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Effect of weed management practices on weeds and yield of wheat under organic conditions of North-West Himalayas

Priyanka Kumari and JP Saini

Abstract
A field experiment was conducted at Model Organic farm of CSKHPKV, Palampur during *rabi* 2015-16 to assess the impact of seedbed manipulations and weed management methods in organically grown wheat. The results indicated that stale seedbed registered significantly lower density and dry matter accumulation of grassy and broadleaf weeds over standard seedbed. The significantly higher wheat grain yield (2711 kg/ha) was recorded in standard seedbed as compared to stale seedbed (2540 kg/ha). Gram intercropping + one manual hoeing being statistically at par with two manual hoeings recorded lower weed dry matter accumulation and higher weed control efficiency in grassy (73.58%) and broadleaf weeds (80.70%). Two manual hoeings produced significantly higher wheat grain yield (3796 kg/ha) as compared to other treatments.

Keywords: Wheat, weed management, organic, intercropping

Introduction
Wheat (*Triticum aestivum* L.), in India, is second to rice in terms of area and production and produced 93.50 mt of wheat from 30.23 mha area (Anonymous, 2016) [1]. Wheat is a versatile crop, growing across a range of agro-ecological zones and gets infested with a variety of weeds. Weed infestation is one of the major factors limiting wheat productivity, as weeds compete for nutrient, water, light, and space with crop plants during the early growth period. Moreover, besides low yield of the crop, they increase production cost, harbor insect-pest and diseases, decrease quality of farm produce, reduce land value and of different factors known for the reduction in crop production, among them weed stand first (Chaudhari *et al*., 2016) [2]. The life cycle of most of them coincides with that of crop they invade, thus ensuring mixing of their seed with those of the crops (Mahroof *et al.,* 2009) [10]. The presence of a mixed population of grassy and broad-leaf weeds throughout the crop season reduces grain yield of wheat by 49 percent (Punia *et al.,* 2005) [17]. Herbicide used to be a key component in almost all weed management strategies, but indiscriminate use of these herbicides has resulted in serious ecological and environmental problems. A strong need was felt to discover alternative weed management options in organic agriculture (Economou *et al.,* 2002) [4].
Different cultural and mechanical practices can provide a sigh of relief for the growers with no chemical application in agriculture. Indian farmers mainly depend on manual hand weeding. It remains a very safe and effective method against most weeds in most crops. However manual weeding is becoming less common because of the non-availability of labor at critical times and increased labor cost (Singh *et al.,* 2015a) [20]. Hence non-chemical methods of weed control like stale seedbed preparation, intercropping and use of mulch can be very effective for weed management. Stale seedbed technique is most appropriate to reduce weed pressure and the weed seed bank in the soil. Stale seedbed conditions by pre-sowing irrigation or rainfall induce sprouting of weeds and subsequent harrowing makes land free from weeds in initial stages of growth (Yadav *et al.,* 1995) [23]. Intercropping uses resources more effectively than a monoculture and thus decreases the amount available for weeds use (Yadollhi *et al.,* 2014) [24].
Hence, it may be used in combination with one hand weeding which may reduce the need for 2 or more hand weeding and bring about higher weed control efficiency. Mulching the soil surface is a good means of decreasing weed emergence and growth, reduce erosion and increase the biological activity of soil (Datta *et al.,* 2017) [3]. Keeping in view the negative effects of herbicides, and increasing demand of organic products, the present investigation was

conducted to study different weed flora, the effect of different weed management practices on weeds and yield of wheat and to find out the best suitable combination of practices for effective weed management in wheat under organic production system.

