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Research Paper

Influence of fertilizer levels and wild oat (*Avena ludoviciana*) management on growth, yield and economics of wheat (*Triticum aestivum*) cultivation

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ABSTRACT

The present study was carried out at the Chaudhary Charan Singh Haryana Agricultural University, Hisar during the winter (*rabi*) season of 2015–16 and 2016–17, to investigate influence of fertilizer levels and different treatments of wild oat (*Avena ludoviciana* Durieu.) management on growth and yield of wheat (*Triticum aestivum* L.). There were 24 treatments and 3 replications with fertilizer (Levels-03) and wild oat (management -08) treatments as main and subplot treatments in split-plot design. Results of the 2 year study showed, higher grain yield (44.7 q/ha), straw yield (66.7 q/ha) and benefit: cost ratio (1.80) in recommended dose of fertilizer (RDF) when compared 120% RDF (40.22 q/ha, 61.24 q/ha and 1.58 respectively). Weed-free (55.3 q/ha, 79.1 q/ha and 2.03) and pinoxaden @ 50 g/ha (54.8 q/ha, 78.6 q/ha and 2.18) being at par with each other resulted in higher grain and straw yields, whereas weedy check exhibited the least values. Clodinafop @ 60 g/ha recorded significantly higher grain, straw yield and benefit: cost (B:C) ratio than with sulfosulfuron @ 25 g/ha though it was significantly lower than the pinoxaden @ 50g/ha. Pendimethalin @ 1.5 kg/ha and metribuzin @ 175 g/ha ensued statistically similar grain, straw yield and B : C ratio, followed by weedy check. The results also indicated that, fertilizers given in larger dosages only served to increase the weed population rather than wheat output. In the higher dosage of fertilizer, weeds becomes resistant to normal dosage of herbicides. Recommended dose of fertilizer along with suitable herbicide application or manual weeding could result in higher yield of wheat.

Key words: *Avena ludoviciana,* Fertilizer level, Pinoxaden, Recommended dose of fertilizer, Wheat, Wild oat

Wheat, (*Triticum aestivum* L.), the king of cereals, originated from the Levant region of the North-East Asia, is one of the most important cereal crops of the world grown in 122 countries and plays an important role in the agricultural system of northern India. This crop has contributed immensely to the advent and flourishment of Green Revolution, increasing production by 6 times in comparison to that of 1960's. There is greater scope to increase wheat productivity by bridging the gap between potential and achieved yield. Fertilization is an important agronomic strategy used extensively to increase crop yield. Though nutrients clearly promote crop growth, many studies have shown that, in some cases, fertilizers benefit weeds more than crops (Di Toamso, 2016). This can lead to a worst-case scenario where fertilizers increase the competitive ability of weeds more than that of the crop, and crop yield remains unchanged or decreased (Dhima and Eleftherohorinos, 2001).

Wheat productivity is a result of many factors, but weed management is one of the major and less cared causes of low yield. Wild oat (*Avena ludoviciana* Durieu.) is a dominant grassy weed making wheat cultivation less remunerative due to significant yield losses. Wild oat is more competitive than any other grass, as it emerges early and competes more vigorously with wheat. Moreover, it responds more favourably with fertilizers and irrigation. The knowledge about weeds will help mitigate them, but also the knowledge about the herbicides and nutrients synergy is vital to promote the growth in getting higher yield of wheat (Goudar *et al*., 2017). Hence an experiment was conducted to study the effect of fertilizer and wild oat management on growth, yield and economics of wheat.

MATERIALS AND METHODS

The present investigation was conducted at the Chaudhary Charan Singh Haryana Agricultural University, Hisar during the winter (*rabi*) season of 2015–16 and

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2016–17. There were 24 treatment combinations in 3 replications, in which fertilizer levels and wild oat management treatments were plotted in main and subplot treatments, respectively, in split-plot design. In the experiment 2 main sources of variations are present with different level, first one was fertilizer levels with 3 main levels, i.e. F_1, recommended dose of fertilizer (RDF, 100%); F_2, 110% RDF and; F_3, 120% RDF; second was wild oat management treatments with 8 sub levels, i.e. W_1, clodinafop @ 60 g/ha; W_2, sulfosulfuron @ 25 g/ha; W_3, pinoxaden@ 50 g/ha; W_4, metribuzin @ 175 g/ha; W_5, pendimethalin @ 1.5 kg/ha (Pre); W_6, pendimethalin + metribuzin @ 1.5 kg/ha (Pre); W_7, weed-free and; W_8, weedy check. Crop was sown with the recommended seed rate 100 kg/ha, with spacing of 20 cm × 10 cm. Variable fertilizer rates were calculated and applied (RDF 100%, 110% RDF and 120% RDF/ha) according to package of practices using seed-cum-fertilizer drill.

