

Original Research Article

Enhancing summer soybean yield through evaluation of herbicidal weed management options

ABSTRACT

An experiment was plotted with an aim of enhancing summer soybean yield through evaluation of herbicidal weed management options on medium black calcareous soil at Junagadh Agricultural University, Junagadh during summer season of 2021. The experiment comprised 12 treatments that were arranged in randomized block design with 3 replications. ~~The consequences pointed out that following to weed free treatment, pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence, hand weeding and inter-culturing at 30 DAS, hand weeding at 15 days after sowing (DAS), pre-mix propaquizafop + imazethapyr 50+75 g/ha as post-emergence at 30 DAS, hand weeding at 15 DAS, pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha as post-emergence at 30 DAS and pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence, pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha as post-emergence at 30 DAS enhanced growth parameters viz., plant height, branches per plant; yield attributes i.e., number of pods per plant and ultimately lead to greater seed yield and stover yield. These herbicidal weed management options also reduced population in addition to dry matter of weeds and had less reduction in yield due to better control of weeds, less crop-weed competition and higher weed control efficiency. There were no any phytotoxicity symptoms observed on succeeding groundnut, pearl millet, sesame and cotton crops.~~

Key words: Soybean, herbicides, ~~pre and post emergence, weed control, growth, yield, phytotoxicity~~

1. INTRODUCTION

Soybean has a ~~protruding place among~~ recent agricultural commodities as the world's most imperative seed legume as well as oilseed crop, which pays about 25% to the worldwide edible oil manufacture, about 2/3 of the world's protein concentrate for cattle feeding and a significant commodity for food producers, pharma business and supplementary industrial practices. Therefore, the thing is no shock that total soybean demand is growing rapidly. It offers 40% protein besides 20% comestible oil, as well as vitamins and minerals. Soybean is recognized as the "Golden bean" and a miracle crop of the 21st century. There is enormous opportunity for soybean cultivation due to high dietary value, more production and short period (90-110 days), less water use and being a leguminous crop benefits in improving the soil productiveness and fertility. Indian growers pay reasonable courtesy to cultivation, especially in respect of manuring, seedbed preparation and irrigation, though not cautious about the weed ~~control part~~ which remains one of the limitations in increasing the production [1, 2]. In India, weeds are one of the key biotic constraints that bound crop output. They strive with crops for natural and pragmatic resources as well as accountable for dipping quantity and quality of agronomic productivity notwithstanding incessant research and extension efforts made [3,4]. Bhan *et al.* [5] assessed that weeds in India diminish crop yields by 31.5% (22.7% in winter and 36.5% in summer and kharif time of year). ~~In further trials, weeds were found as the cause for one-third of the total losses in yield, in addition weakening quality of harvest and triggering health and environmental threats~~ [6]. Yield reduction in soybean owing to poor weed control ranges from 35 to 50% reliant on weed flora and their density [7]. Extreme seed yield drops due to weed invasions in soybean was 78.50% [8]. Therefore, fields must be kept weed free at the early period of crop establishment by implementing available weed control options. Herbicides remain to be the most influential, financially effective and reliable means to control weeds [9,10]. The selection of different herbicides in soybean exposes their effectiveness contrary to either monocotyledonous or dicotyledonous weeds. It is accepted that the effect of herbicide molecules largely depends on crop season, soil, intensity and kind of weed flora [11]. Nevertheless, these herbicides are unsuccessful in controlling differentiated weed flora. Hence, there are crucial requirements to find an appropriate herbicide mix for effective

Comment [MC1]: Use technical and formal words

Comment [MC2]: Weed-free

Comment [MC3]: Hand weeding + inter-culturing at 30 days after sowing (DAS).

Comment [MC4]: Keep the treatment short. Example pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence (PE) / hand weeding (HW) and inter-culturing (IC) at 30 days after sowing (DAS). After expanding the acronym in first treatment, no need to expand in next treatment

Comment [MC5]: Hand-weeding at 15 DAS

Comment [MC6]: No table and data is given for phytotoxicity

Comment [MC7]: Arrange in alphabetical order. And no need to mention herbicides, weed control, pre and post emergence all together.

Comment [MC8]: Change the word

Comment [MC9]: 2/3rd

Comment [MC10]: Write weed management instead of weed control since you have taken interculture operation in addition to herbicides

control of weeds. Herbicide blends are further effective means in taking the weed problem and thus nutrient exhaustion by them than a solo herbicide tactic [12,13].