Materials and Methods

The experiment was conducted during *rabi* season of 2015-16 at the Model Organic Farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur (India) situated at 32˚4´ N latitude and 76˚3´ E longitude at an elevation of about 1224 meters above mean sea level in North-Western Himalayas. The soil of the experimental field was silty clay loam in texture (International pipette method), acidic in reaction (pH 5.3) (1:2.5 soil-water suspension method), low in available nitrogen (205 kg/ha) (Alkaline permanganate method), high in available phosphorus (32 kg/ha) (Olesen's method) and medium in available potassium (190 kg/ha) (Ammonium acetate extraction method). Experiment was laid out in split-plot design with three replications comprising of seedbed manipulations (standard and stale seedbed) in main plots and seven weed management practices [one manual hoeing, two manual hoeings, gram intercropping (no weeding), gram intercropping + one manual hoeing, natural farming (mulching), natural farming (gram intercropping + mulching) and weedy check] in sub plots. Wheat variety HPW 155 was sown on 6th November 2015 under standard seedbed and on 7th December 2015 under stale seedbed following all organic package of practices except the natural farming treatments. In natural farming treatments, weeds were cut with a sickle and left on the surface and used as mulch. Weed population and weed dry weight were recorded periodically using 50 cm x 50 cm quadrate. The dry weight of weeds was recorded (sun-dried) for the counted weeds from each plot and then kept them in the oven at 70 °C till constant weight was achieved. Weed control efficiency (WCE) was worked out based on weed dry weight as per the formula outlined by Mallikarjun *et al.,* (2014) [11].

$$WCE\ (\%) = \frac{\text{Dry wt. of weeds in untreated plot - Dry wt. of weeds in treated plot}}{\text{Dry wt. of weeds in untreated plot}} \times 100$$

Data on weed count have shown a high degree of variation and hence were subjected to square root $\sqrt{(x + 0.5)}$ transformation. The data recorded on various aspects in the present study were subjected to the statistical analysis using analysis of variance as per procedure suggested by Gomez and Gomez, (1984) [5].

Results and Discussion

Effect of seedbed manipulations on weeds and crop

The major weed flora of the experimental plots consisted of *Phalaris minor, Avena fatua, Lolium temulentum,* and *Poa annua* among grasses; *Anagallis arvensis* and *Vicia sativa* among broad-leaved weeds. On average, the grasses and broad leaved weeds constituted 79.7 and 13.6 percent of the total weed population. Almost similar weed flora in wheat has been reported by Kumar *et al.,* (2011) [9]. The density and dry matter accumulation of weeds increased gradually up to 120 DAS, and thereafter it decreased up to the harvest of the crop. Stale seedbed resulted in significantly minimum numbers of weeds and their dry matter accumulation over standard seedbed (Table 1, 2, 3 & 4). This might be ascribed to the fact that stale seedbed produced suitable conditions in the field for germination of weeds that emerged and uprooted during final seedbed preparation, thus minimized weed seed bank in the soil. Similar results have been reported by Safdar *et al.,* (2011) [19]. However, seedbed manipulations could not significantly influence weed control efficiency of grassy and broad-leaved weeds at harvest (Table 4). Standard seedbed significantly increased the grain yield of wheat over stale seedbed (Table 4). The possible cause for decreased wheat grain yield under stale seedbed was due to delay in sowing to control weeds. In a study, Khokhar *et al.,* (2010) [7] found that two weeks delay in sowing beyond November 15 resulted in a 16 percent reduction in grain yield. But in the present investigation, four weeks delay in sowing under stale seedbed reduced wheat grain yield only by 6.31 percent over the standard seedbed. This might be due to less weed pressure under stale seedbed which compensated the yield loss.

Effect of weed management methods on weeds and crop

Weed density

All weed management treatments significantly reduce the density of weeds as compare to the weedy check. Among the different treatments, two manual hoeings recorded significantly lowest density of weeds (Table 1, 2, & 3) and it was at par with gram intercropping + one manual hoeing at all the stages of observations. It might be because two manual hoeings resulted in uprooting and mortality of weeds during early growth stages of the crop which led to lower weed density. Similar results have been reported by Nadeem *et al.,* (2006) [12] and Nanher *et al.,* (2015) [13] who obtained the lowest weed density with hand weeding or weed-free condition. One manual hoeing being at par with gram intercropping at all the stages of observations except at 60 DAS where it was at par with natural farming (gram intercropping + mulching) were the next best treatments in decreasing the density of *Phalaris minor, Avena fatua, Lolium temulentum* and *Poa annua*.