Observations on growth parameters, viz. plant height, number of tillers, dry-matter production and leaf area, were recorded. Plant height (cm) was recorded from the base of the main stem up to the highest growing tip at 60 days after sowing (DAS) and at harvesting stage. Similarly, numbers of tillers were counted per meter row length from the third row on either side in each plot, representing the whole plot at harvesting stage. One-meter plant samples were removed in destructive method for dry-matter analysis at harvesting stage. The samples were sun dried and then oven-dried at 65 ± 2°C till a constant weight was obtained at each stage. After drying, the samples were weighted for recording dry weight and computed for per meter row length in gram. Leaf areas as well as leaf-area index (LAI) were recorded with the help of Laser Area Meter (CI-203), CID, Inc. (USA).

Application of pre- and post-emergence herbicides was done using the flat fan nozzle mounted on a knapsack sprayer with a spray discharge of 120 L/ha at 42 psi pressure. Perfect dosages were calculated and according to the treatment detail dosages of the herbicides were maintained. Prior to the final harvesting of crop, plants from 1-meter row length in each plot were harvested for recording of yield attributes. Two rows from both sides and half-meter length from each side of the plot across the row were harvested to avoid border effect. The crop in the respective plots was left for sun-drying after tagging. Before threshing, the biological yield (straw + grain) of net plot was recorded with spring balance. The crop was threshed plot-wise with the help of the mini thresher and grain yield was recorded accordingly. The experimental data were subjected to Fisher's method of Analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). All the data were analyzed and the results are presented and discussed at a probability level of 5% and represented in tables as pooled analysis of 2015–16 and 2016–17.

RESULTS AND DISCUSSION

Effect of fertilizer on growth and yield of wheat:

Plant height of wheat increased significantly with the application of 120% RDF (39.49 and 84.41 cm at 60 DAS and at harvesting, respectively) as compared to RDF (36.41and 79.61 cm at 60 DAS and at harvesting, respectively) (Table 1). The improvement in plant height owing to 120% RDF application was attributed to proper nourishment of crop and optimum growth. Addition of 120% RDF helped in release of nutrients favourable for crop growth. It also increased the activity of meristematic cells and cell elongation. Our results confirm the findings of Rana *et al.,* (2016).

The rate of production and number of tillers in wheat are dependent on nutrient supply without disturbance by weeds. Application of RDF recorded significantly higher number of tillers/m row length (73.69) than 120% RDF (68.39) (Table 1). The reduction in number of tillers in 120% RDF was related to the weed competition as well as higher weed growth. Higher weed growth has suppressed the crop, encouraged higher number of tillers in wild oat and reduced the production of tillers in wheat (Table 1). These findings are in line with those of Martin and Field (2016), Ahmadvand *et al.,* (2016) and Woldesenb *et al*., (2016). Number of leaves in a plant and the leaf area of a particular plant were directly proportional to the tiller number. Increased number of tillers will surely contribute for the higher number of leaves/plant and higher leaf-area index (LAI). Application of RDF recorded significantly higher LAI (4.16 and 3.50 at 60 and 120 DAS respectively) (Table 1) than 120% RDF. These results are in agreement with the findings of Gholam *et al.,* (2015). Moreover, significantly lower leaf-area index was observed with 120% RDF, which was also owing to higher competitive nature of wild oat as well as suppression of wheat crop by high growth of wild oat, causing competition between crop and weeds.

The dry-matter accumulation was function of many factors that are known as growth parameters. It is well known fact that, the persistence of the assimilatory surface area is a pre-requisite for prolonged photosynthetic activity; higher number of tillers ultimately results in higher dry-matter production. Significantly higher dry-matter production was recorded with RDF (227.43 g) than 120% RDF. Application of RDF increased the photosynthetic efficiency of wheat which led to higher dry-matter production. Significantly lower dry-matter accumulation was recorded with 120% RDF (220.92 g). This was due to optimum nutrition and higher dry-matter distribution in leaf and stem. Moreover higher dry-matter in RDF was due to treatments could be attributed to the variations in the growth-attributing parameters like plant height, total number of tillers, leaf area and leaf-area index these findings are in line with those of Kaur *et al*., (2016).

