max* (L.)], also popular as golden bean has become the miracle crop of 21^{st} century. It serves the dual purpose for being grown both as an oilseed and pulse crop as well (Thakare *et al*., 2006) [12]. It has been termed as miracle bean because of higher protein (40%) and oil (20%) content (Chouhan and Joshi, 2005) [4]. It is an excellent source of protein and oil besides it contains high level of amino acids such as lysine, leucine, lecithin and large amount of phosphorus (0.69%). It has high calorific value releasing 432 calories from 100 gm edible protein as compared to 350 calories from cereals of same quantity. Soybean is the cheapest source of proteins and hence, it is called "Poor man's meat". Soybean helps in maintaining soil fertility and symbiotically fixes nitrogen in soil. The succeeding crops after soybean, require 25% lesser amount of nitrogenous fertilizers. Thus, cost on fertilizers for cropping system is reduced by including the soybean crop. Soybean is world's first ranking crop as a source of vegetable oil. It has now become the largest source of vegetable oil and protein in the world and its large scale cultivation is concentrated in a few countries such as Argentina, Brazil, Canada, China, India, Paraguay and USA. Globally soybean is cultivated over an area of 118.3 million hectares with a production of 318.25 million metric tones and having a productivity of 2.69 metric tones ha^{-1} (Anonymous, 2022) [1]. Soybean has not only gained the vital importance in Indian agriculture but also plays a decisive role in oil economy of India. In India, Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh and Karnataka account for the majority of the cultivation (Tiwari, 2001) [13].

In India, it is cultivated in an area of 12.27 million hectares with an annual production of 12.99 million tones and average productivity of 1059 kg ha^{-1} (Anonymous, 2022) [1]. Major soybean growing states in India are Madhya Pradesh, Maharashtra. Rajasthan, Karnataka, Uttar Pradesh, Andhra Pradesh, Chhattisgarh and Gujarat. In Himachal Pradesh, it is cultivated on 0.6 thousand hectares with a production of 0.8 thousand tones and average productivity of 799 kg ha^{-1} (Anonymous, 2023) [2]. Although the average productivity of soybean in Himachal Pradesh is higher than the national average due to favorable conditions for its growth and development, yet the productivity is much below the potential level of 3000 kg ha^{-1}. Weeds are one of the greatest biological restrictions to crop output in India, although weed control is often overlooked. Weeds compete with crops for natural and applied resources, as well as reducing agricultural productivity and causing harvesting difficulties (Rao *et al*., 2015) [10]. They also serve as hosts for pests and pathogens. Weeds in India diminish crop yields by 32 to 80%, according to Rao *et al*. (2014) [9], because soybean is a rainy season crop and it is infested with a wide variety of weed flora in various flushes that compete with the crop plants for nutrients, light and moisture, in addition to their allelopathic effects. Weed infestation is a major factor affecting crop productivity, particularly during early growth under irrigated conditions. The first 20-40 days period after planting of soybean is considered to be critical with respect to weed crop competition. Seed yield reduction caused by weed infestation in soybean varies from 27% to 84% depending on type of soil, season and intensity of weed infestation (Peer *et al*., 2013) [8]. In order to achieve enhanced crop production and higher benefits from applied inputs, weeds must be kept under check using any of the safe and effective weed control measures.

Weeding by hand is one of the facts that India has a population of over 121 million people, there is still a major problem of timely labour shortages due to rising wages and diminishing efficiency in unfavourable working conditions, making manual weed control more difficult. As a result, farmers require information on effective and workable weed management strategies that are cost-effective. Due to the high cost of hand weeding and the shortage of labour, soybean must be treated with pre and post emergence herbicides for successful weed control (Bhowmik and Mandal, 2001) [3].

