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Efficacy of Tank-Mix Herbicide and Insecticide Combinations for Management of Weed and Pests in Soybean [*Glycine max* (L.) Merrill.]

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ABSTRACT

In India, soybean (*Glycine max*) is mainly grown as rainfed crop. The higher incidence of weed and pests during growth period are one of the important menaces in getting higher yield of this crop. A field experiment was conducted during 2013-2014 and 2014-2015 on vertisol soil at Agharkar Research Institute, Pune (MS), India, to evaluate bio-efficacy of compatible tank-mix combinations of herbicide and insecticides to manage the weed and insect-pests in soybean. Tank-mix application of quinalphos and imazethapyr (68.17 m^{-2}) resulted in significantly lowest weed density followed by imazethapyr (69.33 m^{-2}) at 30 Days after Sowing (DAS). At 45 DAS imazethapyr (26 m^{-2}) recorded significantly lowest weed density, whereas it was non-significantly different due to various treatments at 60 DAS. Sole application of imazethapyr and in combination with Rynaxypyr recorded lowest weed dry matter at 30, 45, and 60 DAS. Application of Rynaxypyr+imazethapyr at 30 DAS (67.36%) and at 60 DAS (85.52%) and sole imazethapyr at 45 DAS (81.66%) recorded higher weed control efficiency than the rest of the treatments. Number of leaf roller and tobacco caterpillar larvae per meter row length (mrl^{-1}) at seven days after treatment was significantly less in treatments involving insecticides. Visual defoliation score was significantly less in treatments involving insecticides than weedy check and sole herbicide.

Keywords: Imazethapyr, Leaf roller, Quinalphos, Tobacco caterpillar, Bio-efficacy and Compatible.

INTRODUCTION

Soybean (*Glycine max*) is one of the most important legume and oil seed crop of the globe. Due to high quality protein (40-42%), edible oil (18-22%), and its use in the food industry for flour, oil, cookies, candy, milk, vegetable cheese, lecithin, and many other products, it has gained status of an important and useful commodity in livelihood of human being over the world (Argaw, 2012). India ranks fifth in soybean production in the world. Area under the soybean crop in India is increasing steadily. Presently, it is cultivated on 10.88 m ha with production of 10.43 m t and productivity of 0.95 t ha^{-1} (SOPA, 2014). As compared to the world and Asian average, the soybean productivity is low in India. Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Andhra Pradesh are the leading soybean producing states of India. Majority of the area under the soybean crop is rainfed and crop is cultivated from June to October. Weeds and insect-pests are the major limiting factors in the production of this crop. Being a rainy season crop, infestation of weeds is high due to high moisture and temperature. Weeds may cause yield reduction up to 67% depending on the intensity of weeds, crop variety, season, soil type, rainfall, duration and period of weed competition (Gaikwad and Pawar, 2002). Weed infestation is persistent

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and complex constraint in soybean, as it influences soybean growth and development through competition for nutrients, water, light, space and production of allelopathic compounds (Vollmann *et al*., 2010). The incessant rains during the *kharif* season do not permit timely inter-cultivation operations and manual control is not possible on account of high cost and shortage of labor during weeding peaks (Singh *et al*., 2014). Weed control through use of chemicals is the only alternative to solve this problem. Pre-emergence, pre-plant incorporation, and post-emergence application of the herbicides control weeds effectively. The abundance of some weed species is likely to be strongly influenced by environmental and cultural conditions and its infestation could be more efficiently managed by proper selection of herbicides (Pinke *et al*., 2016). Due to weedy condition in the field of soybean, the incidence of insect-pests also increases. Severe incidence of pests may cause yield loss up to 40-50%. Hence, present investigation was undertaken to evaluate bio-efficacy of compatible tank mix combinations of insecticides and herbicides to reduce the weed infestation, damage by insect-pests, and to increase the yield of soybean.

MATERIALS AND METHODS

Experimental Site

A field experiment was carried out during *kharif* 2013-14 and 2014-15 at experimental farm of Agharkar Research Institute, Pune (MS), India, to investigate the effect of tank mix combinations of post-emergence herbicide and insecticides on weed and pests of soybean. Soil of the experimental site was vertisol with slightly alkaline pH (7-7.5) and contained 0.70% organic carbon. The available N (430.55 kg ha^{-1}) and P (14.62 kg ha^{-1}) in the soil was medium and available K was high (451.05 kg ha^{-1}). Rainfall during the *kharif* 2013 and 2014 were 562.7 mm and 480.9 mm, respectively.