Economic yield is expressed as function of growth parameters and yield attributes, ultimately crop yield is affected by both the source and sink and the capacity to translocate photosynthates from one part to another. Application of RDF resulted in significantly higher grain yield (44.72 q/ha) over 120% RDF (Table 2). Significantly lower yield in 120% RDF was due to least growth of wheat plants in particular fields and least growth of all growth attributing characters in these plots; hence vigorous growth of wild oat at abundant nutrient level was observed (Anderson, 2016) rather than wheat crop. These results are in conformity with those of Ahmedvand *et al.,* (2016) and Kaur *et al*., (2016). Significantly higher straw yield was registered under RDF (67.63 q/ha) than 120% RDF (61.2 q/ha) (Table 2). The increase in straw yield was owing to increase in vegetative growth, as evident from higher dry-matter production (Table 1) and its accumulation in different plant parts like leaves, stem and increased number of tillers (Table 1). Higher straw yield under RDF than 110% RDF or 120% RDF. Moreover, straw yield in RDF was also the result of higher number of tillers (10.5% more) than 120% RDF which contributed to more biological yield and ultimately straw yield. Nutrients will also provoke the second flush of weeds after 45 DAS leading to poor control of wild oat; hence significantly lower growth of wheat was observed and resulted in lower straw yield in 120% RDF. The results confirm the finding of Martin and Field (2016) and Kaur *et al.,* (2016).

Yield of the crop directly correlates with the yield-attributing characters. Similarly, yield-attributing characters depend on the accumulation of photosynthates and their translocation to ears. The synthesis, accumulation and translocation of photosynthates depend on efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. Application of RDF recorded significantly higher yield components, viz. grains/spike (43.11 g) and spikelets/spike (19.64) than 120% RDF (Table 2). The difference in the performance of yield attributes in different dose of fertilizer due to variations in translocation of photosynthates from vegetative to reproductive parts. These results are in agreement with the findings of Saeed *et al*., (2013).

Effect of wild oat on growth and yield of wheat

Among the treatments of wild oat management, significantly lower plant height (66.3 cm), number of tillers/m row length (57.2) and LAI (2.82) were obtained in weedy condition (Table 1). This could be due to higher weed dominance, offering the highest weed competition for space, light, moisture, sun light and nutrients with the crop. Since weed persistence was more from the beginning to the end of the crop-growth period, they proliferated while the crop starved for space, light as well as all the factors required for crop-growth. All the growth parameters were superior in weed-control treatments to unweeded check. Weed-free condition resulted in significantly higher plant height (99.8 cm), number of tillers (85.1) and LAI (4.1). The enhancement in crop-growth component could be due to less competition by weeds throughout the crop-growth period because of the effective control. These results support the finding of Jain *et al.,* (2016). Post-emergence application of pinoxaden @ 50 g/ha was found at par with weed-free, i.e. significantly higher plant height (99.8 cm), number of tillers (85.1) and LAI (4.1), followed by application of clodinafop 60 g/ha plant height (88.6 cm), number of tillers (76.8) and LAI (3.6) (Table 1). Since, pinoxaden and clodinafop belong to ACCase inhibitors and prohibit fatty acid production and membrane development in grassy weeds like wild oat, the weed control was superior to all other herbicidal treatments like sulfosulfuron, pendimethalin and metribuzin. Weed-free and pinoxaden were superior to weedy check and other herbicidal treatments owing to better control of weeds in the early stages which resulted in reduced crop-weed competition during the critical period of crop-weed competition and helped in better utilization of resources and hence resulted with good crop growth, Katara *et al.,* (2015) and Singh *et al*., (2017) also reported similar results.

