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Research Paper

Productivity of winter (*rabi*) onion (*Allium cepa*) as influenced by sole and sequential application of herbicides

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ABSTRACT

A field experiment was conducted during the winter (*rabi*) seasons of 2014–15 and 2015–16 to study the effect of sole and sequential application of different herbicides on weed control in onion (*Allium cepa* L.). Sequential application of pendimethalin @ 750 g/ha at 3 days after transplanting (DAT) + oxyfluorfen @ 100 g/ha at 20 DAT controlled the grasses, sedges and broad-leaf weeds most efficiently and was at par with oxadiargyl @ 90 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT. Weed competition resulted in about 54.8% yield loss of onion in weedy check plot. The lowest values of total weed density (18.6/m^2), dry weight (6.8 g/m^2), weed index (6.2%) and the highest values of weed control efficiency (89.2%), bulb yield (21.89 t/ha) and benefit: cost ratio (2.84) were registered with sequential application of pendimethalin @ 750 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT. In weedy check, weeds removed 23.9 kg N, 3.8 kg P and 27.6 kg K/ha.

Key words : Onion, Oxadiargyl, Oxyfluorfen, Pendimethalin, Quizalofop ethyl, Sole application, Sequential application, Weed-control efficiency

Onion occupies an important place as a commercial crop in India. It occupies an area of 1.2 million ha with a production of 19.4 million tonnes and productivity of 16.12 tonnes/ha. In Odisha, it covers an area of 35.8 thousand ha with a production of 432 thousand tonnes and productivity of 12.07 tonnes/ha (DES 2016), which is 43.7% less than the national average. It is highly vulnerable to weed infestation due to its slow initial growth, non branching habit, upright leaves, shallow root system, frequent irrigation and high fertilizer requirement. Manual weeding is very difficult due to narrow row spacing (15 cm × 10 cm) of this crop, besides non availability of labours and increased cost involved in it. Yield loss due to weed infestation in onion is to the tune of 40–80% (Channappagoudar and Biradar, 2007). Therefore the farmers are resorting to chemical weed control, which is found to be cheaper than manual weeding. The common chemical weed management practices for onion is pre-emergence application of selective herbicides like pendimethalin, oxadiargyl, butachlor and oxyfluorfen followed by one or two hand weedings. Pre-emergence herbicides have been found effective during initial growth period. However, late emerging broad-leaved weeds hinder bulb development and create problem during harvesting operation. Hence an attempt was made to study the effect of sole and sequential application of different herbicides on weed growth, productivity, nutrient removal and economics of winter (*rabi*) onion.

MATERIALS AND METHODS

A field experiment was carried out at Regional Research and Technology Transfer Station, Orissa University of Agriculture and Technology, Chiplima, Sambalpur, Odisha during winter (*rabi*) 2014–15 and 2015–16. The soil of the experimental field was sandy clay loam with *p*H 6.6, organic carbon 0.43% and available N ($KMnO_4$ method), P (Olsen) and K (NH_4OHC method) content of 230, 10.4 and 158 kg/ha, respectively. Eight treatments consisting of pendimethalin @ 750 g/ha at 3 days after transplanting (DAT); oxadiargyl @ 90 g/ha at 3 DAT; pendimethalin @ 750 g/ha at 3 DAT + oxyflurofen @ 100 g/ha at 20 DAT; oxadiargyl @ 90 g/ha at 3 DAT + oxyflurofen @ 100 g/ha at 20 DAT; pendimethalin @ 750 g/ha at 3 DAT + quizalofop ethyl @ 50 g/ha at 20 DAT; oxadiargyl @ 90 g/ha at 3 DAT + quizalofop ethyl @ 50

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g/ha at 20 DAT; weed free and weedy check were tried in a randomized block design with 3 replications. Onion 'Nasik red' (N-53) was sown in nursery on 2 October and 15 October during 2014 and 2015 and harvested on 15 March and 25 March during 2015 and 2016, respectively. The crop was planted in the main field at a spacing of 15 cm × 10 cm in the plot of size 3 m × 2 m. A uniform recommended dose of N: P: K (120:26.4:83.3 kg/ ha) was applied to all the plots. Full dose of P along with 50% N and 50% K were applied as basal to the onion crop. Rest 50% of both N and K were applied after 3 and 6 weeks after transplanting in 2 equal splits. Pre and post-emergence herbicides were applied as per treatments by knapsack sprayer fitted with flat fan nozzle using a water volume of 500 litre/ha. Nine irrigations were given approximately at 10 days interval and last irrigation was given 20 days before harvest. Plant protection measures were taken as per need of the crop. All other cultural operations were carried out as per the scientific recommendations. Data were recorded on weed growth (density and biomass) at 50 DAT; yield attributes and yields at harvest

