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Effect of herbicides on plant growth and seed yield and quality of soybean (*Glycine max* L. Merr.)

Rakesh Chandra Nainwal ✉

Plant Conservation and Agro-technology, CSIR- National Botanical Research Institute, Lucknow (UK), India.

S. C. Saxena

Department of Agronomy, College of agriculture, G. B. Pant Univ. of Agriculture and Technology, Pantnagar, India.

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ABSTRACT

Weeds create a great problem for soybean production and to overcome this problem a large number of weedicides are being applied prevalently worldwide. Gradually increasing the use of chemical herbicides, not only creating resistance against these chemicals among the weeds and polluting the environment, but also influencing the main crop and deteriorating the produce quality. To focus this problem a two-year experiment was laid down during '*kharif*', at Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, to evaluate the detrimental effect of herbicides on soybean plant growth and seed quality. The study come up with the results that the growth parameters during 60-90 DAS (days after sowing) *viz.,* crop growth rate (CGR 0.235 g/day), relative growth rate (RGR 0.014 g/ g/ day) and net assimilation rate (NAR 2.250 g/cm^2/day) decreased due to higher weed competition in weedy plot. Weed competition also significantly reduced yield parameters like number of branches (3.8) and pod per plant (25.4), seed per pod (2.4), seed yield (386 kg/ ha), seed index (11.8 %), and straw yield (1611 kg/ha). The highest seed yield (2665 kg/ha) was recorded with application of diclosulam (as pre-emergence) followed by one hand weeding, which was statistically equal with the treatment in which diclosulam followed by haloxyfop (as post-emergence) was applied. These herbicides also significantly alter the fatty acid composition of soybean seed oil.

Introduction

Soybean (*Glycine max* (L.) Merrill), an important source of protein (approximately 40-42 %) and oil (approximately 18-20 %), plays a great role in oilseed production and stands an important place in consuming as cooking oil, in the country. Meanwhile, weeds are the major limiting factor, creating hindrance in soybean production, causes around 35-40 % yield reduction (Oerke and Dehne, 2004). Sometimes these weeds causes losses up to the extent higher than other insect, pests and diseases, as competition among the plants and weeds for natural resources like soil nutrients, water, space, sunlight etc. Studies shows around 50-60 % reduction in yield due to weeds (Peer *et al.,* 2013). *Cyperus rotundus* (nut grass) and *Echinochloa colona* (jungle rice) among the monocots, while *Celosia argentea* (silver cock's comb or safed murg) among the dicot weeds are majorly reported for this crop (Singh *et al*., 2004). During the early stage of the crop this crop weed competition is not so much strong, so if weed growth is controlled or checked during this stage, the main crop suppress them afterwards and get benefitted (Halford *et al*., 2001). However selective chemicals (pre and post emergence herbicide) like fluchloralin, pendimethalin, alachlor, imazethapyr, quizalofop ethyl etc., are some recommended selective herbicides for controlling the weeds in soybean. The main advantage of using these herbicides for crop production is to reduce the crop weed competition during early stage of the plant growth and minimizing the seed yield loss (Knezevic *et al.,*

Corresponding author E-mail: *nainwal.rakesh@gmail.com*
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2019) however sometime plant injury at early growth stage due to over dose of chemicals, is a great concern, which later reflected as poor plant growth resulting loss in seed yield and poor seed quality (Mahoney *et al*., 2014).
Therefore, at this stage it become necessary to investigate and explore the repercussion of herbicides on the soybean plant, applied to reduce the weed problems and enhance the plant growth and good quality of seed yield of the soybean. Therefore, an experiment was conducted to study the detrimental effect of herbicides and crop weed competition on plant growth, seed yield and quality of the soybean crop.