Now a days a few herbicides like Imazethapyr, Quizalofop and Fenoxaprop are available, which can be used safely in soybean. Recent investigations have revealed that Imidazolinones group of herbicide is very effective in controlling the weeds in soybean (*e.g*. Imazethapyr). These herbicides are active against broad leaf and grassy weeds, but their effects are variable at different places depending on the soil type, intensity and type of weed flora and rainfall etc. (Yadav *et al*., 2009) [14]. Fluchloralin is one of the dinitroaniline pesticides families and is an economically important class of agricultural compound used to prevent the growth of grasses and weeds in cultivated crops. It is pre sowing, selective or pre-emergence herbicide useful to control annual weeds. Pendimethalin is a selective herbicide used to control broadleaf weeds and grassy weed species in a number of crop, non-crop areas and on residential lawns and ornamentals also. Pendimethalin inhibits root and shoot growth. It controls the weed population and prevents weeds from emerging, particularly during the crucial development phase of the crop. Imazethapyr SL herbicide is a selective herbicide that can be applied as early pre-plant, pre-plant incorporated, pre-emergent or post-emergent treatments in soybean crop. Quizalofop-p-ethyl is a selective, post emergence phenoxy herbicide. Since not much work has been done on the relation to herbicidal weed management to exploit its yield potential, it becomes imperative to identify herbicide and its dose for weed control in soybean. Integrated weed management the conventional methods of weed control (hoeing or hand weeding) are labour intensive, expensive, insufficient and may cause damage to the crop. Chemical weed control is not common as the use of herbicides may be uneconomical due to low yield potential of soybean (Reddy, 2004) [11]. So, to avoid the ill effects of using a single method, use of integration of all possible methods can provide better yield and maximum benefit.

Material and Methods

The field experiment was carried out at the research farm of the School of Agriculture, Abhilashi University, Mandi (H.P.) during the *Kharif* season of 2023. The experimental farm is situated at 30^0 32’ N latitude and 74^0 53’E longitude, with an elevation of 1391 m above mean sea level. The soil of the experimental field was slightly acidic in reaction, medium in organic carbon, low in available nitrogen and medium in available phosphorus and potassium. The pH of the experimental soil was slightly acidic in reaction with an electrical conductivity of 0.25 dS m^{-1}, medium in organic carbon, low in available nitrogen, medium in available phosphorus, potassium. The experiment was laid out in a randomized block design (RBD) with eight treatments and three replications. The treatments consist of T_1= Weedy check, T_2= Weed free, T_3= Hand weeding at 25 & 45 DAS, T_4= Fluchloralin @1.0 kg a.i. ha^{-1} (PE), T_5= Pendimethalin @1.5 kg a.i. ha^{-1} (PE), T_6= Imazethapyr @100 g a.i. ha^{-1} (PE), T_7= Quizalofop - ethyl @50 g a.i. ha^{-1} (PoE) and T_8= Pendimethalin @0.75 g a.i. ha^{-1} + Imazethapyr @75 g a.i. ha^{-1} (PE). Recommended doses of nutrients (20:30:30 kg ha^{-1} NPK) were applied through Urea, SSP and MOP at the time of sowing. MDS-7001 variety of soybean was used in the field experiment.

Weed count of total weeds was recorded using 0.25 m^{-2} quadrant from two randomly selected places in each and every plot and expressed as number m^{-2}. The weeds density of total weeds was recorded at 30, 60 and 90 DAS stages of soybean crop.

To measure the dry weight of the total weeds, a quadrant of 0.25 m^{-2} was placed in two places at random and the weeds were removed those were falling under this and then all the weeds were shade dried and oven dried at 72±2ºC till constant weight was arrived. The dry weight was noted and expressed in g m^{-2}. The dry weight of the total weeds was also recorded at 30, 60 and 90 DAS stages of soybean crop.