Weed density (numbers/m^2), and weed dry weight (g/m^2) were taken from random samples at 2 places in the field with the help of 1 m^2 quadrate at 50 DAT. The weed samples collected in paper bags were air dried in shade initially followed by oven drying at 65 °C for 48 h or till they attain constant weight to determine dry-matter in g/m^2. Data on individual and total weed density and weed dry-weight were subjected to square root transformation $\sqrt{x+0.5}$. Weed-control efficiency (WCE) and weed index (W.I.) were calculated based on the weed dry-matter and onion bulb yield, respectively.

The weed samples collected at 50 DAT were dried at 65 °C, powdered in Willey mill and digested to analyze the various nutrient compositions. The nitrogen, phosphorus and potassium content in weeds were estimated by Kessler's reagent method (Nicholas and Nason, 1957), HNO_3: $HClO_4$ (9:4) digestion, colour development by Vanadomolybdate solution followed by spectrophotometer determination (Jackson, 1973), flame photometric determination after digestion in HNO_3: $HClO_4$ (9:4) (Jackson, 1973), respectively. The nutrient uptake was estimated by multiplying the nutrient concentration with weed biomass.

The uprooting of the bulbs was done manually in this study. After harvest, the bulbs were cured under shade and then leaves were cut 1-2 cm above the bulb and the bulb yield (t/ha) was recorded. The yield attributes and yield data recorded from net plot at harvest. The cost of cultivation, net returns and benefit:cost ratio was calculated based on local market prices.

RESULTS AND DISCUSSION

Effect on weed

Weed flora in weedy check plots mostly consisted of *Echinochloa colona* (L.) Link., *Digitaria sanguinalis* (L.) Scop., *Datyloctenium aegyptium* (L.) Willd., *Brachiaria reptans* Gard. and Hubb., among the grasses; *Cyperus rotundus* L., *Cyperus difformis* L. among the sedges and *Chenopodium album* L., *Celosia argentea* L., *Euphorbia hirta* L., *Euphorbia thymifolia* L., *Amaranthus spinosus* L., *Digera arvensis* Forssk, *Convolvulus arvensis* L. among the broad-leaf weeds during both the years of study. The composition of grasses, sedges and broad-leaf weeds in weedy check plot was 38.1, 36.7 and 25.2%, respectively.

All the weed management practices showed significant reduction in total weed density and dry-weight as compared to weedy check during both the years (Table 1). Sequential application of pendimethalin @ 750 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT recorded the lowest total weed density and dry weight (18.6/m^2, 6.8 g/m^2), which was close to oxadiargyl @ 90 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT (25.2/m^2, 9.1 g/m^2). Sole application of herbicides at 3 DAT recorded higher weed density, which might be due to lesser efficiency of pre-emergence herbicides to suppress the weeds for longer period as ascertained by presence of new flushes of weeds at later stages. On the other hand, lesser weed density under sequential application of herbicides was due to control of the late – emerging weeds. These results were in agreement with those of Kolhe, (2001) and Warde *et al.* (2006).

Sole application of pendimethalin or oxadiargyl had a medium range of weed control effect, i.e. it was more than weedy check and less than sequential application of herbicides. Pendimethalin @ 750 g/ha was more effective in control of total weed density (52.8/m^2) than that of oxadiargyl (61.7/m^2)

Weed-control efficiency of pendimethalin and oxadiargyl when applied alone was 68.8 and 55.1%; while their corresponding figures on sequential application with oxyfluorfen was 89.2 and 85.5%, respectively. This showed all the sequential applications were effective in reducing weed biomass, which increased their efficiency over sole application. The results were well collaborating with the findings of Kathiresan *et al.* (2004).

Data on weed index showed that the least yield reduction (6.2%) was recorded with pre-emergence application of pendimethalin @ 750 g/ha followed by oxyfluorfen @ 100 g/ha at 20 DAT, where as yield reduction varied from 34.8 to 40.1% in the sole herbicide applied plots as compared to weed free treatment. The weed index was lower in all the treatment as compared to weedy check.