Material and Methods

The experiment was laid out at Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand. The soil test of the experiment plots was done before the sowing of the crop and found the soil was neutral (pH=7.2) with silty clay loam texture and with following chemical properties:

Table 1: Initial soil chemical properties before seed sowing

Organic Carbon	0.54 %
Total Nitrogen	0.066 %
Available Phosphorus	24.18 kg/ha
Available Potassium	190.8 kg/ha

The experiment consisted ten treatments of different weedicides doses and their combinations with four replications, was laid out in randomized block design in field. The details of the treatments were as Control plot (weedy); weed free; fluchloralin (1000 g/ha); pendimethalin (1000 g/ha); diclosulam (26 g/ha); diclosulam (18 g/ha) followed by (fb) one hand weeding (20 DAS); fluchloralin (1000 g/ha) fb diclosulam (18 g/ha); haloxyfop (100 g/ha); fluchloralin (1000 g/ha) fb haloxyfop (100 g/ha); diclosulam (18 g/ha) fb haloxyfop (100 g/ha). The seed (variety PS-1347) sowing at the rate of 75 kg/ha was done at 45 cm of row spacing. The spraying of pre-emergence herbicides was done, 24 hr. after seed sowing however, fluchloralin was sprayed one day before of sowing as pre plant incorporated (PPI) herbicide. Haloxyfop as post emergence herbicide was sprayed in standing crop at 25 DAS. The chemical fertilizers were applied as per recommendation (25 kg N + 75 kg P +30 kg S + 10 kg Zn /ha) as basal dose. Plant population was maintained by thinning of the plants at 15-20 DAS. Trizophos 40 EC (insecticide) at the rate of 500 ml /ha in 700 litre of water was sprayed before flowering and pod formation, to protect the crop from insect.

Weed index (WI) was calculated as

$$\boldsymbol{WI = \frac{(A - B)}{A} X100}$$

Where, A and B indicates the seed yield in weed-free and other treated plot, respectively.

Plant growth performance were studied with following growth parameters:

$$\textbf{Crop growth rate } (\boldsymbol{CGR}) = \frac{w_2 - w_1}{t_2 - t_1} \textbf{ (g/day)}$$

Where, W_1 & W_2 are plant dry weight at interval of t_1 & t_2 days after sowing (DAS), respectively. T_1 =30 DAS; t_2 =60 DAS.

$$\textbf{Relative growth rate } (\boldsymbol{RGR}) = \frac{\log_e w_2 - log_{3e}\, w_1}{t_2 - t_1} \textbf{ (g/ g /day)}$$

Where, W_1 & W_2 are plant dry weight at interval of t_1 & t_2 days after sowing (DAS), respectively. T_1 =30 DAS; t_2 =60 DAS.

$$\textbf{Net assimilation rate } (\boldsymbol{NAR}) = \frac{w_2 - w_1}{t_2 - t_1} \times \frac{log_e A_2 - log_e A_1}{A_2 - A_1} \textbf{ (g /cm}^2\textbf{/day)}$$

Where, W_1 & W_2 are plant dry weight at interval of t_1 & t_2 days after sowing (DAS), respectively. T_1 =30 DAS; t_2 =60 DAS.

A_1 & A_2 are Leaf area (cm^2/ plant) of plant at interval of t_1 & t_2 days after sowing (DAS), respectively. T_1 =30 DAS; t_2 =60 DAS.

$$\textbf{Leaf area ratio (LAR)} = \frac{(A_2 - A_1)}{(w_2 - w_1)} \times \frac{(log_e W_2 - log_e W_1)}{(log_e A_2 - log_e A_1)} \textbf{ (cm}^2\textbf{ /g)}$$

Where, W_1 & W_2 are plant dry weight at interval of t_1 & t_2 days after sowing (DAS), respectively. T_1 =30 DAS; t_2 =60 DAS.
A_1 & A_2 are Leaf area (cm^2/ plant) of plant at interval of t_1 & t_2 days after sowing (DAS), respectively. T_1 =30 DAS; t_2 =60 DAS.

The data generated from the study were analyzed with average values of respective treatments and compared by Tukey test ($p < 0.05$), as per procedures of Pimentel-Gomes & Garcia (2002).

Results and Discussion

Weed population and weed index (WI)

The major weed species found in the experiment plot were *Echinochloa colona* (27%) and *Celosia argentia* (34%). The other weeds were *Brachiaria ramose, Digitaria sanguinalis, Eclipta alba, Eleusine indica* and *Trianthema monogyna*. However, the occurrence and intensity of these weed species was varied in different treatments, might be due to herbicide application and manual weeding plots. The highest (87%) for the weed index were obtained from control plot indicates the significantly higher weed population. However, the lowest value, indicating the lower weed population, recorded application of Diclosulam 18g/ha followed by one hand weeding (Table 2). It shows the effectiveness of diclosulam as pre emergence herbicide, to control the wide spectrum of weed flora including monocots and dicots as well (Golubev, 2021).