Field Layout and Treatments Details

The experiment was laid out in Randomized Block Design (RBD) and replicated thrice, containing two post-emergence herbicides and three insecticides, as a sole and combined application to soybean crop as given Table1.

All recommended package of practices, except hand weeding, were followed for raising a good crop. Soybean variety 'MACS 450' was sown on 12th July, 2013 and 11th July, 2014 with seed rate of 65 kg ha^{-1}. Row to row and plant to plant distance was maintained at 45 and 5-7 cm, respectively. The plot size was 5×3.15 m (gross) with seven rows. Tank mix combinations of post emergence herbicides and insecticides were sprayed 20 days after sowing using knapsack sprayer (200 kPa pressure) with 400-500 liter water ha^{-1} as per the quantity given in the treatment details.

Post-emergence herbicides viz., (i) Imazethapyr 10 SL: [2-[4, 5-dihydro-4-

Table 1. Treatment details**.**

Tr. No.	Treatment details
T_1	Rynaxypyr 20 SC @ 100 mL ha^{-1}
T_2	Indoxacarb 14.5 SC @ 300 mL ha^{-1}
T_3	Quinalphos 25 EC @ 1.5 L ha^{-1}
T_4	Imazethapyr 10 SL @ 1.0 L ha^{-1}
T_5	Quizalofop ethyl 5 EC @ 1.0 L ha^{-1}
T_6	Rynaxypyr 20 SC @ 100 mL ha^{-1} + Imazethapyr 10 SL @ 1.0 L ha^{-1}
T_7	Rynaxypyr 20 SC @ 100 mL ha^{-1} + Quizalofop ethyl 5 EC @ 1.0 L ha^{-1}
T_8	Indoxacarb 14.5 SC @ 300 mL ha^{-1} + Imazethapyr 10 SL @ 1.0 L ha^{-1}
T_9	Indoxacarb 14.5 SC @ 300 mL ha^{-1} + Quizalofop ethyl 5 EC @ 1.0 L ha^{-1}
T_{10}	Quinalphos 25 EC @ 1.5 L ha^{-1} + Imazethapyr 10 SL @ 1.0 L ha^{-1}
T_{11}	Quinalphos 25 EC @ 1.5 L ha^{-1} + Quizalofop ethyl 5 EC @ 1.0 L ha^{-1}
T_{12}	Untreated weedy check.

methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-ethyl-3-pyridinecarboxylic acid], (Trade name: Pursuit, Manufacturer: BASF India Ltd., Mumbai, Maharashtra, India) is a systemic broad spectrum herbicide of the imidazolinones, absorbed by the roots and foliage, and translocated through xylem and phloem, and accumulated in the meristematic regions of the weed plant. It is useful for controlling the annual grasses, broad leaved weeds and sedges in the crops like soybean and groundnut (Masoumeh *et al.,* 2013). (ii) Quizalofop ethyl 5 EC: (R)-2-[4-(6-chloroquinoxalin-2-yloxy) phenoxy] propionate (Trade name: TARGA SUPER, Manufacturer: M/s Nissan Chemical Industries Ltd., Tokyo, Japan) is a systemic selective herbicide, absorbed from leaf surface and translocated throughout the plant in xylem and phloem and accumulates in meristematic tissue. Used to control the grassy annual and perennial weeds mostly in soybean and insecticides for controlling pests of soybean used as (Table 2):

In soybean it is used mainly to control leaf eating caterpillars. Herbicide and insecticides were sprayed 20 DAS separately and in combination as per the recommended dose and water volume. Sole application of herbicide was restricted to weeds to escape the crop plant, while sole application of insecticide was made only on soybean plants. The combined herbicide and insecticide mixture was applied over both plants and weeds.

Collection of Data

The effect of different treatment was studied in terms of all types of weed flora (monocot and dicot species), weed density, and weed dry matter at 30, 45 and 60 days after sowing of the crop by placing a quadrat of 1×1 m randomly in each plot, and their subsequent effect on growth and yield of

Table 2. Insecticides used for controlling the insect-pests of soybean.