Wide spectrum novel herbicides are essential to control the widely held weed flora in soybean cultivation. Usage of suitable herbicide at the right time, in the precise dose, by the accurate method and with a suitable sprayer has revealed extra benefits over manual and mechanical weed control in various cases. **Mingling two or further herbicides separately effective against unlike weed flora and individually with diverse mechanisms of action are helpful in dropping the coincidental shift in weed flora and the issue of development of herbicide resistance.** Therefore, there is a prerequisite for innovative post-emergence herbicides and their mixtures, which have a broader spectrum of activity. Many crops i.e., groundnut, cotton, sesame, pearl millet, maize, green gram and black gram etc. are the chief subsequent crops, cultivated after soybean in Gujarat. Different crops have differential sensitivity towards various herbicides. Therefore, an assessment on the residual effects of herbicide on the later crop is vital, before it is finally recommended for field applications to the farmers. Keeping the above aspects in light of facts emphasized and outlined, a field research was studied to expose out most suitable herbicides for weed management.

Comment [MC11]: Change the wording in this sentence to make it more understandable

2. MATERIALS AND METHODS

The field test was carried out in summer ~~time~~ of year 2021 at Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat. Soil of the trial plot was clayey in texture, medium in O.C. (0.71%) and alkaline (pH 8.31 and EC 0.45 dS/m). The soil was medium in available nitrogen (387.00 kg/ha), high in available phosphorus (84.13 kg/ha) and medium in potassium (235.00 kg/ha). The research had 12 treatments which arranged in randomized block design with 3 replications viz. pendimethalin 900 g/ha as **PE** ~~fb~~ HW & IC at 30 DAS (T_1), pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ HW & IC at 30 DAS (T_2), HW at 15 DAS ~~fb~~ pre-mix imazamox + imazethapyr 35+35 g/ha as **PoE** at 30 DAS (T_3), HW at 15 DAS ~~fb~~ pre-mix propaquizafop + imazethapyr 50+75 g/ha as PoE at 30 DAS (T_4), HW at 15 DAS ~~fb~~ pre-mix sodium acifluorfen + clodinafop propargyl 80+165 g/ha as PoE at 30 DAS (T_5), HW at 15 DAS ~~fb~~ pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha as PoE at 30 DAS (T_6), pendimethalin 900 g/ha as PE ~~fb~~ pre-mix imazamox + imazethapyr 35+35 g/ha as PoE at 30 DAS (T_7), pendimethalin 900 g/ha as PE ~~fb~~ pre-mix propaquizafop + imazethapyr 50+75 g/ha as PoE at 30 DAS (T_8), pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ pre-mix sodium acifluorfen + clodinafop propargyl 80+165 g/ha as PoE at 30 DAS (T_9), pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS (T_{10}), weed free check (T_{11}) and unweeded check (T_{12}).

Comment [MC12]: season

Comment [MC13]: Pre-emergence (PE) fb Hand-weeding (HW) and Interculture (IC). Extend the acronym at first in so that it can be understood

Comment [MC14]: Post-emergence (PoE)

Soybean (cv. GJS-3) was sown with 60 kg/ha seed rate and 45 × 10 cm spacing ~~by a depth~~ of 5 cm. The ~~crop was fed with~~ 30:60:00 N-P₂O₅-K₂O kg/ha and 5 t/ha FYM. Herbicides sprays were carried out with a knapsack pump using a flat-fan nozzle using 500 liters of water per hectare. The crop growth characters, yield attributes and yield results were statistically analyzed as per the RBD design. The population of all associated weeds were noted at 20, 40 ~~and~~ 60 DAS and at harvest by means of quadrat (0.5 m × 0.5 m) and ~~changed into~~ No./m². Weed dry weight was reported treatment wise and ~~furnished in~~ kg/ha. The figures on weed count were subjected to square root transformation to normalize their distribution [14]. The WI (weed index) and WCE (weed control efficiency) were calculated in percent by the following formulas [15,16]:

Comment [MC15]: Depth of sowing

Comment [MC16]: Crop was fertilized with recommended dose of fertilizer

Comment [MC17]: Crop was fertilized with recommended dose of NPK

Comment [MC18]: Change the word

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$$WI = \frac{Y_{WF} - Y_T}{Y_{WF}} \times 100$$

Where,
WI = Weed index
Y_{WF} = Yield from weed free plot
Y_T = Yield from treated plot

$$WCE (\%) = \frac{DW_C - DW_T}{DW_C} \times 100$$

Where,
WCE = Weed control efficiency
DW_C = Dry matter accumulation of weeds in unweeded control
DW_T = Dry matter accumulation of weeds in treated plot