Growth parameters

During the experiment, higher values for growth parameters showing the better growth performance of the soybean crop as comparatively control plot. Less interference of weeds in treatments resulted increase in more leaf surface area and higher number of trifoliate per plant, which leads to comparatively more plant dry matter production. These findings were corroborated with Prajapati and Patel (2001). The higher plant growth in terms of CGR, RGR and NAR were also obtained due to increase in leaf size and dry matter per plant. Higher values for growth parameters *viz.*, CGR, RGR, NAR and LAR during 30-60 DAS were also observed as compared to 60-90 (table 2), might be due to more assimilation per unit area of optimum input resources at early stage of plant growth, which was decreased due to shading of leaves in later stage. Osipe *et al*. (2014) also evaluated diclosulam as pre-emergence herbicide to weed control in soybean and reported some phytotoxic effect of higher dose (>38g a.i./ha) of the chemical like leaf injuries and reduction and mortality in the plant stand. In general, studies indicate minimal effects on soybean agronomic performance with application of diclosulam (18 g a.i./ ha) (Braz *et al.,* 2017). Less competition of crop-weed during growth in weed control treatments leads to higher values of dry matter production and higher seed yield per plant (Clewis *et al.,* 2017).

Yield and yield attributes

Significantly higher values of the different yield parameters like branches and pods per plant and number of seed per pod were obtained weed free plot followed by the application diclosulam followed by with HW at 20 DAS (table 3) might be reduction in weed crop competition (Gazola *et al.,* 2016). It shows the effectiveness of the diclosulam to suppress the weed growth and proper utilization of natural resources by crop plants. Reduction in crop weed competition may provide the opportunity to more utilization of natural resources like air, water, sunlight etc., and resulting the increased synthesis and translocation of metabolites for the more pod development and grain formation in the same treatment (Grey & Prostko, 2015). This high amount of photosynthates mobilization from source to sink leads to significantly higher values for seed index (Singh *et al*. 2001). Significantly higher seed and straw yield was obtained from weed free plot which was 81 % more than weedy (control) plot. The seed yield obtained from weed free plot was at par with application of diclosulam followed by one hand weeding followed by application of diclosulam as pre emergence and haloxyfop as post emergence (Singh *et al.,* 2009). The lowest seed yield (454 kg/ha) and straw yield (1611 kg/ha) obtained from weedy plot showed the lowest harvest index (21%, might be due to the higher impact of weed infestation on the crop. According to Ehteshami (1998) results, seed yield dipped while dry weight of weeds went up. Tiwari and Kurchania (1990) also reported that weed infestation in soybean field may reduce yield up to 77 per cent depending upon the intensity, nature and the duration of weed competition.

Effect on seed quality

Significant higher values for seed protein and oil content obtained from herbicidal treated plots (table 4). Competition from ambient weeds reduced oil and protein concentration as weed free condition gave about 12 per cent higher oil content and 15 percent protein content, than control. Similar findings were reported with Abd El-Rhman (2004), Saudy and El-Metwally (2009) and Movahedpour *et al.,* (2011). Among the herbicide treated plots, significantly higher seed protein and oil content were reported from diclosulam treated plots.

Table 2: Effect of herbicides on CGR (g/day), RGR (g/ g/ day), NAR (g/ cm^2/day) and LAR (cm^2/g) at different growth stages of soybean (pooled mean of 2 years)

Treatments	CGR		RGR		NAR		LAR		Weed index
	30-60	60-90	30-60	60-90	30-60	60-90	30-60	60-90	
Control	0.295	0.235	0.026	0.014	2.900	2.250	100.8	61.8	87
Weed free	0.445	0.460	0.028	0.015	4.050	3.700	78.3	41.5	0
Fluchloralin	0.310	0.300	0.026	0.015	3.350	3.200	79.0	44.8	69
Pendimethalin	0.370	0.350	0.027	0.014	3.500	3.150	82.1	46.6	55
Diclosulam	0.400	0.385	0.027	0.014	3.600	3.500	79.7	45.3	23
Diclosulam + HW	0.415	0.415	0.027	0.015	3.800	3.650	80.2	43.9	14
Fluchloralin + Diclosulam	0.370	0.375	0.027	0.015	3.650	3.400	72.4	42.7	31
Haloxyfop	0.340	0.295	0.026	0.014	3.400	3.050	79.4	47.3	64
Fluchloralin + Haloxyfop	0.325	0.285	0.027	0.014	3.350	2.650	88.4	53.8	58
Diclosulam + Haloxyfop	0.380	0.370	0.026	0.014	3.800	3.550	78.1	44.9	20
C.D. at 5%	0.050	0.060	NS	0.001	NS	0.600	8.5	9.1	-