Sr. No.	Details of insecticide	Role / nature of damage
1.	Rynaxypyr 20 SC: Chlorantraniliprole Trade name: Coragen Manufacturer: E.I. DuPont India Pvt. Ltd. Manjusar, Vadodara, Gujrat, India.	A selective insecticide featuring a novel mode of action. By activating the insect ryanodine receptors (RyRs) it stimulates the release and depletion of intracellular calcium stores from the sarcoplasmic reticulum of muscle cells causing impaired muscle regulation, paralysis, and ultimately death of sensitive species (Cordova *et al*., 2006). Used to control effectively mainly the *Spodoptera litura* and other defoliating pests of soybean.
2.	Indoxacarb 14.5 EC: Trade name: KING DOXA Manufacturer: Gharda Chemicals Limited, Mumbai, Maharashtra, India.	A non-systemic insecticide, the activity occurs via blockage of the sodium channels in the insect nervous system and mode of entry is through stomach and contact routes, resulting in impaired nerve function, cessation of feeding, paralysis and death.
3.	Quinalphos 25 EC: Trade name: EKALUX 25 Manufacturer: Syngenta India Limited Pune, Maharastra, India.	A systemic insecticide, having acaricide and insecticidal activity with stomach and contact action by penetrating the plant tissues through translaminar action and exhibits a systemic effect. Used to control lepidopteron, hemipteron, colepteron and dipteron insect-pests of different crops. In soybean it is used mainly to control leaf eating caterpillars.

soybean. The collected weeds from each quadrat were immediately separated into monocot and dicot species and weighed to record fresh weight. After drying in an electric oven at 70°C, till the weight became constant, the obtained biomass was expressed as g m^{-2}. The weed index was computed by using the formula given below:

$$\text{Weed Index (WI) \%} = \frac{X - Y}{X} \times 100$$

Where, *X*= Weight of seed yield (q ha^{-1}) in treatment which has highest yield and *Y*= Weight of seed yield (q ha^{-1}) in treatment for which weed index is to be calculated).

Weed Control Efficiency (WCE) was calculated by using the formula given by Mani *et al*. (1973).

$$\text{WCE (\%)} = \frac{DWC - DWT}{DWC} \times 100$$

Where, *WCE*= Weed Control Efficiency in percent, *DWC*= Dry matter Weight of weed in Control plot and *DWT*= Dry matter Weight of weed in Treated plot.

Moderate infestation of leaf roller and tobacco caterpillar was noticed on the trial plot in 2013. However, infestation of these pests was very low in 2014. Low infestation of stem fly was observed in both years of the experiment. Data on number of leaf roller and tobacco caterpillar larvae per meter row length (mrl^{-1}) was recorded one Day Before Treatment (DBT) and 7 Days After Treatment (DAT) at random three places per plot and averaged. Visual Defoliation Score (VDS) was recorded in 1-9 scale based on visual observation on leaf damage by leaf roller and tobacco caterpillar. Stem fly damage was recorded on 10 random plants as length of stem tunneled in centimeter at physiological maturity stage. Percentage stem tunneling was calculated as:

$$\text{Stem tunneling (\%)} = \frac{\text{Length of stem tunneled (cm)}}{\text{Plant height (cm)}} \times 100$$

The percentage stem tunneling data was transformed in square root before analysis of variance. Data on growth parameters like plant height (cm), number of branches per plant, yield attributes like number of pods per plant, 100 seed weight (g), biological yield (kg $plot^{-1}$) and yield (kg $plot^{-1}$) of soybean was recorded at harvest. Harvest index (%) was determined using the formula as: *Harvest index (%) = [Seed yield (kg $plot^{-1}$)/Biological yield (kg $plot^{-1}$)]×100*

Seed yield obtained per plot was converted into kilogram per hectare. Economics of combined application of herbicide and insecticide was calculated in terms of gross returns (₹ ha^{-1} i.e. Indian rupee ha^{-1}) by multiplying seed yield (kg ha^{-1}) with the prevailing market price of soybean in the market, and net returns were calculated subtracting the cost of cultivation (₹ ha^{-1}) of each treatment from gross returns obtained. Cost of cultivation was calculated taking into consideration the prevailing prices of inputs and labor charges to carry out different operations for the years under the study.

