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RESEARCH ARTICLE

Evaluation of chemical and non-chemical weed control methods in onion: An integrated weed management approach

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Abstract

An integrated weed management experiment was conducted to compare the efficacy of chemical and non-chemical weed management methods in onion under the All India Network Research Project on Onion and Garlic. The three-year combined results revealed that all the weed management methods significantly influenced weed density. The lowest monocot, dicot, total weed population, weed biomass and highest weed control efficiency were recorded in treatment Plastic mulch. The highest bulb equatorial diameter (5.87 cm), polar diameter (4.32 cm), gross yield (317.63 q/ha) and marketable yield (267.34 q/ha) were recorded in treatment Plastic mulch. However, the highest benefit: cost ratio (2.89:1.0) was recorded in herbicidal treatment oxyflurofen 23.5% EC @ 1.5 mL/l at pre-transplanting + one hand weeding at 30 DAT + Quizalofop Ethyl 5% EC application at 60 DAT. Due to heavy infestation of weed competition, poor growth and development were recorded in treatment un-weed check results 49.0 to 88.80% yield reduction.

Keywords: Organic mulch, Oxyflurofen, Pendimethalin, Polythene mulch, Quizalofop Ethyl.

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Introduction

Onion (*Allium cepa* L.) is an important commercial bulbous vegetable crop widely cultivated worldwide. The importance of onion cultivation is of its characteristic flavor and high nutritional and medicinal values (Gupta and Bhasker, 2020) and is an indispensable item in every kitchen used as salad, culinary purposes for flavoring as spices in pickles and sauce. India is a leading country in area and production after China, but the average productivity is 18.27 MT/ha (National Horticultural Research and Development Foundation database - NHRDF, 2019), which is very low as compared to other onion-producing countries due to several constraints, one of the major plant protection constraints is weed infestation. Onion has poor competitive power against weeds during the vegetative since its initial slow growth, shallow root system, smaller cylindrical upright leaves and lack of adequate foliage due to being very susceptible to weeds and considerably reducing plant growth and development (Smith et al., 2008). The weeds compete with onions for light, nutrients, water, and space and also provide shelter to several harmful pathogenic pests and insects (Smith et al., 2008; Boyham et al., 2016). Due to this, yield loss has been estimated at 40 to 58% is much higher than those caused by diseases and insect pests (Channapagoudar

& Biradar, 2007) or even ranging from 49-86% depending upon the type and intensity of weed flora (James & Harlen, 2010). The critical period of onion for weed competition ranges from 20 DAT to 60 DAT, which is the prime factor that decides the growth and yield. Therefore, weed management is order imperative as it plays a vital role in good onion production. Many methods are available that can be controlled effectively, like the manual weeding method is very effective and recorded significantly higher biomass due to the least crop weed competition (Islam et al., 2020), but it is very expensive, tedious and time demand and also may cause bulb injury. Under such situations, alternative integrated weed management strategies have shown good promise for better control of weeds in the advancement of agriculture and technology.

The chemical weed management approach is the most widely used and very effective. Numerous experiments have been conducted and have indicated that many herbicides can be used effectively and selectively to control the weeds in onions (Vishnu et al., 2015; Islam et al., 2020). Using herbicides alone, in combination with manual weeding, showed better weed control efficiency and maximum yield (Islam et al., 2020). Pre-emergent herbicide application would control early-season broad-leaved weed during the initial stages of crop weed competition. At the same time, the treatment may not be effective long enough to control the weed. Later stages of crop require hand weeding or application of post-emergence herbicides may be needed to control the pre and post-emerged weed population effectively (Panse et al., 2014). Mulching is a process of covering the transplanting area of soil with natural or synthetic materials, which continues throughout the cropping period. Mulching decreases soil water evaporation, maintains uniform soil moisture, and inhibits weed growth. The synthetic mulches were successfully implemented in different crops like brinjal (Shweta et al., 2018), tomato (Jia et al., 2020), etc. The organic mulches of different crop straws like rice, sunflower, sugarcane, soybean, and others can be used as natural mulching materials, which significantly reduce the weed population (Nwosisi et al., 2019; Kaur et al., 2020). The final choice of any weed control method implementation in the field totally depends on its effectiveness and economic returns. Each method has its own merits and demerits because a wider range of weeds occur and differ in their growth habit and life cycles. In this aspect, the application of new and wide-spectrum herbicides alone or integrated with hand weeding, plastic mulches, and organic mulch have been implemented in weed management of onion as a chemical and non-chemical approach. Hence, the present investigation was undertaken to find out the appropriate combination of chemical and non-chemical weed management practices and to study the impact of integrated weed management in onion, which is economically viable.

