Original Research Article

Enhancing summer soybean yield through evaluation of herbicidal weed management options

ABSTRACT

The farmers ofGujarat have turned to soybeancultivation as soybean demand is increasing promisingly.Improper weed management is one of the reasons forthe large yield gapbetween the potential and the actual yield of soybeanharvested by the farmers. So, the selection of different herbicides in soybean is necessary for effective management of complex weed flora.An experiment was plotted with an aim ofenhancing summer soybean yield through evaluation of herbicidal weed management options on medium black calcareoussoil atJunagadh Agricultural University, Junagadh during summer season of 2021. The experiment comprised12treatments that were arranged in randomized block design with 3 replications.Theoutcomes of the results revealed thatfollowing to weed-free treatment, pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence (PE) *fb* hand-weeding (HW)&inter-culturing (IC) at 30 days after sowing (DAS),HW at 15 DAS*fb* pre-mix propaquizafop+ imazethapyr 50+75 g/ha as post-emergence (PoE) at 30 DAS, HW at15 DAS *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS and pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS enhanced growth parameters*viz*., plant height, branches per plant; yield attributes i.e., number of pods per plant and ultimatelylead 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.

Key words:Growth,herbicides,soybean,summer, yield

1. INTRODUCTION

Soybean is a very important legume crop, which is the cheapest, richest and easiest source of best quality protein, fat and oil.Soybean has a prominent place amongstrecent agricultural commodities as the world's most imperative seed legumeas well as oilseed crop, which pays about 25% to the worldwide edible oil manufacture, about 2/3rdof the world's protein concentrates for cattle feeding andasignificant commodity for food producers, pharma business and supplementary industrial practices. Therefore,the thing is no shock that total soybean demand is growingrapidly. It offers 40% protein besides 20% comestible oil, as well vitamins and minerals.Soybean is recognized as the "*Golden bean*" and a miracle crop of the 21st century. There is enormousopportunity for soybean cultivation due to high dietaryvalue, 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 preparationand irrigation, though not cautious about the weed management which remains one of the limitations in increasing the production[1, 2].In India, weeds are one of the keybioticconstrictions that bound crop output.They strive with crops for natural and pragmatic resources as well accountable for dipping quantity and quality of agronomic productivitynotwithstandingincessant research and extension efforts made [3,4]. It was found that weedsdecreasecrop yields by 31.5% (22.7% in winter and 36.5% in summer and *kharif* time of year)in India [5].Yield reduction in soybean owing to poor weed control ranges from 35 to 50% reliant on weed flora and their density [6, 7].Extreme seed yield drops due to weed invasionsin soybean was 78.50% [8].Therefore, fieldsmust be kept weed-free at theearlyperiod 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 effectivenesscontrary toeithermonocotyledonous or dicotyledonous weeds. It is accepted that the effect of herbicidemolecules largely depends on crop season, soil, intensity and kind of weed flora[11].Nevertheless, these herbicides areunsuccessfulin controllingdifferentiated weed flora. Hence, there are crucialrequirements to find an appropriate herbicide mix for effective control of weeds. Herbicide blends are afurther effective means in taking theweed problem and thus nutrient exhaustion by them than a solo herbicide tactic[12,13].

The selection of different herbicides is essential for effective management of widely held weed flora in soybean cultivation.Usage of suitable herbicide at the right time, in theprecise dose, by theaccurate method and with asuitable sprayer hasrevealedextrabenefits over manual and mechanical weed control in variouscases.Mixing two or more herbicides separately effective against different weed flora and individually with diverse mechanisms of action are helpful in reducing the accidentalshift in weed flora and the chances of development of herbicideresistance.Therefore, there is a prerequisitefor 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 gramare the chiefsubsequent crops, cultivated after soybean in Gujarat.Different crops have differential sensitivity towardsvarious 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 aspectsin light of facts emphasized and outlined,field research was studied to exposeutmost suitable herbicides for weed management.