Table 1. Effect of pre- and post-emergence herbicides on weed density and dry-matter production, weed-control efficiency at 50 days after planting and weed index in *rabi* onion (pooled data of 2 years)

Treatment	Weed density (Nos./m^2)				Weed dry matter production (g/m^2)					
	Grasses	Sedges	Broad-leaved	Total	Grasses	Sedges	Broad-leaved	Total	WCE (%)	WI (%)
Pendimethalin 750 g/ha at 3 DAT	3.5 (11.5)	3.5 (11.7)	5.5 (29.6)	7.3 (52.8)	2.5 (5.5)	2.3 (4.6)	3.2 (9.5)	4.5 (19.6)	68.8	34.8
Oxadiargyl 90 g/ha at 3 DAT	2.3 (5.0)	3.4 (11.1)	6.8 (45.6)	7.9 (61.7)	2.7 (6.6)	2.5 (5.6)	4.1 (16.0)	5.4 (28.2)	55.1	40.1
Pendimethalin 750 g/ha at 3 DAT + oxyflurofen 100 g/ha at 20 DAT	2.0 (3.6)	2.0 (3.5)	3.5 (11.5)	4.4 (18.6)	1.5 (1.7)	1.4 (1.4)	2.0 (3.7)	2.7 (6.8)	89.2	6.2
Oxadiargyl 90 g/ha at 3 DAT + oxyflurofen 100 g/ha at 20 DAT	2.1 (4.1)	2.3 (4.8)	4.1 (16.4)	5.1 (25.2)	1.6 (2.0)	1.5 (1.9)	2.4 (5.2)	3.1 (9.1)	85.5	15.4
Pendimethalin 750 g/ha at 3 DAT + quizalofop ethyl 50 g/ha at 20 DAT	2.3 (4.6)	2.6 (6.1)	4.7 (21.2)	5.7 (31.9)	1.7 (2.2)	1.7 (2.4)	2.7 (6.8)	3.5 (11.4)	81.8	18.3
Oxadiargyl 90 g/ha at 3 DAT + quizalofop ethyl 50 g/ha at 20 DAT	3.0 (8.3)	3.2 (9.8)	5.4 (29.0)	6.9 (47.1)	2.1 (4.0)	2.1 (3.9)	3.1 (9.3)	4.2 (17.2)	72.6	24.3
Weed free	0.7 (0.0)	0.7(0.0)	0.7 (0.0)	0.7(0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	100	0.0
Weedy check	7.7 (58.5)	7.5(56.4)	6.2 (38.5)	12.4(153.4)	5.4 (28.3)	4.8 (22.2)	3.6 (12.4)	7.9 (62.8)	0.00	54.8
SEm ±	0.13	0.26	0.20	0.31	0.11	0.19	0.14	0.22		
CD (P=0.05)	0.38	0.78	0.61	0.92	0.32	0.58	0.41	0.65		

DAT, Days after transplanting; Figure in parentheses refer to original values and outside values subject to square root transformation ($\sqrt{x+0.5}$); WCE, weed-control efficiency; WI, weed index

Yield attributes and yield

All the weed management treatments showed significantly higher values of yield attributes and yield over the weedy check due to less competition for moisture, light and nutrient. Yield parameters like plant height (48.6 cm), bulb length (8.1cm) and bulb diameter (6.3 cm) and bulb weight (84.36 g) were the highest under weed free treatments, which were at par with herbicidal treatment of pendimethalin @ 750 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT and significantly superior to sole application of pendimethalin @ 750 g/ha at 3 DAT (Table 2). Neck thickness did not vary significantly among the treatments. Weed infestation caused 54.8% reduction in mean bulb yield of onion. Similar yield reduction in onion due to weed competition was also reported by Murthy *et al.* (2008). Sequential application of pendimethalin @ 750 g/

Table 2. The effect of different weed management practices on yield attributes and yield of *rabi* onion (pooled data of 2 years)

