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Dhaigude GS
Department of Agronomy, MPKV, Rahuri, Maharashtra, India

Dhonde MB
Department of Agronomy, MPKV, Rahuri, Maharashtra, India

Andhale RP
Department of Agronomy, MPKV, Rahuri, Maharashtra, India

Corresponding Author
Dhaigude GS
Department of Agronomy, MPKV, Rahuri, Maharashtra, India

Study of economics and sequence evaluation of weed management practices under organic production system of soybean-wheat cropping sequence

Dhaigude GS, Dhonde MB and Andhale RP

Abstract
A field experiment was conducted at All India Coordinated Research Project on Integrated Farming System, MPKV, Rahuri (MS) to study the effect of weed management practices under organic production system of soybean - wheat cropping sequence during the year 2017-18 and 2018-19. Experiment comprising T_1-weed free, T_2 - one hand hoeing at 15 DAS + one hand weeding at 35 DAS, T_3-intercropping with green manure (sunnhemp) with 1:1 row proportion, T_4 - stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + one hand weeding at 20 DAS, T_5 - locally available weed mulch (mixed weed residue) @ 2 t ha^{-1} + one hand pulling at 20 DAS, T_6 - incorporation of neem seed cake 15 days before sowing @ 0.5 t ha^{-1} + one hand weeding at 20 DAS, T_7 - summer soil solarization with 25 microns transparent polyethylene mulch + one hand weeding at 20 DAS and T_8 - weedy check. Weed free was gives maximum gross monetary (Rs. 222613 and 258563 ha^{-1}), net monetary returns (Rs. 94422 and 124808 ha^{-1}), benefit cost ratio (1.74 and 1.93), system productivity (Rs.5779 and 6088 kg ha^{-1}), production efficiency (11.65 and 12.14 kg day^{-1} ha^{-1}) and economic efficiency (363 and 480.ha^{-1} day^{-1}) followed by stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + one hand weeding at 20 days after sowing during both the years of investigation, respectively.

Keywords: soil solarization, stale seedbed, soybean, wheat etc.

Introduction
Organic agriculture is a production system that sustains the health of soil, ecosystem and people. The prime aim of organic agriculture is to keep soil alive and in good health to release the nutrients by using the organic waste and other biological materials along with beneficial microbes to crops for increased production in an eco-friendly pollution free environment. The increased population pressure has forced many countries to use chemicals to increase the farm productivity for meeting their ever-increasing food requirements. The applications of such high input intensive technologies have adverse effects on soil productivity and environmental quality. Increased use of herbicides which increases weed resistance to herbicides. Herbicide used to be a key component in all most all weed management strategies, but indiscriminate use of that herbicide has resulted in serious ecological and environmental problems. Weeds are self grown plants which appear simultaneously with crop plant and results in intense crop-weed competition and cause reduction in yield varying from 27-71 per cent (Arora and Tomar, 2012) [2].

Soybean (*Glycine max* (L.) Merr.) an important oilseed and pulse crop. The area and production of soybean is highest in USA followed by Brazil and Argentina. In India it is grown over an area of 10.47 million hectare with total production 11.39 million tonnes with an average productivity of 1049 kg ha^{-1} (Anonymous, 2018) [1]. In Maharashtra it is cultivated on an area of 3.80 million hectare with the total production of 3.88 million tonnes with an average productivity of 1012 kg ha^{-1} (Anonymous, 2018) [1].

Wheat is most important staple crops of India as well as of world. It occupies second position both in terms of area and production in our country. It is cultivated on an area of 29.58 millions hectare with annual production of 97.30 million tonnes and productivity of 3371 kg ha^{-1}. In Maharashtra it is cultivated on area of 8.00 million hectares with production of 12.07 million tonnes and productivity of 1508 kg ha^{-1}. (Anonymous, 2018) [1].

Material and Methods
A field experiment was conducted at All India Coordinated Research Project on Integrated

Farming System, Mahatma Phule Krishi Vidyapeeth, Rahuri (MS) during two successive years to evaluate the weed management practices under organic production system of soybean- wheat cropping sequence. The experimental soil was clayey in texture, slightly alkaline in reaction (pH 7.80), low in organic carbon (0.45 per cent), low in available nitrogen (188.20 kg ha^{-1}), medium in available phosphorus (16.22 kg ha^{-1}) and very high in available potassium (356.48 kg ha^{-1}). The *kharif* soybean was sown on 19^{th} June, 2017 and 23^{rd} June, 2018 with 45x10 cm spacing by using a seed rate of 75 kg ha^{-1} and harvested on 01^{st} October, 2017 and 05^{th} October 2018 during first and second year of experimentation, respectively. The *rabi* wheat was sown on 13^{th} November, 2017 and 15^{th} November, 2018 during first and second year of experimentation with 22.5 cm line sowing by using a seed rate of 100 kg $ha^{-1}$and harvested on 03^{rd} March, 2018 and 09^{th} March, 2019, respectively.