Materials and Methods

The present investigation was carried out at the research farm of RRS, NHRDF, Nashik (Maharashtra) during *rabi,* 2016-17, 2017-18 and 2018-19 under the All India Network Research Project on Onion and Garlic (AINRPOG). The experimental site is located at an altitude of about 492 m mean sea level, a latitude of 20′ N, and has longitude of 73° 57′ E. The onion variety used in this experiment, Agrifound Light Red, which was developed and released by NHRDF. The experiment was laid out in a randomized block design with six treatments replicated four times. The 55-day-old seedlings were transplanted in the irrigation system as the method of Bhasker et al. (2018) and the plot size was 5.10 × 1.2 m with spacing of 15 cm row to row and 10 cm plant to plant. The seedlings were transplanted and harvested on dated 29.12.2016 & 11.04.2017, 03.01.2017 & 21.04.2018 and 19.12.2018 & 10.04.2019 during *rabi,* 2016-17, 2017-18 and 2018-19 respectively. The soil of the experimental area was black and heavy clay with pH (7.60), EC (0.13 dS/m), organic carbon (0.75 mg/g), available N (374.0 kg/ha), P (84.45 kg/ha), K (447.0 kg/ha) and S (19.77 kg/ha). The meteorological data of three consecutive years of experimental site during the cropping period has given in Table 1. Three herbicides include pre-emergence herbicide pendimethalin [N-(1-ethylpropyl)-3, 4-dimethyl 1-2, 6 dinitro benzenamine], pre- and post-emergence herbicide oxyfluorfen [2-chloro-4 (trifloromethyl) phenyl-3-oxy-4- nitrophenol ether] and post-emergence herbicide quizolofop ethyl [(R)-2-[4-(6-chloroquinoxaline -2- phenoxy] ethyl propionate] were made in different combinations. The treatments include T_1 - Oxyflurofen 23.5% EC @ 1.5 mL/l at pre-transplanting + one hand weeding at 60 DAT; T_2 - Oxyflurofen 23.5% EC @ 1.5 mL/l at pre-transplanting + one hand weeding at 30 DAT + Quizalofop Ethyl 5% EC application at 60 DAT; T_3 - Pendimethalin 30% EC @ 1.5 mL/l at pre-transplanting + one hand weeding at 30 DAT + Quizalofop Ethyl 5% EC application at 60 DAT; T_4 - Organic mulch (Soybean straw); T_5 - Plastic mulch (Silver and black); T_6 – Un weed check control (No manual weeding and no herbicide application throughout cropping period - kept as control). The herbicide doses were made as a tank mixture and applied to the onion crop two times; the first application was done at pre-transplanting and the second application was done at 60 DAT after one hand weeding. In the treatment of plastic mulch, the black and silver plastic mulch with a thickness 20 microns was spread over on raised beds with black shade downside on which the seedlings holes were made manually with distance 15×10 cm, whereas in the treatment of organic mulch, 15 DAT of seedlings soybean straw was spread by hand in 6 cm thickness as carpet over a raised bed in between row spaces in respective treatment.