Dry matter accumulation serves as a reliable measure of the relative influence of different treatments on the plant growth and yield attributes. Enhancement in yield of economic plant part is usually dependent on total dry-matter production and its distribution among different parts of the plant. Presence of weeds throughout the growing season caused a reduction of 42 to 44% in dry weight by the crop compared to weed-free. The density and dry weight of weeds were the highest in weedy plots and therefore dry weight by the crop was the least. Dry weight by wheat crop was significantly higher in weed-free plots (248.1 g) (Table 1) and in plots treated with pinoxaden @ 50 g/ha (247.4 g) followed by clodinafop @ 60 g/ha (232.9 g). This may be attributed to effective weed control over weed competition. Hence, crop plants could fully utilize the available resources of space, solar radiation, soil moisture and nutrients, resulting in enhanced photosynthesis and more dry weight accumulation (Katara *et al*., 2015). Dry weight by crop with the application of PRE herbicide treatments was lower than PoE herbicides. Lower dry matter was accumu-

Table 1. Influence of fertilizer levels and wild oat management treatments on different growth parameters in wheat (pooled data of 2015–16 and 2016–17).

WMT	Plant height (cm)								Total number of tillers/m				Leaf-area index								Dry matter/plant (g)			
	60 DAS Fertilizer levels (F)				At harvesting Fertilizer levels (F)				At harvesting Fertilizer levels (F)				60 DAS Fertilizer levels (F)				120 DAS Fertilizer levels (F)				At harvesting Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	38.6	42.3	43.2	41.3	84.4	90.2	91.2	88.6	79.4	78.3	72.8	76.8	4.45	4.40	3.88	4.25	3.75	3.70	3.34	3.60	236.5	234.8	226.9	232.7
W_2	35.3	39.3	40.1	38.2	78.8	84.4	85.5	82.9	75.5	74.3	68.4	72.7	4.25	4.14	3.66	4.02	3.55	3.54	3.16	3.42	229.3	227.6	220.3	225.8
W_3	47.1	47.7	49.1	48.0	98.7	99.5	100.8	99.7	84.4	84.7	85.9	85.0	4.64	4.70	4.76	4.70	4.01	4.04	4.01	4.02	245.6	247.0	249.1	247.2
W_4	29.8	33.3	34.6	32.6	68.0	74.6	75.7	72.8	66.5	65.7	59.0	63.7	3.86	3.72	3.30	3.63	3.17	3.16	2.84	3.06	215.8	214.1	204.9	211.6
$W_{5 (PP)}$	29.7	33.2	34.7	32.5	68.1	74.3	75.3	72.5	66.1	65.2	58.0	63.1	3.85	3.67	3.31	3.69	3.16	3.14	2.81	3.04	215.0	213.3	203.9	210.9
$W_{6 (PP)}$	32.9	36.2	37.6	35.6	73.6	78.9	81.1	77.9	72.7	71.5	65.0	69.7	4.06	3.85	3.54	3.82	3.36	3.37	3.04	3.26	223.8	222.1	213.3	219.7
W_7	47.2	48.5	49.7	48.5	98.2	99.9	101.5	99.9	84.5	84.6	86.2	85.1	4.67	4.72	4.97	4.79	4.02	4.06	4.01	4.03	246.2	247.8	249.8	247.9
W_8	26.3	30.5	31.5	29.4	61.5	68.0	69.5	66.3	60.4	59.2	51.9	57.2	3.53	3.39	3.13	3.35	2.95	2.92	2.60	2.82	207.2	205.4	195.2	202.6
Mean	36.4	38.9	39.5	-	79.6	83.7	84.4	-	73.7	72.9	68.4	-	4.16	4.08	3.82	-	3.50	3.49	3.23	-	227.4	226.5	220.4	-
	SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
F	0.3		1.1		0.3		1.3		0.3		1.2		0.03		0.11		0.02		0.07		0.3		1.1	
W	0.4		1.2		0.4		1.2		0.5		1.3		0.03		0.09		0.03		0.07		0.6		1.6	
W at F	0.8		2.2		0.7		2.0		0.8		2.3		0.05		0.15		0.05		0.13		1.0		4.9	
F × W	0.8		2.2		0.7		2.1		0.8		2.3		0.06		0.16		0.05		0.13		1.0		4.7	