Weed control efficiency of different weeds management practices at 30, 60 and 90 DAS stages of soybean crop was calculated on the basis of weed dry weight by the following formula:

$$\text{W.C.E.}(\%) = \frac{W_0 - W_1}{W_0} \times 100$$

Where,
W.C.E. = Weed control efficiency (%)
W_0 = Weed dry weight of weedy check (g)
W_1 = Weed dry weight of treated plot (g)

Results and Discussion

Total weed count (m^{-2})

Population of total weeds influenced significantly with weed management practices during experimentation at periodic intervals (Table-1). Data presented in Table-1 indicated that significantly lesser weed population (0.00 m^{-2}) was recorded under treatment T_2 (Weed free treatment) followed by treatment T_3 (Hand weeding at 25 & 45 DAS) during course of study. In case of herbicidal treatments, combination of pre-emergence application of treatment T_8 (Pendimethalin @ 0.75 g a.i. ha^{-1} + Imazethapyr 75 @ g a.i. ha^{-1}) recorded significantly lesser number of weeds at 60 and 90 DAS, respectively over rest of the treatments, whereas, at 30 DAS, significantly lesser number of total weeds was recorded under post emergence application of treatment T_7 (Quizalofop - ethyl @50 g a.i. $ha^{-1)}$ during experimentation. However, highest total weed population at 30, 60 and 90 DAS stages of soybenan crop was noded under treatment T_1 (Weedy check).

Table 1: Effect of weed management practices on total weed count (m^{-2}) at various stages of soybean crop

S. N.	Treatment	Total weed count (m^{-2})		
		30 DAS	60 DAS	90 DAS
T_1	Weedy check	6.53 (42.12)	8.85 (77.83)	9.50 (89.67)
T_2	Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	Hand weeding at 25 & 45 DAS	1.44 (1.56)	2.90 (7.90)	4.12 (16.46)
T_4	Fluchloralin @1.0 kg a.i. ha^{-1} (Pre emergence)	3.66 (12.92)	5.48 (29.57)	6.48 (41.49)
T_5	Pendimethalin @1.5 kg a.i. ha^{-1} (Pre emergence)	3.04 (8.76)	4.85 (23.03)	6.19 (37.79)
T_6	Imazethapyr @100 g a.i. ha^{-1} (Pre emergence)	3.13 (9.27)	5.12 (25.74)	6.30 (39.17)
T_7	Quizalofop-ethyl @50 g a.i. ha^{-1}(Post emergence)	2.34 (4.96)	5.25 (27.07)	6.44 (41.03)
T_8	Pendimethalin @0.75 kg a.i. ha^{-1}+ Imazethapyr @75 g a.i. ha^{-1} (PE)	2.38 (5.17)	4.48 (19.57)	5.89 (34.17)
0SEm±		0.11	0.15	0.18
LSD (p=0.05%)		0.32	0.46	0.57

*Values are subjected to square root transformation (√ x + 0.5), Original data given in parenthesis

Using weed control techniques on a weed-free treatment which was maintained weed-free throughout the growing season and had a minimal weed count in comparison to other treatments markedly decreased the overall number of weeds. It might be caused by the weed-free environment, pre- and post-emergence herbicide applications, and twice-hand weeding, which increased weed death in the early and later growth stages of the soybean crop and effectively reduced the overall weed population in a timely manner. These outcome of present field experiment is supported with the findings of Monsefi *et al.* (2014) [6], Rajendra *et al.* (2021) [20] and Kadam *et al.* (2018) [15].

Total weed dry matter (g m^{-2})

Different weed management practices had significant effect on dry matter accumulation of total weeds during experimentation at periodic intervals (Table-2). Data pertaining in Table-2 revealed that significantly lesser dry matter of total weeds were recorded under treatment T_2 (Weed free) followed by treatment T_3 (Hand weeding at 25 & 45 DAS) during course of study. In case of herbicidal treatments, combination of pre-emergence application of treatment T_8 (Pendimethalin @ 0.75 g a.i. ha^{-1} + Imazethapyr @ 75 g a.i. ha^{-1}) recorded significantly minimum dry matter of total weeds at 60 and 90 DAS, respectively over rest of the treatments, while,in the case of 30 DAS, significantly lower dry weight of total weeds were recorded under post emergence application of T_7 (Quizalofop-ethyl @ 50 g a.i. ha^{-1}) during experimentation. However, maximum total weed dry matter in soybean crop at all stages (*i.e.* at 30, 60 and 90 DAS) was recorded under weedy check treatment (T_1).