The observations on weed density counted based on a quadrate of size 1.0 m × 1.0 m was placed randomly at three

Table 1: Agro-meteorological data of experimental area during the crop growing season rabi 2016-17, 2017-18 and 2018-19

Months	*Rabi 2016-17*					*Rabi 2017-18*					*Rabi 2018-19*				
	Temp. (ºC)		*RH (%)*		*Rain fall (mm)*	*Temp. (ºC)*		*RH (%)*		*Rain fall (mm)*	*Temp. (ºC)*		*RH (%)*		*Rain fall (mm)*
	Max.	*Min.*	*Max.*	*Min.*		*Max.*	*Min.*	*Max.*	*Min.*		*Max.*	*Min.*	*Max.*	*Min.*	
December	25.64	7.73	53	31	-	24.50	8.75	64	41	6.0	22.42	7.59	57.29	40.95	
January	25.04	7.02	56	32	-	25.75	9.10	56	36	-	23.72	6.26	50.80	30.84	-
February	28.10	9.91	48	28	-	29.30	9.91	50	32	-	27.64	9.80	44.43	28.87	-
March	30.06	14.16	40	23	-	30.06	16.20	40	25	-	31.02	12.50	34.52	20.43	-
April	34.67	16.88	37	22	-	27.5	12.61	29	18	-	36.12	17.67	33.32	17.68	1.0
May	35.65	19.95	47	30	26.8	30.77	17.81	32	20	-	35.13	19.67	37.72	23.36	-

Table 2: Efficacy of different weed control methods on monocot and dicot weed population in onion

Treatment	*Monocot population (m²)*				*Dicot population (m²)*				*Total weed population count (m²)*			
	2016-17	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*
Oxyflurofen + 1 HW at 40-60 DAT	9.13 (3.10)	18.27 (25.14)	17.79 (24.39)	18.03 (24.77)	3.85 (2.08)	3.85 (2.08)	5.76 (2.46)	4.80 (12.47)	12.98 (5.18)	22.12 (27.22)	23.55 (26.85)	22.83 (37.24)
Oxyflurofen + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	13.46 (3.74)	22.12 (28.04)	18.21 (24.72)	20.16 (26.38)	1.44 (1.39)	2.40 (1.70)	3.37 (1.95)	2.89 (9.68)	14.9 (5.13)	24.52 (29.74)	21.58 (26.67)	23.05 (36.06)
Pendimethalin + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	13.46 (3.74)	16.83 (24.18)	15.38 (22.58)	16.10 (23.38)	4.81 (2.30)	2.40 (1.70)	3.37 (1.95)	2.89 (9.68)	18.27 (6.04)	19.23 (25.88)	18.75 (24.53)	18.99 (33.06)
Plastic mulch	0.0 (0.71)	0.0 (0.71)	4.33 (10.33)	2.16 (5.17)	0.0 (0.71)	0.0 (0.71)	2.40 (1.69)	1.20 (4.40)	0.0 (1.42)	0.0 (1.42)	6.73 (12.02)	3.36 (9.57)
Organic mulch	2.88 (1.84)	5.29 (12.53)	9.14 (16.89)	7.21 (14.71)	3.85 (2.08)	6.25 (2.58)	7.21 (2.69)	6.73 (14.71)	6.73 (3.92)	11.54 (15.11)	16.35 (19.58)	13.94 (29.42)
Weedy check	3.37 (1.97)	40.87 (39.72)	32.42 (34.68)	36.65 (37.20)	16.83 (4.16)	12.50 (3.58)	20.19 (4.49)	16.34 (23.50)	20.2 (6.13)	53.37 (43.3)	52.61 (39.17)	52.99 (60.7)
S.E.m±	0.03	2.05	3.87	2.19	0.04	0.19	0.41	1.44	0.07	2.24	4.28	3.63
LSD (p=0.05)	0.06	4.37	8.25	4.47	0.09	0.40	0.87	2.93	0.15	4.77	9.12	7.4