Statistical Analysis

The collected data were subjected to Analysis Of Variance (ANOVA) using standard variance techniques suggested by Gomez and Gomez (1984). Means of all treatments were calculated and the differences were tested for significance using the Least Significant Differences (LSD) test at 0.05 Probability (P) level. The data on number of weeds were subjected to square root transformation.

RESULTS AND DISCUSSION

Effect on Weeds

Weed flora observed in the experimental field during *kharif* 2013 and 2014 as given in Table3.

The weed count significantly differed with the combine spray of herbicide and insecticide, except at 60 days after sowing (Table 4). Among the different combinations of herbicide and insecticides, at 30 days after sowing quinalphos+imazethapyr recorded significantly lowest density of weeds (68.17 m^{-2}) followed by imazethapyr (69.33 m^{-2}) and quinalphos+quizalofop ethyl (69.67 m^{-2}). However, the weed density in untreated weedy check plot was higher (111 m^{-2}) at 30 days after sowing. At 45 days after sowing weed density was significantly low in plots treated with imazethapyr (26 m^{-2}) and highest in untreated weedy check (56.17 m^{-2}). Post-emergence application of imazethapyr was responsible for inhibition of AcetoLactate Synthase (ALS) or AcetoHydroxy Aacid Synthase (AHAS) in broad leaf weeds, which caused destruction of these weeds at 3-4 leaf stage (Chandel and Saxena, 2001) and resulted in low weed density. Differences for weed density at 60 days after sowing were non-significant. Application of imazethapyr (3.17%) showed lowest weed index compared to the other treatment combinations. Lowest weed index showed the decreased magnitude of the yield reduction due to presence of weeds in comparison with the treatment imazethapyr which yielded higher than other treatments or combinations. Spray of Rynaxypyr+imazethapyr at 30 days after sowing (25.62 g m^{-2}) recorded significantly lowest weed dry matter followed by spray of quinalphos+imazethapyr (27.35 g m^{-2}), indoxacarb+imazethapyr (28.29 g m^{-2}), and imazethapyr (28.72 g m^{-2}) alone (Table 5). At 45 days after sowing, application of imazethapyr (11.45 g m^{-2}) recorded significantly lowest weed dry matter compared to untreated weedy check (72.15 g m^{-2}). Combined application of Rynaxypyr and imazethapyr (4.62 g m^{-2}) at 60 DAS recorded significantly lower weed dry matter than untreated weedy check (34.03 g m^{-2}). Application of imazethapyr alone and in combination with insecticide recorded the lowest weed density and weed dry matter at 30, 45, and 60 days after sowing. Jadhav and Gadade (2012) reported that imazethapyr+imazimox 30 g ha^{-1} and imazethapyr 0.1 kg ha^{-1} as post-emergence application showed the reduced weed density and weed dry weight. Similarly, Yousefi *et al.,* (2012) reported the application of imazethapyr at reduced rate greatly affected the growth and biomass production of *X. strumarium or A. retroflexus* in soybean as compared to untreated plots. The weed control efficiency was higher with the combined application of Rynaxypyr and imazethapyr (67.36%) at 30 days after sowing and at 60 days after sowing (85.52%) and also with the application of imazethapyr (81.66%) at 45 days after sowing. The results regarding the application of imazethapyr are in corroboration with Singh (2007) and

Table 3. Weed flora observed in experimental field during *kharif* 2013 and 2014.

Monocot weed species	Dicot weed species
Cynodon dactylon (L.),	*Parthenium hysterophorus* (L.),
Cyperus rotundus (L.),	*Amaranthus oleracea* (L.),
Commelina benghalensis (L.),	*Portulaca oleracea* (L.),
	Euphorbia hirta (L.),
	Amaranthus tricolor (L.),
	Acalypha indica (L.),
	Bidens pilosa (L.),
	Lactuca runcinata (L.)