The most crucial factor in determining how well weed treatments work against them is the overall dry matter accumulation of weeds. The data analysis showed that as crop growth phases advanced, so did the accumulation of dry matter. Treatment T_1 (Weedy check) had the largest dry matter accumulation of all weeds at all crop growth stages. It may be the result of weeds growing more vigorously and continuously. Conversely, weed-free treatment resulted in a decreased dry matter buildup of all weeds. This could be explained by the fact that weeds were controlled in weed-free environments by applying herbicides both before and after the emergence of the soybean crop, which decreased the number of weeds and their generation of dry matter. Similar results related to this field trial were also found by Prachand *et al.* (2014) [7], Nepalia *et al.* (2017) [17] and Sankaranarayanan *et al.* (2002) [19].

Table 2: Effect of weed management practices on dry matter of total weed (g m^{-2}) at various growth stages of soybean crop

S. N.	Treatment	Total weed dry matter (g m^{-2})		
		30 DAS	60 DAS	90 DAS
T_1	Weedy check	7.28 (52.50)	9.87 (97.02)	10.60 (111.77)
T_2	Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_3	Hand weeding at 25 & 45 DAS	1.56 (1.94)	3.22 (9.85)	4.58 (20.52)
T_4	Fluchloralin @1.0 kg a.i. ha^{-1} (Pre emergence)	4.07 (16.10)	6.11 (36.86)	7.23 (51.72)
T_5	Pendimethalin @1.5 kg a.i. ha^{-1} (Pre emergence)	3.38 (10.92)	5.40 (28.71)	6.90 (47.11)
T_6	Imazethapyr @100 g a.i. ha^{-1} (Pre emergence)	3.47 (11.56)	5.71 (32.08)	7.02 (48.83)
T_7	Quizalofop-ethyl @50 g a.i. ha^{-1}(Post emergence)	2.59 (6.18)	5.85 (33.74)	7.19 (51.14)
T_8	Pendimethalin @0.75 kg a.i. ha^{-1} + Imazethapyr @75 g a.i. ha^{-1} (PE)	2.64 (6.44)	4.99 (24.39)	6.56 (42.59)
SEm±		0.12	0.17	0.21
LSD (*p=0.05%*)		0.36	0.52	0.63

*Values are subjected to square root transformation (√ x + 0.5), Original data given in parenthesis

Weed control efficiency (%)

Weed control efficiency varied due to weed management practices during course of investigation (Table-3 and Fig.-1) at periodic intervals. The highest weed control efficiency was observed with treatment T_2 (Weed free) treatment followed by treatment T_3 (Hand weeding at 25 & 45 DAS). In case of herbicidal treatments, combination of pre-emergence application of Pendimethalin @ 0.75 g a.i. ha^{-1} + Imazethapyr @ 75 g a.i. ha^{-1} (T_8) recorded maximum weed control efficiency at 60 and 90 DAS, respectively over rest of the treatments, however, at 30 DAS stage of soybean crop, maximum weed control efficiency was recorded under post emergence application of (T_7) Quizalofop-ethyl @ 50 g a.i. ha^{-1} during experimentation. Whereas, the lowest weed control efficiency of different weed management practices at 30, 60 and 90 DAS stages of soybean crop was recorded under treatment T_1 (Weedy check).

Table 3: Effect of weed management practices on weed control efficiency (%) at various growth stages of soybean crop

S.N.	Treatment	Weed control efficiency (%)		
		30 DAS	60 DAS	90 DAS
T_1	Weedy check	0.00	0.00	0.00
T_2	Weed free	100.00	100.00	100.00
T_3	Hand weeding at 25 & 45 DAS	96.30	89.85	81.64
T_4	Fluchloralin @1.0 kg a.i. ha^{-1} (Pre emergence)	69.33	62.01	53.73
T_5	Pendimethalin @1.5 kg a.i. ha^{-1} (Pre emergence)	79.20	70.41	57.86
T_6	Imazethapyr @100 g a.i. ha^{-1} (Pre emergence)	77.99	66.93	56.32
T_7	Quizalofop-ethyl @50 g a.i. ha^{-1} (Post emergence)	88.22	65.22	54.24
T_8	Pendimethalin @0.75 kg a.i. ha^{-1}+ Imazethapyr @75 g a.i. ha^{-1} (PE)	87.73	74.86	61.89