F_1, Recommended dose of fertilizer (150: 60: 60 kg/ha); F_2, 110% recommended dose of fertilizer (165: 66: 66 kg/ha); F_3, 120% recommended dose of fertilizer (180: 72: 72 kg/ha); WMT, wild oat management treatments; DAS, days after sowing; W_1, clodinafop @ 60 g/ha; W_2, sulfosulfuron @ 25 g/ha; W_3, pinoxaden @ 50 g/ha; W_4, metribuzin @ 175 g/ha; W_5, pendimethalin @ 1.5 kg/ha; W_6, pendimethalin + metribuzin (1.5 kg/ha); W_7, weed free; W_8, weedy check

Table 2. Grain and straw yield including yield-attributing characters of wheat at harvest as influenced by fertilizer levels and wild oat management treatments in wheat (pooled data of 2015–16 and 2016–17)

WMT	Yield-attributing characters																			
	Grains/spike				Spikelets/spike				Biological yield (q/ha)				Straw yield (q/ha)				Grain yield (q/ha)			
	Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)				Fertilizer levels (F)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
W_1	44.3	44.1	41.6	43.3	20.60	20.47	17.98	19.68	123	121	106	117	73.0	72.7	63.5	69.7	50.1	48.2	42.2	46.8
W_2	43.3	43.1	39.6	42.0	19.92	19.83	17.37	19.04	116	113	98	109	69.9	68.8	59.4	66.0	45.8	44.5	38.5	42.9
W_3	45.1	45.2	45.7	45.3	21.38	21.58	22.17	21.71	130	132	138	133	76.6	77.5	81.7	78.6	53.6	54.4	56.5	54.8
W_4	42.0	41.8	36.9	40.2	18.60	18.45	16.27	17.78	100	96	83	93	61.0	59.2	51.0	57.1	39.1	36.8	32.4	36.1
$W_{5 (PP)}$	41.9	41.6	36.6	40.1	18.50	18.26	15.74	17.57	99	94	82	92	60.9	57.9	50.3	56.7	37.9	35.9	31.9	35.2
$W_{6 (PP)}$	42.4	42.2	38.0	40.9	19.44	19.09	16.76	18.43	108	105	91	101	65.6	63.7	54.8	61.4	42.8	41.5	35.8	40.0
W_7	45.2	44.9	46.1	45.4	21.67	21.88	22.38	21.98	132	132	139	134	77.2	77.7	82.3	79.1	54.4	54.6	56.9	55.3
W_8	40.5	40.3	34.6	38.5	17.02	16.89	15.61	16.50	91	87	74	84	56.9	54.7	46.9	52.9	34.2	32.3	27.5	31.3
Mean	43.1	42.9	39.9	-	19.64	19.56	18.03	-	112	110	101	-	67.6	66.5	61.2	-	44.7	43.5	40.2	-
	SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)		SEm±		CD (P=0.05)	
F	0.10		0.41		0.10		0.40		0.6		2.4		0.6		2.3		0.4		1.6	
W	0.19		0.54		0.11		0.32		1.2		3.4		0.7		1.9		0.7		2.1	
W at F	0.33		0.94		0.20		0.56		2.1		5.9		1.2		3.3		1.3		3.6	
F × W	0.32		0.93		0.21		0.60		2.0		5.8		1.2		3.5		1.2		3.6	

F_1, Recommended dose of fertilizer (150: 60: 60 kg/ha); F_2, 110% recommended dose of fertilizer (165: 66: 66 kg/ha); F_3, 120% Recommended dose of fertilizer (180: 72: 72 kg/ha); WMT, wild oat management treatments; DAS, days after sowing; W_1, clodinafop @ 60 g/ha; W_2, sulfosulfuron @ 25 g/ha; W_3, pinoxaden@ 50 g/ha; W_4, metribuzin @ 175 g/ha; W_5, pendimethalin @ 1.5 kg/ha; W_6, pendimethalin + metribuzin (1.5 kg/ha); W_7, weed free; W_8, weedy check lated by the crop in plots treated with pendimethalin 1.5 kg/ha (202.7 g), followed by PoE application of metribuzin @ 175 g/ha (210.9 g) due to intense competition for various growth resources from weeds, as these were not effectively controlled. These results are in conformity with those of Yadav *et al.,* (2016) and Singh (2020). It is evident from the above discussion that adopting of any weed-control practice enhanced the crop growth over unweeded control and for herbicidal treatments PoE application was superior to Pre- application, because of weed control at the right stage of crop growth period. Overall, hand-weeding was superior to herbicidal treatments because of complete removal of weeds but laborious and costly. Various yield attributes of wheat were significantly affected by different herbicidal treatments.