3. RESULTS AND DISCUSSION

3.1 Effect on growth, yield attributes and yield

The data depicted in Table1revealed that plant population was not significantly affected by different weed management treatments. Though, the growth characters viz.,plant height at harvest and number of branches/plant were recordedsignificantly higher under the weed-free ~~check~~,pre-mix pendimethalin + imazethapyr 750+50 g/ha ~~as~~ PE ~~fb~~ HW & IC at 30 DAS, HW at 15 DAS ~~fb~~ pre-mix propaquizafop + imazethapyr 50+75 g/ha ~~as~~PoE at 30 DAS and HW at 15 DAS ~~fb~~ pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha as PoE at 30 DAS and pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS as these treatments had lesser ~~crop-weed war~~for nutrient, moisture, space and sunlight owing to presence of less number of weeds.Next to the weed free, superior yield attributes like number of pods per plant was recorded with pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ pre- mix fluzifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS, pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ HW & IC at 30 DAS, HW at 15 DAS ~~fb~~ pre-mix propaquizafop + imazethapyr 50+75 g/ha as PoE at 30 DAS and HW at 15 DAS ~~fb~~ pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha as PoE at 30 DAS. The minimum results of yield attributes were found under unweeded check.

Comment [MC20]: Weed free will always be better. After weed-free, mention only 3 best weed management treatments

Comment [MC21]: pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE).

Comment [MC22]: What is crop weed war? Use technical and formal terms 'crop-weed competition'

The data on seed and stover yield influenced by different herbicides are also presented in Table1.All the treatments showed significantly higher seed and stover yields of soybean over unweeded check. The extent of rise in seed and stover yield of soybean with the weed free check, pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ HW & IC at 30 DAS, HW at 15 DAS ~~fb~~ pre-mix propaquizafop + imazethapyr 50+75 g/ha as PoE at 30 DAS, pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS and HW at 15 DAS ~~fb~~ pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha as PoE at 30 DAS was to the tune of 194.30, 190.00, 185.17, 178.79 and 140.00% in seed yield and 151.81, 143.16, 137.22, 131.59 and 115.79% in stover yield over unweeded control, respectively. ~~This might~~ have improved nutrients and water uptake by the crop resulting ingreater rate of photosynthesis and breakdown of photosynthates into numerous metabolic sinks needed for such yield parameters.~~The enhanced yield attributing characters and increased yields might be due~~competent control of weeds by combination of hand weeding and pre-emergence herbicides or combination of hand weeding with pre-mix post-emergence herbicides or combination of pre-emergence and pre-mix post-emergence herbicides as proved by fewer number of weeds and dry mass of weeds,which might a reduced amount of removal ofnutrients besides water through weeds.~~The contemporarydiscoveries~~are in the close vicinity of those noted with diverse weed management conducts by Kale *et al.*[17], Sandil *et al.*[18], Pundas *et al.*[19], Patil *et al.*[20] and Rupareliya *et al.*[21].

Comment [MC23]: Followed by

Comment [MC24]: These treatments must have attributed to improved..

Comment [MC25]: to

Comment [MC26]: explain it thoroughly. How the combination of each treatments resulted in effective weed control

Comment [MC27]: refer to other research article published in this journal and use technical terms

Comment [MC28]: experimental field

3.2 Weed flora and weed parameters

The major weed flora in the ~~investigationallocation~~was ~~founded by~~monocot weeds viz., *Echinochloa colona* (L.) ~~Link~~(10.38%), *Brachiaria ramosa* (L.) ~~Stapf~~ (9.43%), *Eluopus villosus*~~Hook.f~~(6.60%), *Dactyloctenium aegyptium* (L.) ~~Willd~~(4.72%) and; dicot weeds viz., *Digera arvensis*~~Forsk~~ (12.26%), *Boerhavia diffusa* L.(8.49%),*Corchorus fascicularis* L. (7.78%),*Trianthema portulacastrum*L. (6.55 %), *Leucas aspera* ~~Link~~-(5.66%), *Commelina nudiflora* L. (3.77%), *Euphorbia hirta* L. (2.62%), ~~and~~*Physalis minima*L. (1.88%) and *Portulaca oleracea* L. (1.28%); and sedge weed viz., *Cyperus rotundus* L. (19.18%).