Table 3: **Effect of different weed control treatments on oil and protein content and fatty acid composition (%) of soybean (pooled mean of 2 years)**

Treatments	Oil content	Protein content	Fatty acid composition			
			Saturated fatty acid (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)
Control	17.8	35.2	10.13	15.07	63.69	10.09
Weed free	19.9	40.5	12.11	16.87	64.10	8.02
Fluchloralin	18.7	37.7	10.97	17.16	62.68	10.47
Pendimethalin	18.3	38.6	11.02	17.33	62.08	10.31
Diclosulam	18.4	38.4	10.79	18.33	62.31	10.00
Diclosulam + HW	19.2	38.5	10.23	16.56	61.89	11.59
Fluchloralin + Diclosulam	19.1	39.2	11.28	19.71	60.28	9.34
Haloxyfop	19.0	37.8	11.16	13.80	66.41	8.82
Fluchloralin + Haloxyfop	19.3	38.4	11.67	18.61	61.17	9.53
Diclosulam + Haloxyfop	19.8	38.0	11.17	16.74	63.03	9.09
C.D. at 5%	0.9	1.3	0.31	1.75	2.04	1.24

Table 4: Effect of herbicides and crop weed competition on yield and yield attributes of soybean (pooled mean of 2 years)

Treatments	Branches/ plant	Pods/ plant	Grain/ pod	Seed index (%)	Seed yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Control	3.8	25.4	2.4	11.8	386	1611	21
Weed free	5.9	60.6	2.8	12.4	2853	4499	39
Fluchloralin	5.1	40.4	2.5	11.9	886	1641	37
Pendimethalin	4.5	41.4	2.5	11.0	1235	2638	32
Diclosulam	5.5	48.6	2.6	12.0	2172	3637	38
Diclosulam + HW	5.4	52.6	2.7	12.4	2665	4226	38
Fluchloralin + Diclosulam	4.9	39.7	2.5	12.3	1963	3257	38
Haloxyfop	3.5	33.5	2.4	11.6	1042	1661	39
Fluchloralin + Haloxyfop	4.0	36.6	2.3	12.0	1209	1786	42
Diclosulam + Haloxyfop	5.1	53.4	2.7	12.4	2303	4129	36
C.D. at 5%	1.5	14.8	0.4	0.8	453	1158	11

Better weed control measures reduce the weed interference for soybean crop growth and improved the seed quality in terms of seed protein might be due to higher number of nodules and their dry weight leading to more nitrogen fixation and assimilation and its translocation to seed. Porwar *et al.* (1999) also reported higher oil and protein content in seed by using weed control treatments as compare to weedy. Herbicidal treatments also affect the saturated fatty acid composition of soybean seed oil, ranged from 10 to 12 %. The higher values of total fatty acid were reported by weed free plot. The lower values of total saturated fatty acid in some herbicidal treatments, might be due to altering or reducing the rate of lipid metabolism by these chemicals. Farag *et al*. (2006) also reported that fatty acid composition of soybean oil was altered by herbicides application. However, diclosulam treated treatments showed not much phytotoxic symptoms to soybean plant and alteration in fatty acid composition (Golubev, 2021).

Conclusion
Significantly higher quality of seed yield obtained by the spraying of diclosulam followed by hand weeding showed the effectiveness of the weedicide to suppress all type of weeds when applied as pre emergence. Thus application of diclosulam at the rate 18g/ha followed by one manual weeding at 20-25 DAS may be recommended in soybean to minimize the weed load and provide higher crop yield in sustainable manner as well as up to some extent eco-friendly in nature.

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Conflict of interest
The authors declare that they have no conflict of interest.

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