Table 4. Weed count and weed index (%) influenced by herbicide and insecticide application.[a]

Treatments (Herbicides+Insecticides)	Weed count at 30 DAS	Weed count at 45 DAS	Weed count at 60 DAS	Weed index (%)
T_1: Rynaxypyr	92.67 (9.65)	47.17 (6.90)	8.00 (2.91)	13.72
T_2: Indoxacarb	87.83 (9.40)	46.50 (6.85)	13.00 (3.67)	9.75
T_3: Quinalphos	71.17 (8.46)	47.33 (6.91)	11.00 (3.39)	15.35
T_4: Imazethapyr	69.33 (8.36)	26.00 (5.15)	8.00 (2.91)	3.17
T_5: Quizalofop ethyl	86.33 (9.32)	45.83 (6.81)	9.67 (3.19)	10.97
T_6: Rynaxypyr+Imazethapyr	71.33 (8.47)	42.17 (6.53)	7.33 (2.80)	6.58
T_7: Rynaxypyr+Quizalofop ethyl	71.50 (8.48)	47.50 (6.93)	7.17 (2.77)	11.13
T_8: Indoxacarb+Imazethapyr	71.17 (8.46)	42.00 (6.52)	7.00 (2.74)	6.58
T_9: Indoxacarb+Quizalofop ethyl	82.33 (9.10)	34.00 (5.87)	10.17 (3.27)	6.44
T_{10}: Quinalphos+Imazethapyr	68.17 (8.29)	45.17 (6.76)	8.50 (3.00)	8.34
T_{11}: Quinalphos+Quizalofop ethyl	69.67 (8.38)	47.33 (6.92)	8.83 (3.05)	6.62
T_{12}: Untreated weedy check	111.0 (10.56)	56.17 (7.53)	13.33 (3.72)	18.35
SEm±	7.88	5.25	1.93	2.00
CD (P= 0.05)	22.52	15.00	NS	5.71

[a] Figures in the parenthesis are square root transformation of the original values.

Barkhade *et al*. (2013) who reported that imazethapyr at the rate of 75 g ha^{-1} was effective against both monocot and dicot weeds and were at par with one hand weeding done at 20 days after sowing.

Effect on Insect-Pests of Soybean

Results on insect damage in different treatments are presented in Table 6. The data indicates that the number of larvae per mrl^{-1} of leaf roller and tobacco caterpillar 7 DAT was significantly lower than the untreated check and sole treatments of herbicides. Similar findings were reported by Barkhade *et al*. (2013) who showed that less number of larvae mrl^{-1} of *Spodoptera* were observed with the sole insecticide and combination of insecticide and herbicides than the sole herbicide and untreated check. Similarly,

Table 5. Weed dry matter (g) and Weed control efficiency (WCE %) influenced by herbicide and insecticides over weedy check.[a]

Treatments (Herbicides+Insecticides)	Weed DM at 30 DAS	WCE (%) at 30 DAS	Weed DM at 45 DAS	WCE (%) at 45 DAS	Weed DM at 60 DAS	WCE (%) at 60 DAS
T_1: Rynaxypyr	59.23	25.19	40.77	46.02	19.98	45.27
T_2: Indoxacarb	56.13	29.22	42.43	39.77	21.44	40.78
T_3: Quinalphos	44.12	42.49	40.79	46.76	16.67	50.22
T_4: Imazethapyr	28.72	61.56	11.45	81.66	7.85	78.99
T_5: Quizalofop ethyl	44.88	46.61	46.85	37.49	23.87	41.69
T_6: Rynaxypyr+Imazethapyr	25.62	67.36	18.30	73.91	4.62	85.52
T_7: Rynaxypyr+Quizalofop ethyl	46.12	41.50	38.25	49.56	11.78	71.64
T_8: Indoxacarb+Imazethapyr	28.29	64.09	23.50	67.97	6.17	81.82
T_9: Indoxacarb+Quizalofop ethyl	36.38	51.26	25.78	63.65	12.02	69.10
T_{10}: Quinalphos+Imazethapyr	27.35	64.04	23.18	66.32	7.53	77.59
T_{11}: Quinalphos+Quizalofop ethyl	37.47	53.33	36.77	49.92	12.31	63.00
T_{12}: Untreated weedy check	78.58	0.00	72.15	0.00	34.03	0.00
SEm±	5.73	6.65	5.77	6.35	2.58	6.15
CD (P= 0.05)	5.73	19.00	16.48	18.15	7.39	17.57

[a] DM: Dry Matter; DAS: Days After Sowing, WCE: Weed Control Efficiency.