Both natural farming treatments at 60 DAS and one manual hoeing being at par with gram intercropping from 90 DAS to harvest were the other best treatments in reducing the density of *Anagallis arvensis* and *Vicia sativa.* This might be due to more crop canopy and synergistic allelopathic effects by the intercropping treatments which reduced weed density. The results conform with Naeem *et al.,* (2012) [14]. Mulching in natural farming was effective in decreasing the density of broad-leaved weeds as compared to grassy weeds but the positive effect of mulching was manifested at the beginning of the investigation. Later, decomposition of grass has started and thereby mulch had no important influence. These results confirm with Jadaugiene *et al.,* (2006) [6].

Weed dry matter accumulation

Gram intercropping + one manual hoeing at par with two manual hoeing was significantly superior over rest of the weed management treatments in reducing dry matter accumulation of grassy and broad-leaved weeds at all the stages of observations (Table 4). This might be due to intercropping compared to monoculture use resources more efficiently and therefore decrease the amount of available resources for weeds and also smothering effect has a positive influence. These are in agreement with the findings of Qayyum *et al.,* (2011) [16].

In dry matter accumulation of grassy weeds, one manual hoeing statistically at par with natural farming (gram intercropping + mulching) at 60 DAS and gram intercropping at par with one manual hoeing from 90 DAS to harvest were

other best treatments. However, natural farming (gram intercropping + mulching) at 60 DAS and gram intercropping at par with one manual hoeing from 90 DAS to harvest were the next best treatment concerning broad leaved weeds.

Natural farming treatments suppressed broad-leaved weeds more effectively than grassy weeds but the suppressive effect of mulch after few weeks has gone down and the second flush of weeds started germinating. Similar were the findings of Ranjit and Suwanketnikom, (2003) [18] who concluded that straw mulch suppressed grassy weeds up to 23% and broad-leaved weeds up to 36% compared to weedy check at 4 weeks after sowing of wheat.

Weed control efficiency

Gram intercropping + one manual hoeing resulted in significantly higher weed control efficiency of 73.58 percent of grassy weeds and 80.70 percent of broad-leaved weeds (Table 4). This might be due to the weed smothering ability of the legumes due to profuse canopy which resulted in higher weed control efficiency. Similar findings have been reported by Nongmaithem *et al.,* (2012) [15]. This was followed by two manual hoeings, gram intercropping and one manual hoeing treatments. The natural farming (mulching) treatment gave the lowest weed control efficiency.

Wheat yield

Among weed management treatments, two manual hoeings produced significantly higher grain yield as compared to other treatments (Table 4). The percent increase in yield under two manual hoeings to the tune of 10.67 and 36.99 percent over one manual hoeing and gram intercropping + one manual hoeing, respectively. All the weed management treatments were observed significantly superior to weedy check except natural farming (gram intercropping + mulching) treatment. The higher grain yield of wheat in two manual hoeings might be due to lesser weed competition, lowest weed density and higher plant density under sole cropping compared with intercropping combinations. The findings corroborated the results obtained by Sharma and Sharma, (1998) [22] and Kumar and Agarwal, (2013) [8]. Weeds in weedy check reduced grain yield to the tune of 52.00 percent over two manual hoeings. Similar findings were noticed by Singh *et al.,* (2015b) [21] who obtained 50.00 percent wheat yield reduction in weedy check over weed-free condition.