The experiment was laid out in Randomized Block Design with three replications. Treatments under the experiment were tested for weed management practices in organic soybean-wheat sequence during 2017-18 and 2018-19. Eight treatments of weed management *viz.* T_1-weed free (2 hand weedings at 20 and 35 days after sowing and 1 hand pulling at 50 days after sowing), T_2 - one hand hoeing at 15 DAS + one hand weeding at 35 DAS, T_3- intercropping with green manure (sunnhemp) with 1:1 row proportion (intercrop sunnhemp was sown by dibbling method at the time of sowing of *kharif* soybean and *rabi* wheat and buried into soil at 40- 45 DAS) T_4 - stale seed bed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + one hand weeding at 20 DAS (stale seedbed was prepared 15 days before sowing of soybean and wheat crop. Pre sowing irrigation was given to stale seedbed plot and with help of one hand hoeing the first flush of weeds was removed at 10 days after pre sowing irrigation. The previous crop mulch *viz.*, wheat straw and soybean straw was applied 10 days after sowing between the two rows of *kharif* soybean and *rabi* wheat crop, respectively.) T_5 - locally available weed mulch (mixed weed residue) @ 2 t ha^{-1} + one hand pulling at 20 DAS (locally available weeds were collected and sun dried till complete drying of weeds. The dried weeds were applied in treatment 10 days after sowing of crops between the two rows of *kharif* soybean and *rabi* wheat crop, respectively), T_6 - incorporation of neem seed cake 15 days before sowing @ 0.5 t ha^{-1} + one hand weeding at 20 DAS, T_7 - summer soil solarization with 25 microns transparent polyethylene mulch + one hand weeding at 20 DAS (Summer soil solarization was carried out between 1^{st} of May to 30^{th} of May (Period of 30 days). The plots selected for soil solarization was heavily irrigated one day before spreading of sheet. After irrigation plot was covered with 0.025 mm (25 micron) transparent polyethylene sheet) and T_8 - weedy check. Economics efficiency (Gangwar *et al.*, 2006) and production efficiency was calculated by using following formula.

System productivity (q ha^{-1}) = Soybean grain yield of respective treatment (q ha^{-1}) + SGEY of wheat yield of respective treatments (q ha^{-1})

$$\text{Economic efficiency (Rs.ha}^{-1}\text{ day}^{-1}) = \frac{\text{Net monetary returns over year (Rs. ha}^{-1})}{\text{Total duration of cropping sequence (days)}}$$

$$\text{Production efficiency (kg day}^{-1}\text{ ha}^{-1}) = \frac{\text{System productivity (kg ha}^{-1})}{\text{Total duration of cropping sequence (days)}}$$

$$\text{B:C ratio} = \frac{\text{Gross monetary returns (Rs)}}{\text{Cost of cultivation (Rs)}}$$

Results and Discussion

Economics

Total gross monetary returns

Significantly maximum total gross monetary returns were recorded by weed free (Rs.222613 and 258563 ha^{-1}) and it was at par with summer soil solarization with 25 µ transparent polyethylene mulch + 1 HW at 20 DAS (Rs.218118 and 251651 ha^{-1}) and stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS (Rs.204903 and 235006 ha^{-1}) during both the years of experimentation, respectively.

Net monetary returns

Weed free and stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS was recorded maximum net monetary returns *viz.*, Rs. 94422, 124808 and 76619, 98874 ha^{-1} during first and second years of investigation, respectively. This might be due to initial moisture provided to field, stimulate the weed seed to germinate. The hand hoeing flush out germinated weeds. Reduction in row spacing helps to reduces competition between crop and weeds for resource. The application of straw mulch act as barrier to germinate remaining weed seeds present in deep layer of soil which was followed by hand weeding which created weed free environment to early growth stages of crop that allowed to better yield of crop. These findings are in close conformity by Sindhu *et al.* (2011) [6].

Benefit: cost ratio

The maximum benefit cost ratio was recorded with weed free (1.74 and 1.93) and stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS (1.60 and 1.73) during both the years of investigation as compared to rest of weed management treatment, respectively.

Table 1: Mean gross monetary returns, net monetary returns and B:C ratio of soybean- wheat cropping sequence as influenced by different weed management treatment

Tr. No.	Treatment	Gross monetary return (Rs ha^{-1})		Net monetary returns (Rs.ha^{-1})		B:C Ratio	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1	Weed free	222613	258563	94422	124808	1.74	1.93
T_2	1 hoeing at 15 DAS + 1 HW at 35 DAS	169522	193553	53342	71431	1.46	1.58
T_3	Intercropping with sunnhemp with 1:1 row proportion	146857	173747	30073	50644	1.26	1.41
T_4	Stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS	204903	235006	76619	98874	1.60	1.73
T_5	Weed mulch @ 2 t ha^{-1} + 1 HP at 20 DAS	155473	183930	36183	58181	1.30	1.46
T_6	Incorporation of neem seed cake @ 0.5 t ha^{-1} + 1 HW at 20 DAS	183401	212598	53071	75602	1.41	1.55
T_7	Summer soil solarization with 25 µ transparent polyethylene mulch + 1 HW at 20 DAS	218118	251651	71347	98775	1.49	1.65
T_8	Weedy check	130495	148453	23178	34478	1.22	1.30
	S.Em. ±	6533	7784	6533	7784	-	-
	C.D. at 5%	19815	23609	19815	23609	-	-