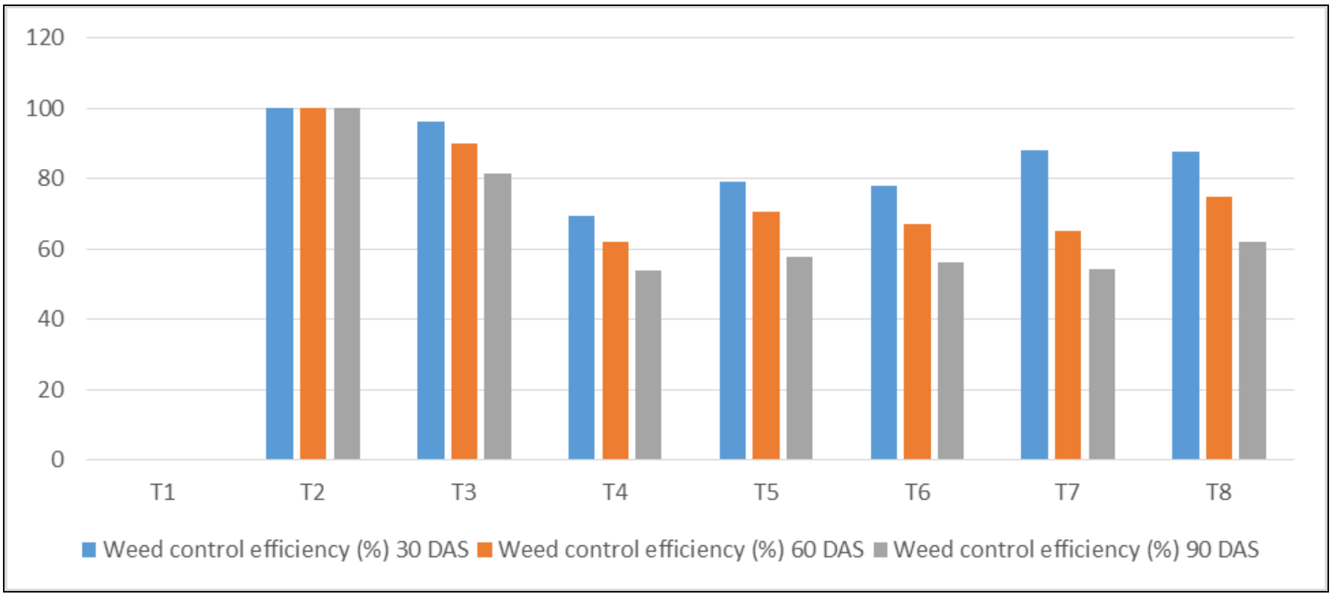

Fig 1: Effect of weed management practices on weed control efficiency (%) at various growth stages of soybean crop

Because maintaining a weed-free environment led to fewer weeds and reduced buildup of dry matter, which is directly connected with weed control efficiency, the weed-free treatment had the greatest weed control efficiency. The lowest weed count and lowest dry weight of weeds were achieved through the effective weed control obtained under pre-emergence and post-emergence application of herbicides mixture at initial and later growth stage. This led to better weed control efficiency of herbicides along with weed free condition. The results of this field study is similar to the findings of field investigations of Habimana *et al.* (2013) [5], Nainwal *et al.* (2010) [16] and Sangeetha *et al.* (2012) [18].

Conclusion

The application of weed free treatment recorded minimum count and dry matter of total weeds and highest weed control efficiency at 30, 60 and 90 DAS stage of soybean crop. However, among the herbicidal treatments, the application of Pendimethalin @ 0.75 g a.i. ha^{-1} + Imazethapyr @75 g a.i. ha^{-1} observed the mimimum count and dry matter of total weeds and highest weed control efficiency at 30, 60 and 90 DAS stage of soybean crop. This field experiment shows the importance of different weed management practices in soybean crop at different crop growth stages.

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Competing interests

Authors have declared that no competing interests exist.

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