Conclusion

It is conclusively inferred that stale seedbed resulted in lower weed density and dry matter accumulation over standard seedbed but due to delay in sowing to control weeds standard seedbed recorded higher wheat grain yield over stale seedbed. Two manual hoeings registered the highest grain yield of wheat and remained statistically at par with gram intercropping + one manual in terms of weed density and dry matter accumulation. Thus, effective weed management in wheat under organic conditions can be achieved by two manual hoeings (40 and 70 DAS) or gram intercropping + one manual hoeing (40 DAS) with stale seedbed preparation.

Table 1: Effect of seedbed manipulations and weed management methods in wheat on weed density (No./m^2)

Treatments	*Phalaris minor* (No./m^2)					*Avena fatua* (No./m^2)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Seedbed manipulations										
Standard seedbed	6.26 (41.43)	7.94 (66.19)	8.83 (83.33)	8.23 (71.33)	7.76 (63.71)	5.64 (32.67)	7.40 (57.95)	8.31 (72.05)	7.83 (64.19)	7.10 (52.48)
Stale seedbed	5.11 (27.48)	6.90 (49.90)	7.70 (62.00)	7.10 (53.10)	6.51 (44.57)	4.75 (23.48)	6.55 (44.81)	7.28 (55.86)	6.88 (49.10)	6.33 (41.33)
CD (P=0.05)	0.42	0.32	0.22	0.33	0.38	0.32	0.45	0.54	0.45	0.32
Weed Management										
One Manual hoeing	4.69 (22.25)	6.72 (44.83)	7.41 (54.67)	6.93 (47.83)	6.33 (40.00)	4.46 (19.67)	6.45 (41.33)	6.90 (47.33)	6.69 (44.50)	6.03 (36.17)
Two Manual hoeings	4.42 (19.50)	5.72 (32.67)	6.38 (40.67)	5.88 (34.67)	5.39 (28.83)	4.28 (18.00)	5.22 (26.83)	6.25 (39.17)	5.81 (33.33)	5.52 (30.17)
Gram intercropping (no weeding)	6.48 (41.67)	6.89 (47.17)	7.65 (58.33)	7.11 (50.33)	6.61 (43.67)	5.52 (30.17)	6.57 (42.83)	7.11 (50.33)	6.90 (47.33)	6.25 (38.83)
Gram intercropping + one manual hoeing	4.57 (20.67)	5.98 (35.50)	6.68 (44.17)	6.15 (37.50)	5.55 (30.50)	4.45 (19.50)	5.48 (29.83)	6.46 (41.67)	6.05 (36.33)	5.69 (32.00)
Natural farming (Mulching)	5.89 (34.33)	7.87 (61.83)	8.75 (76.83)	8.05 (64.83)	7.67 (59.00)	5.22 (27.00)	7.33 (53.50)	8.09 (65.00)	7.68 (58.67)	6.87 (46.83)
Natural farming (Gram intercropping + mulching)	4.90 (23.77)	7.41 (54.67)	8.02 (64.33)	7.60 (57.67)	7.29 (52.83)	4.65 (21.50)	6.95 (48.00)	7.77 (60.00)	7.26 (52.50)	6.56 (42.67)
Weedy check	8.84 (79.00)	11.38 (129.67)	12.99 (169.67)	11.93 (142.67)	11.11 (124.17)	7.80 (60.67)	10.82 (117.33)	12.00 (144.17)	11.11 (123.83)	10.08 (101.67)
CD (P=0.05)	0.34	0.31	0.32	0.30	0.29	0.20	0.37	0.27	0.25	0.29

Table 2: Effect of seedbed manipulations and weed management methods in wheat on weed density (No./m^2)

Treatments	*Lolium temulentum* (No./m^2)					*Poa annua* (No./m^2)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Seedbed manipulations										
Standard seedbed	5.38 (29.62)	6.73 (47.67)	7.91 (64.71)	7.34 (56.05)	6.57 (45.05)	4.51 (20.62)	5.63 (31.95)	6.48 (42.67)	6.12 (37.60)	5.46 (30.48)
Stale seedbed	4.03 (17.05)	6.01 (37.67)	6.93 (49.67)	6.18 (39.62)	5.77 (34.38)	3.62 (13.29)	5.27 (27.71)	5.84 (34.14)	5.34 (28.42)	4.58 (20.81)
CD (P=0.05)	0.28	0.43	0.32	0.35	0.34	0.32	0.35	0.32	0.35	0.43