System productivity

Weed free was significantly superior over the rest of weed management treatments by recording maximum system productivity (5779 and 6088 kg ha^{-1}) and it was at par with soil solarization with 25 µ transparent polyethylene mulch + 1 HW at 20 DAS (5662 and 5924 kg ha^{-1}) and stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS (5322 and 5527 kg ha^{-1}) during both the year of investigation. Significantly minimum system productivity was recorded by weedy check. This might be due to maximum grain and straw yield of soybean and wheat obtained under summer soil solarization may be due to enhancement of nutrient availability, stimulation of microbial population and effective weed control during crop weed competition which reflected into increasing yield attributes and yield of both crops. The stale seedbed technique provided optimal environment around the buried weed seeds for germination, thereby forcing the weed seeds in soil seed bank to germinate. Germinating seeds were controlled through hand weeding and suppressed through straw mulching which enhanced the better crop environment for betterment of crop yield. These similar results were reported by Das and Yaduraju (2008) and Kumar *et al.* (2012) [3, 5].

Table 2: Mean system productivity of soybean - wheat cropping sequence based on soybean equivalent yield as influenced by different weed management treatment

Tr. No.	Treatment	System productivity (kg ha^{-1})		Production efficiency (kg day^{-1} ha^{-1})		Economic Efficiency (Rs. day^{-1} ha^{-1})	
		2017-18	2018-19	2017-18	2018-19	2017-18	2018-19
T_1	Weed free	5779	6088	11.65	12.14	363	480
T_2	1 hoeing at 15 DAS + 1 HW at 35 DAS	4405	4550	9.50	9.37	205	275
T_3	Intercropping with sunnhemp with 1:1 row proportion	3817	4093	8.25	8.80	116	195
T_4	Stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS	5322	5527	10.87	11.26	295	380
T_5	Weed mulch @ 2 t ha^{-1} + 1 HP at 20 DAS	4040	4330	8.72	9.07	139	222
T_6	Incorporation of neem seed cake @ 0.5 t ha^{-1} + 1 HW at 20 DAS	4764	5006	9.86	10.39	204	291
T_7	Summer soil solarization with 25 µ transparent polyethylene mulch + 1 HW at 20 DAS	5662	5924	11.32	11.79	274	380
T_8	Weedy check	3392	3494	7.27	7.45	89	133
	S.Em. ±	170	184	0.46	0.46	25	30
	C.D. at 5%	517	558	1.39	1.39	76	89

Production efficiency

Maximum and significantly higher production efficiency was recorded by weed free (11.65 and 12.14 kg day^{-1} ha^{-1}) and it was at par with summer soil solarization with 25 µ transparent polyethylene mulch + 1 HW 20 DAS (11.32 and 11.79 kg day^{-1} ha^{-1}) and stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS (10.87 and 11.26 kg day^{-1} ha^{-1}) during both the year of investigation. Significantly minimum production efficiency was observed under weedy check treatment (T_8) during both the years of study. This might be due to soil solarization improves grain yield may be due to increased plant growth response after soil solarization. The main component of this effect may be seen in the control of weeds and release of mineral nutrients from soil. All these factors accounted for enhancement of plant biomass and grain yield. The stale seedbed technique provided optimal environment around the buried weed seeds for germination, thereby forcing the weed seeds in soil seed bank to germinate. Germinating seeds were controlled through hand weeding and suppressed through straw mulching which enhanced the better crop environment for betterment of crop yield.

Economic efficiency

Weed free was recorded significantly maximum economic efficiency (Rs. 363 and 480 day^{-1} ha^{-1}) and significantly minimum was by weedy check during both the years of study. Among the weed management treatments except weed free, stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} + 1 HW at 20 DAS (Rs. 295 and 380 day^{-1} ha^{-1}) was recorded significantly maximum economic efficiency followed by summer soil solarization with 25 µ transparent polyethylene mulch + 1 HW at 20 DAS (Rs. 274 and 380 day^{-1} ha^{-1}) during both the years of investigation. This might be due to the stale seedbed technique provided optimal environment around the buried weed seeds for germination, thereby forcing the weed seeds in soil seed bank to germinate. Germinating seeds were controlled through hand weeding and suppressed through straw mulching which enhanced the better crop environment for betterment of crop yield. The input used in stale seedbed was cheaper and also the straw mulch effectively control weeds and enhance the crop yield as compared to rest of weed management treatments.

Conclusion

It may be concluded that in organic production system of soybean - wheat cropping sequence for better weed control and maximum net profit, weed free (Two hand weeding at 20 and 35 days after sowing and one hand pulling at 50 days after sowing) or stale seedbed + reduced row spacing (33 %) + previous crop mulch @ 2 t ha^{-1} applied at 10 days after sowing + one hand weeding at 20 days after sowing to both the crops during *kharif* and *rabi* season found suitable weed management practices.

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