Crop performance to a great extent is governed by the all the yield parameters. It is, therefore, imperative that if all the yield-attributing parameters were higher, grain yield would be higher. Weed-free and application of pinoxaden @ 50 g/ha recorded significantly higher yield components when compared with rest of the herbicidal treatments but similar to others, viz. grains/spike (45.4 and 45.3) and spikelets/spike (21.9 and 21.7) over weedy check and rest of the herbicide treatments (Table 2). This might be owing to the fact that, the crop has not experienced nutrient stress at any growth stage. The superior performance of weed-free and pinoxaden was owing to effective weed control, crop weed competition was eliminated and crop had a better growing environment and thus resulted in more values of growth parameters and allowed the crop for better establishment and better nutrient uptake. Higher production of photosynthates owing to sufficient assimilatory area of vigorous plants would have synthesized the carbohydrates and translocated to the reproductive parts such as developing spikes and spikelets which resulted in better grain-filling and more grain weight leading to increased yield components. The results are in agreement with the findings of Tesfay *et al.,* (2016) and Sharma *et al.,* (2016).

Grain yield being a complex character, is sum of many morphological and biochemical events which occur during the crop growth and development. The yield per unit land area depends on the total bio-productivity and its partitioning into the economically important parts. The grain yield was significantly more in all the herbicidal treatments as compared to weedy check (Table 2). Significantly higher yield was recorded with weed-free (55.3 q/ha) being on a par with pinoxaden @ 50 g/ha (54.8 q/ha), followed by clodinafop (46.81 q/ha). This could be ascribed to reduction in weed competition and better crop growth by the application of herbicides in sequence killing most of the weed cohorts which helped the crop to utilize nutrients, moisture, light and space more efficiently and thus produced more dry weight, more tillers, more grains/spike and test weight, hence increased grain yield. These findings are in line with those of Bhagat *et al.*, (2017). Weedy check showed significantly lower yield (31.33 q/ha) among all the wild oat management treatments, followed by pendimethalin (35.2 q/ha) and metribuzin (36.1 q/ha). This might be due to high infestation of weeds from initial stages onwards and other herbicides were ineffective to control wild oat. Hence, under stress the crop plants could not grow to their full potential, which ultimately reduced the grain yield to the extent of 53–56% compared to weed-free. Sulfosulfuron, pendimethalin + metribuzin and clodinafop will not be effective as pinoxaden. This was perhaps because all the weed cohorts were not killed by pre- and post-herbicides and hence these weeds continued to grow with the crop plants competing with them for the natural resources and thus resulting in poor crop growth in terms of lower dry weight, lesser number of effective tillers, grains/spike and grains and finally lower grain yields. Similar findings were reported by Anisha (2014).

Straw yield indicates the vegetative growth of crop which influences grain yield to a great extent. Biological yield represents the total biomass produced by the crop during its growth period. Straw yield was affected by various treatments in a similar manner as that of grain yield with the highest straw yield being produced in weed-free and pinoxaden @ 50 g /ha, followed by clodinafop 60 g/ha. This was because of effective control of weeds which provided a favourable environment for the crop to flourish and accumulate more dry weight and hence more straw yield was recorded. Other Pre- and PoE herbicide treatments were found inferior to pinoxaden. Weedy treatment recorded the least straw yield (52.8 q /ha) (Table 2) due to suppression of crop by weeds and hence less dry weight accumulation by the crop. These results are in close conformity with those of Vyavahare and Bhilare (2015).

Economics

Economics is the main parameter which finally decides the adoption levels at farming situations of any newly introduced technology by the farmers. It should be technically and economically viable. Therefore, the economic analysis of the results is very important. Higher net returns were realized with the application of 100% RDF (₹45,782/ha). Higher net returns were owing to the higher gross returns (₹1.02, 690/ha). Higher gross returns and net returns were mainly because of the higher yield of the crop (44.7 q/ha). The higher net returns and gross returns also resulted in higher benefit : cost ratio (1.80). Application of 120% RDF showed lower value in the net returns (₹34,196 /ha) mainly because of the low yields (40.2 q/ha) and gross returns (₹92,520/ha) and also higher cost of cultivation of

Table 3. Economic analysis as influenced by fertilizer levels and wild oat management treatments in wheat cultivation (pooled data of 2015–16 and 2016–17)