Weed Management										
One Manual hoeing	4.06 (16.50)	5.87 (34.17)	6.82 (46.33)	6.27 (39.17)	5.54 (30.33)	3.48 (11.83)	5.10 (25.50)	5.69 (32.00)	5.39 (28.67)	4.64 (21.17)
Two Manual hoeings	3.84 (14.67)	4.70 (21.67)	6.15 (37.50)	5.19 (26.67)	5.02 (24.83)	3.27 (10.50)	4.51 (19.83)	5.13 (26.00)	4.87 (23.33)	4.08 (16.33)
Gram intercropping (no weeding)	4.89 (24.17)	6.01 (35.83)	6.92 (47.67)	6.39 (40.67)	5.71 (32.17)	4.56 (20.17)	5.34 (28.17)	6.02 (36.00)	5.59 (31.00)	4.86 (23.17)
Gram intercropping + one manual hoeing	4.04 (16.50)	4.92 (23.83)	6.37 (40.00)	5.36 (28.50)	5.15 (26.17)	3.45 (11.67)	4.78 (22.33)	5.33 (28.17)	5.12 (25.83)	4.24 (17.67)
Natural farming (Mulching)	4.60 (21.00)	6.87 (47.00)	7.46 (55.33)	7.21 (52.00)	6.43 (41.17)	4.30 (18.00)	5.95 (35.00)	6.76 (45.67)	6.14 (37.33)	5.68 (31.83)
Natural farming (Gram intercropping + mulching)	4.25 (18.00)	6.45 (41.17)	7.22 (51.83)	6.81 (46.17)	5.99 (35.50)	3.60 (12.83)	5.65 (31.50)	6.41 (40.83)	5.86 (34.00)	5.26 (27.33)
Weedy check	7.26 (52.50)	9.75 (95.00)	11.01 (121.33)	10.07 (101.67)	9.36 (87.83)	5.79 (33.33)	6.82 (46.50)	7.77 (60.17)	7.14 (51.00)	6.37 (42.00)
CD (P=0.05)	0.24	0.24	0.23	0.23	0.24	0.24	0.28	0.33	0.26	0.38

Table 3: Effect of seedbed manipulations and weed management methods in wheat on weed density (No./m^2)