Treatment	Plant height (cm)	Bulb length (cm)	Bulb diameter (cm)	Neck length (cm)	Neck thickness (cm)	Bulb weight (g)	Bulb yield (t/ha)		
							2014–15	2015–16	Pooled
Pendimethalin 750 g/ha at 3 DAT	35.9	4.9	4.5	5.42	1.26	48.93	12.88	17.54	15.21
Oxadiargyl 90 g/ha at 3 DAT	33.4	4.8	4.4	5.50	1.28	48.17	11.28	16.65	13.97
Pendimethalin 750 g/ha at 3 DAT + oxyflurofen 100 g/ha at 20 DAT	45.3	6.8	5.9	5.98	1.39	78.18	20.81	22.97	21.89
Oxadiargyl 90 g/ha at 3 DAT + oxyflurofen 100 g/ha at 20 DAT	42.8	5.9	5.3	5.76	1.34	70.34	18.13	21.32	19.73
Pendimethalin 750 g/ha at 3 DAT + quizalofop ethyl 50 g/ha at 20 DAT	41.9	5.8	5.1	5.72	1.33	65.69	17.89	20.21	19.05
Oxadiargyl 90 g/ha at 3 DAT + quizalofop ethyl 50 g/ha at 20 DAT	38.6	5.1	4.6	5.63	1.31	52.77	16.15	19.21	17.68
Weed free	48.6	8.1	6.3	6.24	1.45	84.36	23.11	23.54	23.33
Weedy check	32.4	3.6	3.3	5.42	1.26	37.93	9.22	11.87	10.55
SEm±	1.39	0.29	0.31	0.22	0.07	6.42	1.30	1.20	1.00
CD (P=0.05)	4.17	0.88	0.92	0.67	NS	19.31	3.90	3.60	3.00

DAT, Days after transplanting

ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT (21.89 t/ha) yielded at par to weed free treatment (23.33 t/ha). Effective and timely weed management under this treatment reduced the density as well as dry-weight of weeds which facilitated the crop plants to have sufficient space, light, nutrient and moisture and thus recorded increased plant height, bulb diameter, bulb length, bulb weight and finally the yield. Weedy check recorded the lowest bulb yield (10.55 t/ha) due to presence of more weeds, which interfered with growth and development of the crop and compete for nutrients, moisture, light and space. The results were in close conformity with those by Ved *et al.* (2000) and Patel *et al*. (2012).

Correlation analysis

The bulb yield was negatively correlated with the total weed density (r = -0.920) and total weed biomass (r= -0.925) (Fig. 1 and 2). The linear relationships between weed density (N) and bulb yield (Y), and weed dry-weight (W) and bulb yield (Y) of onion are given here as under, equation (1) and (2) respectively.

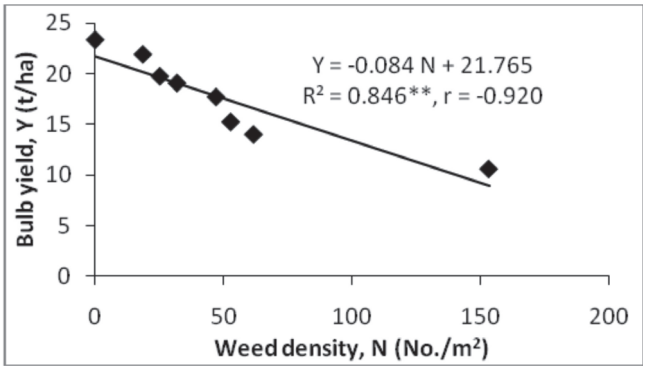

Fig. 1. Effect of weed density on bulb yield of onion

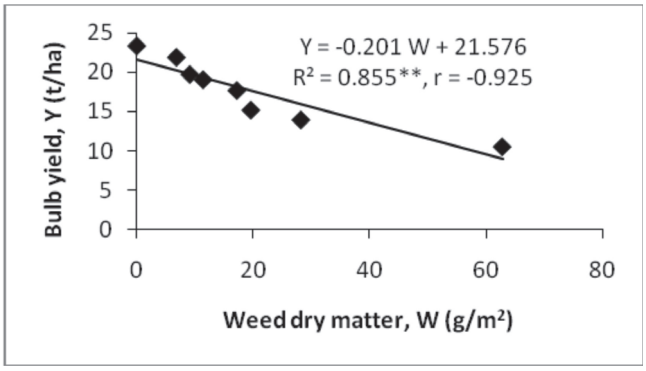

Fig. 2. Effect of weed dry matter on bulb yield of onion

$Y = 21.765 - 0.084\ N$ ($R^2 = 0.846^{**}$) …(1)

$Y = 21.576 - 0.201W$ ($R^2 = 0.855^{**}$) …(2)

Both the regressions were highly significant (P = 0.01) with high values of coefficient of determination (R^2). It is evident from equation (1) that 84.6% of variation in bulb yield could be explained by weed density and the decrease in yield per unit increase in weed density is estimated to be 0.08 t/ha. Similarly from equation (2), it may be inferred that 85.5% of variation in bulb yield could be explained by weed dry-weight with every unit increase in weed dry-weight, the bulb yield of onion was expected to decrease by 0.2 t/ha.