WMT	Economic analysis															
	Cost of cultivation (₹)				Gross returns (₹)				Net returns (₹)				Benefit : cost ratio			
	Fertilizer levels (F)			Mean	Fertilizer levels (F)			Mean	Fertilizer levels (F)			Mean	Fertilizer levels (F)			Mean
	F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3		F_1	F_2	F_3	
W_1	55,509	56,082	56,655	56,082	11,3841	110,625	96,747	107,071	58,332	54,543	40,092	50,989	2.05	1.97	1.71	1.91
W_2	55,504	56,077	56,650	56,077	1,05,398	102,892	89,026	99,105	49,894	46,815	32,375	43,028	1.90	1.83	1.57	1.77
W_3	56,356	56,930	57,503	56,930	1,21,267	122,856	128,102	124,075	64,910	65,926	70,599	67,145	2.15	2.16	2.23	2.18
W_4	54,969	55,543	56,116	55,543	90,567	86,011	75,239	83,939	35,598	30,469	19,123	28,397	1.65	1.55	1.34	1.51
$W_{5 (PP)}$	56,906	57,479	58,053	57,479	88,398	83,964	74,159	82,174	31,492	26,484	16,106	24,694	1.55	1.46	1.28	1.43
$W_{6 (PP)}$	57,417	57,990	58,563	57,990	98,653	95,707	82,532	92,297	41,236	37,717	23,968	34,307	1.72	1.65	1.41	1.59
W_7	60,066	61,071	63,370	61,502	122,786	123,366	129,069	125,074	62,720	62,296	65,699	63,572	2.04	2.02	2.04	2.03
W_8	58,538	59,111	59,685	59,111	80,608	76,482	65,288	74,126	22,070	17,371	5,604	15,015	1.38	1.29	1.09	1.25
Mean	56,908	57,535	58,324	-	102,690	100,238	92,520	-	45,782	42,703	34,196	-	1.80	1.74	1.58	-

F_1, Recommended dose of fertilizer (150: 60: 60 kg/ha); F_2, 110% recommended dose of fertilizer (165: 66: 66 kg/ha); F_3, 120% Recommended dose of fertilizer (180: 72: 72 kg/ha); WMT, wild oat management treatments; DAS, days after sowing; W_1, clodinafop @ 60 g/ha; W_2, sulfosulfuron @ 25 g/ha; W_3, pinoxaden @ 50 g/ha; W_4, metribuzin @ 175 g/ha; W_5, pendimethalin @ 1.5 kg/ha; W_6, pendimethalin + metribuzin (1.5 kg/ha); W_7, weed free; W_8, weedy check

the crop in 120% RDF (₹58,324/ha) (Table 3). These are result is also in accordance with findings of James and Lowell (1982) for fertilizer levels.

The weedy check had lower benefit : cost ratio (0.52) than weed-free and pinoxaden @ 50 g/ha (2.03 and 2.18), the main reason for this was the yield levels. Higher yield was noticed in the weed-free and pinoxaden @ 50 g/ha (55.3 and 54.8 q/ha) than weedy check (31.3 q/ha). Pendimethalin (1.5 kg/ha) and metribuzin @ 175 g/ha showed the lowest benefit : cost ratio (1.43 and 1.51, respectively) among the rest of treatments; however main reason for lower benefit : cost ratio was the cost of cultivation (₹57,479 and ₹55,543) and poor yield levels, because of cost of herbicide as well as the amount of herbicide was high in both the treatments and poor weed-control efficiency by was also recorded. The above results are similar to earlier findings by Dev *et al.,* (2014) and Ahmedvand *et al.,* (2016).

Experimental finding indicates that increasing levels of fertiliser application not always contributes to yield enhancement of target crop, as it also has simultaneous positive effect on weed growth. A proper combination of weed management along with balanced dose of fertilizer could significantly enhance the crop yield and productivity by controlling weed population. Application of proper dose of pinoxaden or maintaining a weedy check condition along with RDF could be beneficial for overall improvement productivity of wheat. As maintaining weedy check condition could be labour intensive sometimes and injudicious application of pinoxaden in a way could be unsustainable for a crop production system, maintenance of balance between the two is essential in a long-term for a sustainable as well as eco-friendly weed management system.

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