2. MATERIALS AND METHODS

The field test was carried out in summerseasonof year2021 at Weed Control Research Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh (Gujarat) at 21.5° N latitude and 70.5° E longitude with an altitude of 60 m above the mean sea level. The climate is typically subtropical characterized by fairly cold and dry winter,hot and dry summer and warm and moderately humid monsoon.Soil of the trial plot was clayey in texture, medium in O.C. (0.71%)and alkaline (pH 8.31 and EC0.45 dS/m).The soil was medium in available nitrogen (387.00 kg/ha), high in available phosphorus (84.13kg/ha) and medium in potassium (235.00 kg/ha). The researchhad12treatments which arranged in randomized block design with 3 replications *viz*.,pendimethalin 900g/ha as pre-emergence (PE)*fb* hand-weeding(HW)&inter-culturing (IC)at 30 days after sowing (DAS) (T_1), pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE)*fb* HW & IC at 30 DAS (T_2), HW at 15 DAS *fb* pre-mix imazamox + imazethapyr 35+35 g/ha as post-emergence(PoE) at 30 DAS (T_3), HW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (PoE) at 30 DAS (T_4), HW at 15 DAS *fb* pre-mix sodium acifluorfen + clodinafop propargyl 80+165 g/ha (PoE) at 30 DAS (T_5), HW at 15 DAS *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS (T_6), pendimethalin 900 g/ha (PE)*fb* pre-mix imazamox + imazethapyr 35+35 g/ha (PoE) at 30 DAS (T_7), pendimethalin 900 g/ha (PE)*fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (PoE) at 30 DAS (T_8), pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb* pre-mix sodium acifluorfen + clodinafop propargyl 80+165 g/ha (PoE) at 30 DAS (T_9), pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE)*fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS (T_{10}), weed-free check (T_{11}) and unweededcheck (T_{12}).

Soybean (*cv*. GJS-3) was sownwith 60 kg/ha seed rate and 45 × 10 cm spacing at 5 cm depth.The crop wasfertilized with recommended dose of fertilizer(30:60:00 N-P_2O_5-K_2Okg/ha) and 5 t/ha FYM. Herbicides sprayswerecarried 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 resultswere statistically analyzedas per theRBD design.The population of all associated weeds were noted at 20, 40, 60 DAS and at harvest by means ofquadrate (0.5 m × 0.5 m) and converted into No./m^2. Weed dry weight was reported treatment wise and converted in kg/ha.The figures on weed count were subjected to square root transformation to normalize their distribution [14]. TheWI (weed index)and WCE(weed control efficiency) were calculated in percent by the following formulas [15,16]:

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

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

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

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,followed bypre-mix pendimethalin + imazethapyr 750+50 g/ha (PE)*fb* HW & IC at 30 DAS, HW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (PoE) at 30 DAS and HW at 15 DAS *fb* pre-mix fluazifop-p-butyl + fomesafen125+125 g/ha (PoE) at 30 DAS and pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DASas these treatments had lesser crop-weed competition fornutrient, 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 (PE)*fb* pre- mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE)at 30 DAS, pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE)*fb* HW & IC at 30 DAS, HW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (PoE) at 30 DAS and HW at 15 DAS *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS.The minimum results of yield attributes were found under unweeded check.

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, followed bypre-mix pendimethalin + imazethapyr 750+50 g/ha (PE)*fb* HW & IC at 30 DAS, HW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (PoE) at 30 DAS, pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE)*fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at30DAS and HW at 15 DAS *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (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.These treatments must have attributed to improvednutrients 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 tocompetent 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.These findings are in the close vicinity of those notedbyKale *et al.*[17], Sandil*et al.*[18], Pundas*et al.*[19], Patil *et al.*[20] and Rupareliya *et al.*[21].

3.2 Weed flora and weed parameters

The major weed flora in the experimental fieldwas monocot weeds *viz*., *Echinochloacolona*(10.38%), *Brachiariaramose* (9.43%), *Eluropusvillosus* (6.60%),*Dactylocteniumaegyptium*(4.72%) and; dicot weeds *viz*., *Digera arvensis* (12.26%),*Boerhaviadiffusa*(8.49%),*Corchorus fascicularis*(7.78%),*Trianthemaportulacastrum*(6.55 %), *Leucas aspera* (5.66%), *Commelinanudiflora* (3.77%), *Euphorbia hirta*(2.62%), and *Physalis minima*(1.88%) and *Portulaca oleracea* (1.28%); and sedge weed*viz*., *Cyperus rotundus* (19.18%).