Nutrient removal

The N, P and K removal by weeds was significantly influenced by various weed management practices (Table 3). Nutrient removal by weeds was zero in weed free plot, followed by pendimethalin @ 750 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT. However, the highest removal of 23.9 kg N, 3.8 kg P and 27.6 kg K/ha was re-

Table 3. Influence of weed management practices on nutrient removal by weeds and economics of *rabi* onion (pooled data of 2 years)

Treatment	Nutrient removal by weeds (kg/ha)			Cost	Net returns	Benefit:
	N	P	K	(× 10^3₹/ha)	(× 10^3₹/ha)	cost ratio
Pendimethalin 750 g/ha at 3 DAT	3.2 (9.6)	1.5 (1.8)	3.6 (12.8)	81.6	146.6	1.79
Oxadiargyl 90 g/ha at 3 DAT	3.7 (13.5)	1.7 (2.3)	4.3 (18.0)	77.4	132.2	1.71
Pendimethalin 750 g/ha at 3 DAT + oxyflurofen 100 g/ha at 20 DAT	1.9 (3.1)	1.1 (0.6)	2.7 (6.8)	85.6	242.8	2.84
Oxadiargyl 90 g/ha at 3 DAT + oxyflurofen 100 g/ha at 20 DAT	2.1 (4.0)	1.1 (0.8)	2.6(6.3)	93.0	203.0	2.18
Pendimethalin 750 g/ha at 3 DAT + quizalofop ethyl 50 g/ha at 20 DAT	2.4 (5.1)	1.2 (0.9)	2.9(7.9)	84.0	201.8	2.40
Oxadiargyl 90 g/ha at 3 DAT + quizalofop ethyl 50 g/ha at 20 DAT	2.8 (7.6)	1.4 (1.4)	3.5(11.7)	88.0	177.2	2.01
Weed free	0.7 (0.0)	0.7 (0.0)	0.7(0.0)	106.0	244.0	2.30
Weedy check	4.9 (23.9)	2.1 (3.8)	5.3(27.6)	77.2	81.1	1.05
SEm±	0.11	0.05	0.14	2.4	3.2	0.22
CD (P=0.05)	0.32	0.14	0.41	6.9	9.2	0.63

DAT, Days after transplanting; Data subjected to square root transformation ($\sqrt{x+0.5}$); original values are in parentheses

corded in weedy check plot. Among sole application of herbicides, significantly higher value of NPK uptake was noticed in the treatment oxadiargyl @ 90 g/ha followed by pendimethalin @ 750 g/ha over weedy check plot and were found superior to sequential application of herbicides. It is well augmented that the weeds should be eradicated in two stages of crop growth. Any negligence in weed removal deprived the crop of its share (Sable *et al.*, 2013).

Economics

The highest net monetary returns ₹242.8 × 10^3/ha was obtained with application of pendimethalin @ 750 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT with benefit: cost ratio of 2.84 (Table 3). Though weeds were controlled more effectively and bulb yield was the highest in weed free treatment, but its cost of cultivation was high (₹106.0 × 10^3/ha) because of the higher human labour engagement and labour wage. The engagement of human labours for controlling weeds was reduced with application of pre and post-emergence herbicides, which was responsible for reduction in total cost of cultivation, resulting higher B: C ratio. Similar findings were also reported by Patel *et. al.* (2011)

It was concluded that chemical weed control is beneficial over manual weed control and the highest bulb yield and maximum economic returns in winter (*rabi*) onion were obtained with pre-emergence application of pendimethalin @ 750 g/ha at 3 DAT + oxyfluorfen @ 100 g/ha at 20 DAT, besides obtaining broad spectrum weed control throughout the crop growth period.

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