Table 6. Effect of herbicide and insecticide tank-mix application on insect-pests of soybean.[a]

Treatments (Herbicides+Insecticides)	Leaf roller (Larvae mrl^{-1})		Tobacco caterpillar (Larvae mrl^{-1})		Visual defoliation score	Stem fly damage (% stem tunneling)					
						2013		2014		Pooled	
	1 DBT	7 DAT	1 DBT	7 DAT		%	SQR	%	SQR	%	SQR
T_1: Rynaxypyr	6.53	0.89	9.35	0.44	1.33	4.93	2.22	2.57	1.60	3.75	1.94
T_2: Indoxacarb	6.98	2.22	8.54	1.22	1.67	3.79	1.94	1.76	1.32	2.76	1.67
T_3: Quinalphos	5.87	3.78	8.69	2.11	2.00	3.96	1.99	2.81	1.67	3.39	1.84
T_4: Imazethapyr	7.23	6.00	8.12	6.00	3.33	13.21	3.63	11.81	3.44	12.51	3.54
T_5: Quizalofop ethyl	7.68	6.67	7.58	7.44	4.00	7.79	2.78	7.19	2.68	7.49	2.74
T_6: Rynaxypyr+Imazethapyr	7.46	1.00	7.18	1.00	1.00	5.21	2.28	3.33	1.82	4.27	2.07
T_7: Rynaxypyr+Quizalofop ethyl	6.82	0.89	7.55	0.56	1.33	4.97	2.23	1.91	1.37	3.44	1.85
T_8: Indoxacarb+Imazethapyr	6.63	2.22	8.45	0.56	1.67	5.85	2.40	3.95	1.98	4.90	2.21
T_9: Indoxacarb+Quizalofop ethyl	7.68	2.33	8.64	1.33	2.00	3.63	1.90	2.05	1.43	2.84	1.69
T_{10}: Quinalphos+Imazethapyr	7.14	2.67	7.71	1.44	2.33	4.46	2.11	5.76	2.40	5.11	2.26
T_{11}: Quinalphos+Quizalofop ethyl	6.79	3.44	8.48	1.56	2.67	3.17	1.76	1.95	1.39	2.56	1.60
T_{12}: Untreated weedy check	7.32	7.33	9.78	8.78	4.33	9.75	3.10	8.52	2.92	9.14	3.02
SEm±	0.16	0.31	0.11	0.24	0.32	0.70	0.12	0.26	0.08	0.48	0.10
CD (P= 0.05)	NS	0.92	NS	0.73	0.96	2.05	0.37	0.76	0.23	1.4	0.30

visual defoliation score was significantly less in the treatments involving insecticides than the sole herbicide treatments. In general, stem fly damage was low in both years. Pooled data of the two years indicated significantly less percent of stem tunneling in sole insecticide as well as their combination with herbicides than untreated check and sole treatment of imazethapyr, in which the percent stem tunneling was found to be unexpectedly significantly higher than the untreated check.

Effect on Growth and Yield of Soybean

Sole and combined application of herbicides and insecticides recorded statistically similar plant height, branches per plant, and pods per plant. Neither the sole application nor combination of herbicides and insecticides affected the growth parameters during both study years. Yield contributing characters viz., 100 seed weight and harvest index were not significantly different due to the application of herbicide and insecticides (Table 7). However, soybean yield was significantly influenced by herbicides and insecticide application. The inhibitory effect of herbicides in combination with insecticide reduced the weed population during the important growth stages of soybean resulting in the minimal crop-weed competition for nutrition, space, sun light, aeration and led to increase in soybean yield. The effect of herbicide and insecticides revealed that seed yield of soybean was significantly higher in application of imazethapyr (3071 kg ha^{-1}) and closely followed by quinalphos+qiuizalofop ethyl (2977 kg ha^{-1}), indoxacarb+imazethapyr (2976 kg ha^{-1}), indoxacarb+quizalofop ethyl (2975 kg ha^{-1}) and Rynaxypyr+imazethapyr (2973 kg ha^{-1}). Higher yield of soybean in these treatments was due to weed free condition during the important growth stages of soybean. Kundu *et al*. (2011) and Upadhyay *et al*. (2012) have also reported higher soybean yield due to better weed control by use of imazethapyr 10 SL @ 1.0 L ha^{-1}. Sole and in combination with insecticide, imazethapyr and quizalofop ethyl reduced the weed population competing with the soybean crop during the important growth stages leading to increased soybean yield per hectare.