Data on weed parameters as mentioned in Table2 indicated that among the different treatments, weed free check registered the minimum total weed count at 20, 40, 60DASandatharvest and the dry weight of weeds, which was remained comparable with pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ HW & IC at 30 DAS, pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE ~~fb~~ pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS and pre-mix propaquizafop + imazethapyr 50+75 g/ha as PoE at 30 DAS. Conversely, highest weed density as well as dry weight of weeds wereestimated under unweeded check.

Table 1. Effect of different weed management options on growth and yield parameters of summer soybean

Treatments	Plant population per ha at harvest	Plant height (cm)	No. of branches/plant	No. of pods/plant	Seed yield (kg/ha)	Stover yield (kg/ha)
T ₁ : Pendimethalin <i>fb</i> HW & IC	205741	41.28 ab	3.30 bcd	35.87 bc	1302 bc	2006 bc
T ₂ : Pendimethalin+imazethapyr <i>fb</i> HW & IC	207593	45.29 ab	3.93 ab	40.83 ab	1682 ab	2417 ab
T ₃ : HW 15 DAS <i>fb</i> imazamox+imazethapyr	205000	40.05 ab	3.23 cd	34.80 bc	1198 c	1762 c
T ₄ : HW 15 DAS <i>fb</i> propaquizafop+imazethapyr	207222	43.71 ab	3.87 abc	39.90 abc	1654 ab	2358 ab
T ₅ : HW 15 DAS <i>fb</i> sodium acifluorfen+clodinafop propargyl	205185	41.65 ab	3.30 bcd	35.33 bc	1222 c	1809 c
T ₆ : HW 15 DAS <i>fb</i> fluazifop-p-butyl+fomesafen	206667	42.32 ab	3.80 abc	38.80 abc	1392 abc	2145 abc
T ₇ : Pendimethalin <i>fb</i> imazamox + imazethapyr	203704	39.09 b	2.87 d	33.67 c	1182 c	1753 c
T ₈ : Pendimethalin <i>fb</i> propaquizafop + imazethapyr	206481	41.94 ab	3.37 bcd	37.30 bc	1343 abc	2127 abc
T ₉ : Pendimethalin + imazethapyr <i>fb</i> sodium acifluorfen + clodinafop propargyl	202593	39.17 b	3.20 cd	34.47 c	1222 c	1765 c
T ₁₀ : Pendimethalin + imazethapyr <i>fb</i> fluazifop-p-butyl + fomesafen	210741	42.83 ab	3.80 abc	41.00 ab	1617 ab	2302 ab
T ₁₁ : Weed free check	213889	46.68 a	4.33 a	44.27 a	1707 a	2503 a
T ₁₂ : Unweeded check	201111	32.98 c	2.07 e	22.00 d	580 d	994 d
SEm ±	7159	1.97	0.20	1.87	120	125
CD (P = 0.05)	NS	5.77	0.57	5.49	353	367
CV (%)	6.01	8.23	9.88	8.88	15.53	10.88

Table 2. Effect of various weed management options on **total weed count**, weed dry weight, **WI** and WCE in summer soybean