Data on weed parameters as mentioned in Table2 indicated that among the different treatments, weed-free check registered the minimum weed density at 20, 40, 60DASandatharvest and the dry weight of weeds, which was remained comparable with pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb* HW & IC at 30 DAS, pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS andHW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (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 *fb* HW & IC	205741	41.28 ab	3.30 bcd	35.87 bc	1302 bc	2006 bc
T_2	: Pendimethalin+imazethapyr*fb* HW & IC	207593	45.29 ab	3.93 ab	40.83 ab	1682 ab	2417 ab
T_3	: HW 15 DAS *fb* imazamox+imazethapyr	205000	40.05 ab	3.23 cd	34.80 bc	1198 c	1762 c
T_4	: HW 15 DAS *fb* propaquizafop+imazethapyr	207222	43.71 ab	3.87 abc	39.90 abc	1654 ab	2358 ab
T_5	: HW 15 DAS *fb* sodium acifluorfen+clodinafop propargyl	205185	41.65 ab	3.30 bcd	35.33 bc	1222 c	1809 c
T_6	: HW 15 DAS *fb* fluazifop-p-butyl+fomesafen	206667	42.32 ab	3.80 abc	38.80 abc	1392 abc	2145 abc
T_7	: Pendimethalin *fb* imazamox + imazethapyr	203704	39.09 b	2.87 d	33.67 c	1182 c	1753 c
T_8	: Pendimethalin *fb* propaquizafop + imazethapyr	206481	41.94 ab	3.37 bcd	37.30 bc	1343 abc	2127 abc
T_9	: Pendimethalin + imazethapyr *fb* sodium acifluorfen + clodinafop propargyl	202593	39.17 b	3.20 cd	34.47 c	1222 c	1765 c
T_{10}	: Pendimethalin + imazethapyr *fb*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 weed density, weed dry weight, WI and WCE in summer soybean

Treatments	Weed density (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 *fb* 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*fb* 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 *fb* 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 *fb* 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 *fb* 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 *fb* 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 *fb* 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 *fb* 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 *fb* 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 *fb*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	-	-	-	-	-	-

WI = Weed index,WCE = Weed control efficiency,HW = Hand-weeding, IC =Inter-culturing

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

Data pertaining to WI and WCE (Table 2) revealed that the highest WI (66.00%) was observedwith unweeded check, whichsuggeststhat 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 (PE)*fb* HW & IC at 30 DAS, followed by HW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha (PoE) at 30 DAS.This could be owing to the exclusion of weeds by integration of herbicides and manual weeding.The collectiveinfluence on weed dry weightandseed 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 (PE)*fb*HW & IC at 30 DAS and pre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha(PoE)at 30 DAS.It is the clear outcome of the effectivecontrol of weeds underneath these treatments through hand-weeding or incorporation of hand-weeding with herbicides or combination of pre-emergence&post-emergence herbicides,whichlead to lesser number of weeds and eventuallydeclined weed biomass. Moreover, thecompact crop canopy might have curbed weed growth and finally less biomass. These verdicts are inline withGohil*et al*. [9],Harpreet *et al.*[22],Patel *et al.*[23]and Kutariye*et al.*[24].

3.3 Economics

The data on the economics*viz.*,cost of cultivation, gross and net returns, as wellas B:C ratio arefurnished in Table2.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 (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 (PE) *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS. Thisbettermonetary returns in summersoybeanwere due to low cost of cultivation and higher gross returns over rest of thetreatments.The tread in monetary returns was attributed to the weed management treatmenteffecton seed and stoveryield.Theresults are in conformityof those reported by Upadhyay *et al*.[12].

4. CONCLUSION

On the basis of above findings, it is concluded that higheryieldand profitability of summersoybeancanbe achieved through effective weed managementbyeither application of pre-mix pendimethalin + imazethapyr 750+50 g/ha as pre-emergence (PE) *fb* hand-weeding (HW)&inter-culturing (IC) at 30days after sowing(DAS) orHW at 15 DAS *fb* pre-mix propaquizafop + imazethapyr 50+75 g/ha as post-emergence (PoE) at 30 DAS orpre-mix pendimethalin + imazethapyr 750+50 g/ha (PE) *fb*pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS orHW at 15 DAS *fb* pre-mix fluazifop-p-butyl + fomesafen 125+125 g/ha (PoE) at 30 DAS.

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