Effect on Oil content and Oil yield

Oil content of the soybean was not significantly influenced due to application of herbicides and insecticides (Table 8). Better nutrition to soybean crop may results in improvement in the oil

content. Weed control treatments did not

Table 7. Effect of herbicide and insecticide combination on growth and yield of soybean.

Treatments (Herbicides+Insecticides)	Plant height (cm)	Branches plant^{-1}	Pods plant^{-1}	Seed index (g)	Harvest index (%)	Seed yield (kg ha^{-1})
T_1: Rynaxypyr	67.37	3.13	46.97	14.72	47.05	2764
T_2: Indoxacarb	67.30	3.23	52.17	14.76	47.45	2875
T_3: Quinalphos	65.90	3.20	46.47	14.52	43.70	2697
T_4: Imazethapyr	62.83	2.90	53.57	14.98	47.32	3071
T_5: Quizalofop ethyl	66.30	3.10	55.70	14.76	47.04	2846
T_6: Rynaxypyr+Imazethapyr	63.50	2.90	50.80	14.54	45.54	2973
T_7: Rynaxypyr+Quizalofop ethyl	67.60	3.00	53.80	14.62	44.34	2831
T_8: Indoxacarb+Imazethapyr	63.40	2.67	51.57	14.55	47.04	2976
T_9: Indoxacarb+Quizalofop ethyl	66.97	3.00	51.00	14.91	47.80	2975
T_{10}: Quinalphos+Imazethapyr	62.53	3.10	50.03	14.63	46.47	2914
T_{11}: Quinalphos+Quizalofop ethyl	66.80	3.17	52.07	14.59	46.14	2977
T_{12}: Untreated weedy check	68.17	2.80	50.13	14.49	44.96	2613
SEm$\pm$	1.71	0.28	2.49	0.17	0.96	62.63
CD (P= 0.05)	NS	NS	NS	NS	NS	178

Table 8. Effect of herbicide- insecticide combination on quality and economics of soybean.[a]

Treatments (Herbicides+Insecticides)	Oil content (%)	Oil Yield (kg ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1: Rynaxypyr	17.72	496.31	27590	86769	58579	3.14: 1
T_2: Indoxacarb	17.62	509.84	27599	89433	61834	3.25: 1
T_3: Quinalphos	17.83	484.29	26833	83920	57087	3.14: 1
T_4: Imazethapyr	17.59	542.09	28129	95329	67200	3.40: 1
T_5: Quizalofop ethyl	17.74	510.54	28079	88681	60602	3.18: 1
T_6: Rynaxypyr+Imazethapyr	17.58	526.57	29470	92428	62958	3.15: 1
T_7: Rynaxypyr+Quizalofop ethyl	17.49	499.30	29420	88107	58686	3.01: 1
T_8: Indoxacarb+Imazethapyr	17.56	526.10	29479	92556	63076	3.15: 1
T_9: Indoxacarb+Quizalofop ethyl	17.66	528.70	29429	92494	63065	3.15: 1
T_{10}: Quinalphos+Imazethapyr	17.61	516.05	28713	90566	61852	3.17: 1
T_{11}: Quinalphos+Quizalofop ethyl	17.93	537.85	28663	92641	63978	3.25: 1
T_{12}: Untreated weedy check	17.50	462.61	25249	81449	56200	3.22: 1
SEm±	0.10	11.00	-	1926	-	-
CD (P= 0.05)	NS	31.43	-	5503	-	-

[a] Sale price of soybean ₹ 3100/- per quintal.

influence the oil content. Oil yield (542.09 kg ha^{-1}) was significantly higher in the treatment imazethapyr due to increased yield as a result of better weed control.