Treatments	Total weed count (No./m ²) at				Weed dry weight (kg/ha)	WI (%)	WCE (%)	Gross returns (₹/ha)	Cost of cultivation (₹/ha)	Net returns (₹/ha)	B:C ratio
	20 DAS	40 DAS	60 DAS	Harvest							
T ₁ : Pendimethalin <i>fb</i> HW & IC	3.34 (10.67)	2.19 (4.33)	4.18 (17.00)	5.11 (25.67)	434 cd	23.69	64.89	82160	49324	33070	1.67
T ₂ : Pendimethalin+imazethapyr <i>fb</i> HW & IC	1.77 (2.67)	1.68 (2.33)	3.29 (10.33)	4.22 (17.33)	200 e	1.45	83.83	105759	49091	56668	2.15
T ₃ : HW 15 DAS <i>fb</i> imazamox+imazethapyr	0.88 (0.33)	2.67 (6.67)	5.37 (28.33)	6.92 (47.33)	685 b	29.84	44.59	75377	48539	26838	1.55
T ₄ : HW 15 DAS <i>fb</i> propaquizafop+imazethapyr	0.88 (0.33)	2.11 (4.00)	3.52 (12.00)	4.97 (24.33)	294 de	3.07	76.23	103975	48653	55323	2.14
T ₅ : HW 15 DAS <i>fb</i> sodium acifluorfen+clodinafop propargyl	1.05 (0.67)	2.96 (8.33)	5.40 (28.67)	6.98 (48.33)	679 b	28.39	45.07	76951	48254	28696	1.59
T ₆ : HW 15 DAS <i>fb</i> fluazifop-p-butyl+fomesafen	1.05 (0.67)	2.02 (3.67)	3.93 (15.00)	5.49 (29.67)	371 cd	18.44	70.02	87809	47638	40170	1.84
T ₇ : Pendimethalin <i>fb</i> imazamox + imazethapyr	3.54 (12.00)	3.34 (10.67)	5.87 (34.00)	7.45 (55.00)	773 b	30.74	37.47	74432	45829	28603	1.62
T ₈ : Pendimethalin <i>fb</i> propaquizafop + imazethapyr	3.54 (12.00)	2.47 (5.67)	4.60 (20.67)	5.63 (31.33)	491 c	21.34	60.27	84809	45943	38866	1.85
T ₉ : Pendimethalin + imazethapyr <i>fb</i> sodium acifluorfen + clodinafop propargyl	1.95 (3.33)	3.57 (12.33)	5.69 (32.00)	7.52 (56.00)	736 b	28.39	40.49	76864	46860	30005	1.64
T ₁₀ : Pendimethalin + imazethapyr <i>fb</i> fluazifop-p-butyl + fomesafen	1.95 (3.33)	2.34 (5.00)	3.84 (14.33)	5.34 (28.00)	287 de	5.24	76.82	101642	46162	55480	2.20
T ₁₁ : Weed free check	0.88 (0.33)	1.34 (1.33)	2.04 (3.67)	2.79 (7.33)	41 f	0.00	96.69	107414	56725	50689	1.89
T ₁₂ : Unweeded check	5.63 (31.33)	6.87 (47.00)	8.74 (77.33)	10.28 (106.0)	1237 a	66.00	0.00	36802	41241	-4439	0.89
SEm ±	0.12	0.18	0.30	0.24	51.61	-	-	-	-	-	-
CD (P = 0.05)	0.34	0.51	0.89	0.70	151.39	-	-	-	-	-	-
CV (%)	9.18	10.85	11.12	6.78	17.23	-	-	-	-	-	-

The data on weed density subjected to square root ($\sqrt{x + 0.5}$) transformation and figures in parenthesis are original values.

Comment [MC29]: write it as weed density

Comment [MC30]: mention WI,WCE,HW,IC full form below the table

Data pertaining to WI and WCE (Table 2) revealed that the highest WI (66.00%) was observed with unweeded check, which suggests that unobstructed weed growth lessened the soybean yield. Besides weed free, lower WI (1.45%) was noted under pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE fb HW & IC at 30 DAS followed by HW at 15 DAS fb pre-mix propaquizafop + imazethapyr 50+75 g/ha as PoE at 30 DAS. This could be owing to the exclusion of weeds by integration of herbicides and manual weeding. The collective influence on weed dry weight and seed yield under these treatments might have been accountable for exceptional weed indices. The data on WCE indicated that highest WCE (96.69%) was recorded under weed free check followed by pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE fb HW & IC at 30 DAS and pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE fb pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS. It is the clear outcome of the effective control of weeds underneath these treatments through hand weeding or incorporation of hand weeding with herbicides or combination of pre-emergence & post-emergence herbicides, which lead to lesser number of weeds and eventually declined weed biomass. Moreover, the compact crop canopy might have curbed weed growth and finally less biomass. These verdicts are inline with Gohil *et al.* [9], Harpreet *et al.* [22], Patel *et al.* [23] and Kutariye *et al.* [24].

Comment [MC31]: the value is too high

3.3 Economics

The data on the economics viz., cost of cultivation, gross and net returns, as well as B:C ratio are furnished in Table 2. The scrutiny of results cleared that the maximum gross returns (₹ 107414/ha) and cost of cultivation (₹ 56725/ha) were obtained with weed free check, maximum net returns (₹ 56668/ha) were achieved with pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE fb HW & IC at 30 DAS and higher B:C ratio (2.20) was obtained with pre-mix pendimethalin + imazethapyr 750+50 g/ha as PE fb pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha at 30 DAS.

4. CONCLUSION

Effective management of complex weed flora with moneymaking production of summer soybean can be realized by either application of pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence fb HW & IC at 30 DAS or HW at 15 DAS fb pre-mix propaquizafop + imazethapyr 50+75 g/ha as post-emergence at 30 DAS or pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence fb pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha post-emergence at 30 DAS or HW at 15 DAS fb pre-mix fluzifop-p-butyl + fomesafen 125+125 g/ha as post-emergence at 30 DAS.

Comment [MC32]: change the word

Comment [MC33]: rewrite the sentence again with best 3 weed management treatments excluding weed-free

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