Treatments	*Anagallis arvensis* (No./m^2)					*Vicia sativa* (No./m^2)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
Seedbed manipulations										
Standard seedbed	4.20 (18.38)	5.35 (29.38)	5.94 (35.57)	5.39 (29.90)	4.96 (25.38)	3.20 (10.52)	3.88 (15.52)	4.44 (20.52)	4.13 (17.57)	4.02 (16.76)
Stale seedbed	3.08 (9.76)	4.48 (20.14)	4.87 (24.38)	4.83 (23.48)	3.86 (15.48)	2.62 (6.90)	3.29 (10.76)	3.45 (11.95)	3.35 (11.14)	2.97 (9.10)
CD (P=0.05)	0.50	0.29	0.37	0.42	0.50	0.24	0.45	0.64	0.25	0.30
Weed Management										
One Manual hoeing	3.79 (14.33)	4.46 (19.50)	4.98 (24.67)	4.74 (22.00)	3.94 (15.50)	3.00 (8.67)	3.23 (10.00)	3.67 (13.17)	3.40 (11.17)	3.08 (9.67)
Two Manual hoeings	2.69 (7.00)	4.00 (15.50)	4.31 (18.33)	4.06 (16.00)	3.19 (10.17)	2.11 (4.00)	2.72 (7.00)	2.99 (8.67)	3.01 (8.67)	2.36 (5.17)
Gram intercropping (no weeding)	4.17 (17.17)	4.66 (21.50)	5.23 (27.17)	4.95 (24.33)	4.19 (17.33)	3.29 (10.50)	3.44 (11.50)	3.71 (13.50)	3.53 (12.17)	3.39 (11.33)
Gram intercropping + one manual hoeing	2.96 (8.50)	4.18 (17.00)	4.57 (21.00)	4.28 (17.83)	3.38 (11.50)	2.34 (5.00)	2.85 (7.67)	3.08 (9.17)	3.02 (8.67)	2.54 (6.33)
Natural farming (Mulching)	3.28 (10.83)	5.27 (27.67)	5.90 (34.50)	5.44 (29.33)	5.14 (26.17)	2.71 (7.00)	3.92 (15.17)	4.49 (19.67)	3.99 (15.83)	4.15 (16.83)
Natural farming (Gram intercropping + mulching)	2.99 (8.67)	5.03 (25.50)	5.58 (30.67)	5.20 (27.00)	4.67 (21.50)	2.40 (5.33)	3.85 (14.50)	4.26 (18.00)	3.93 (15.17)	3.74 (14.00)
Weedy check	5.62 (32.00)	6.84 (46.67)	7.29 (53.00)	7.11 (50.33)	6.36 (40.83)	4.52 (20.50)	5.09 (26.17)	5.43 (31.50)	5.32 (28.83)	5.19 (27.17)
CD (P=0.05)	0.35	0.24	0.28	0.23	0.46	0.33	0.36	0.52	0.35	0.41

Table 4: Effect of seedbed manipulations and weed management methods in wheat on weed dry matter accumulation, weed control efficiency and crop yield

Treatments	Dry matter accumulation (g/m^2) Grassy weeds (GW)					WCE (%) GW	Dry matter accumulation (g/m^2) Broad leaved weeds (BLW)					WCE (%) BLW	Wheat grain yield (kg/ha)
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest	At harvest	60 DAS	90 DAS	120 DAS	150 DAS	At harvest	At harvest	
Seedbed manipulations													
Standard seedbed	49.60	109.47	151.19	125.45	92.92	53.17	13.01	23.76	34.97	28.91	22.07	58.22	2711
Stale seedbed	36.40	85.34	111.69	95.54	71.22	56.29	7.71	16.50	26.07	20.39	14.80	57.91	2540
CD (P=0.05)	3.97	6.41	9.19	5.68	6.80	NS	3.43	1.52	2.18	1.56	3.64	NS	100
Weed Management													
One Manual hoeing	28.41	77.89	105.43	90.67	66.32	63.02	10.74	15.85	24.30	20.02	14.34	67.19	3430
Two Manual hoeings	26.34	56.71	85.40	66.64	50.48	72.31	4.21	10.40	18.03	14.07	9.89	77.55	3796
Gram intercropping (no weeding)	45.94	72.80	100.43	85.87	62.16	65.86	13.72	13.88	22.89	18.21	13.27	69.88	2292
Gram intercropping + one manual hoeing	25.24	52.97	82.48	62.24	47.92	73.58	3.36	8.56	16.20	11.90	8.68	80.70	2771
Natural farming (Mulching)	39.02	104.42	136.94	117.50	88.04	51.23	7.77	22.19	33.40	26.99	21.07	52.01	2382
Natural farming (Gram intercropping + mulching)	31.50	92.27	122.16	104.49	77.83	57.09	5.32	19.22	30.26	23.56	17.78	59.36	1885
Weedy check	105.62	224.79	287.22	246.07	180.80	-	26.64	50.81	67.11	57.81	44.04	-	1822
CD (P=0.05)	3.20	5.36	5.54	4.84	4.49	1.94	2.01	2.30	1.84	2.37	1.58	3.23	132

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