Economics of Application of Herbicide and Insecticides

Application of imazethapyr at 20 DAS gave highest gross returns (₹ 95,329/- ha^{-1}), net monetary returns (₹ 67,200/- ha^{-1}) and benefit: cost ratio (3.40:1), closely followed by quinalphos+quizalofop ethyl gross (₹ 92,641/-) and net returns (₹ 63,978/- ha^{-1}), respectively. Minimum gross monetary returns (₹ 81,449/- ha^{-1}), net monetary returns (₹ 56,200/- ha^{-1}) were recorded under untreated weedy check (Table 5). Application of imazethapyr was more remunerative (1:3.40) than the rest of the treatments, probably due to the better weed control efficiency which resulted in higher grain yield and higher returns. Meena *et al*. (2011) and Ram *et al*. (2013) have also reported significantly higher gross and net returns with the application of imazethapyr 10% @ 100 g ha^{-1} over weedy check in soybean. Higher cost of cultivation was incurred in combination of herbicide and insecticide application treatments than the sole application and weedy check. The trend of the economic gain due to combined application of herbicide and insecticides in terms of net returns was obtained as: quinalphos+quizalofop ethyl, indoxacarb+imazethapyr, indoxacarb+quizalofop ethyl and Rynaxypyr+imazethapyr. All the tank-mix combinations of herbicide and insecticide showed economic feasibility over sole treatments, except sole imazethapyr. Singh *et al*. (2006) reported similar variation in net returns and B:C ratio among treatments due variation in yield and expenditure incurred by herbicide and insecticide treatments.

Thus, it can be concluded that compatible tank mix combinations of insecticides and POE herbicides can be effectively used to control both weeds and insect-pests in soybean. This will also reduce the cost of labor incurred in spraying insecticides and herbicides separately.

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توانایی مخلوط تانکی ترکیب هایی از علف کش و حشره کش برای مدیریت علف هرز و آفات در سویا [*Glycine max* (L.) Merrill.]

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چکیده

سویا در هندوستان عمدتا به صورت گیاه دیم کشت می شود. از مهمترین مزاحمت ها در رسیدن به عملکرد بالای این گیاه وجود مقدار زیادی علف هرز و آفات گیاهی است. به منظور ارزیابی توانایی زیستی(bio-efficacy) ترکیب های سازگار از مخلوط تانکی (tank-mix) ترکیب های علف کش و آفت کش برای مدیریت علف ها و آفت ها در سویا، این پژوهش در طی سالهای ۱۴-۲۰۱۳ و ۱۵-۲۰۱۴ در یک خاک ورتی سول در موسسه تحقیقاتیAgharkar درمنطقه Pune (MS) در هندوستان اجرا شد. کار برد مخلوط تانکی quinalphos وimazethapyr (به میزان ۶۸/۱۷ در متر مربع) و بعد از آن imazethapyr (به میزان۶۹/۳۳ در متر مربع) ۳۰ روز بعد از کاشت منجر به کاهش معنادار تراکم علف ها شد. در۴۵ روز بعد از کاشت، imazethapyr (به میزان ۲۶ در متر مربع) به طور معناداری کمترین تراکم علف را داشتند در حالیکه این تیمار در ۶۰ روز بعد از کاشت تفاوت معنی داری با تیمارهای مختلف نداشت. در کنترل علف هرز، کاربرد imazethapyr به تنهایی و در ترکیب با Rynaxypyr کمترین میزان ماده خشک را در ۳۰، ۴۵، و ۶۰ روز بعد از کاشت. کاربردimazethapyr+ Rynaxypyr در۳۰ روز بعد از کاشت (۶۷/۳۶٪) و ۶۰ روز بعد از کاشت (۸۵/۵۲٪) و کاربرد imazethapyr در ۴۵ روز بعد از کاشت (۸۱/۶۶٪) کارآیی بیشتری از تیمارهای دیگر نشان دادند. هفت روز بعد از اعمال تیمارها، تعداد leaf roller و لاروtobacco caterpillar در هرمتر ردیف طولی به طور معناداری در تیمارهای حاوی حشره کش کمتر بود. بر اساس مشاهدات عینی از برگ ریزی، تیمارهای حاوی حشره کش ها به طور معناداری کمتر از تیمار شاهد و تیمار مصرف علف کش به تنهایی برگ ریزی داشت.