Figures in the parentheses shows arcsin transformed values

sites per plot and weeds growing within this quadrate were counted, fresh weeds biomass and dry weeds biomass collected from one m² area. Fresh weeds were first dried under the sun and then kept in in electric oven at 66°C for 72 ± hr until a constant weight was achieved. Weed control efficiency (WCE) was calculated by using a formula of Gill & Vijayakumar (1969) and expressed in percentage i.e. WCE $= \frac{DW1 - DW}{DW1} \times 100,$ where; DW_1 is dry weight of un-weeded control and DW is a dry weight of treatments. Visual phytotoxicity symptoms due to herbicide impact on onion leaves were evaluated after 3, 7, 12 and 15 days after post-emergent application of respective herbicide treatments. The data for growth parameters were recorded at 80 DAT and yield attributing parameters and net production value were recorded after crop harvest. Data on various characters were statistically subjected to analysis of variance (ANOVA) and the means were separated by using LSD test at a 5% level of significance. The three years of data obtained were combined through the statistical software IBM SPSS package.

Results and Discussion

Effects on weed population and weed biomass

The most abundant weed species observed in the experimental area i.e. sedge - *Cyperus rotundas*, monocot weeds – *Cynodon dactylon*, *Dinebra retroflexa*, *Commelina banghalensis*, *Echinochloa colona* and dicot weeds - *Euphorbia hirta*, *Amaranths viridis*, *Parthenium hysterophorous*, *Portulaca oleracea*, *Physalis minima*, *Scoparia dulcis*, *Chenopodium album* and *Convolvulus arvensis*. The predominant weed is *Cyperus rotundas* from sedge, *Cynodon dactylon* from monocot and *Portulaca oleracea* and *Scoparia dulcis* form dicot weed. All the chemical and non-chemical weed management methods are significantly effective in controlling the weed population as compared with un-weeded control checks. The lowest weed population count of monocot (2.16/ m^2), dicot (1.20/m^2) as well as total weed population (3.36/m^2) were recorded in treatment plastic mulch. Among all the treatments, plastic mulch achieved the highest weed density depression results with no monocot and dicot weed population during the first and second seasons, while during the third season, lowest weed density of monocot (4.33/m^2), dicot (2.4/m^2) and total weed population count (6.73/m^2) were recorded (Table 2). The cent percentage reduction in dry matter of monocot and dicot and total dry weight was recorded during the first and second seasons, while in the third season, 96.06, 96.23, and 96.14% of monocot and dicot and total weeds, respectively, were reduced over un-weeded control check. The biomass reduction of weeds is the index to determine the efficiency of weed management methods to control the weeds in onion. The plastic mulch effectively suppressed all monocot and dicot weeds throughout crop season by intercepting nearly all incoming radiation and inhibited the emerging of all weeds from the mulch, while during third season, some of the weed population emerged from the hole where the onion plant was grown. The organic mulch is also significantly suppresses all types of weed throughout the crop season by inhibiting weed emergence and subsequent growth. The weed population counts in organic mulch recorded 2.88/m^2, 5.29/m^2 and 9.14/m^2 in the first season, 3.85/m^2, 6.25/m^2 and 7.21/m^2 in the second year, 6.73/m^2, 11.54/m^2 and 16.35/m^2 in the third season, a monocot, dicot and total weed population, respectively. The reduction in weed dry matter in organic mulch relative to un-weeded control check amounted to 90.05, 84.40 and 86.29 in first season, 95.05, 85.74 and 91.17 in second season and 94.48, 85.22 and 88.58 in the third season, a monocot, dicot and total weed, respectively. Nwosisi et al. (2019) and Kaur et al. (2020) reported that organic mulch significantly reduced the weed population and also obtained significantly better yield over an un-weeded control check. The weed control efficiency is an index of a particular treatment can be understood that the competition stress of weed on crop and the treatments that checked the weed population and had lesser weed dry matter resulted in higher weed control efficiency. The highest weed control efficiency (98.06%) was recorded in treatment plastic mulch followed by treatment pendimethalin 30% EC @ 1.5 ml/l at pre-transplanting + one hand weeding at 30 DAT + quizalofop Ethyl 5% EC application at 60 DAT(Table 3). However, the organic mulch comes in the second rank in terms of weed density, while treatment pendimethalin 30 % EC @ 1.5 ml/l of water at pre-transplanting + one hand weeding at 30 DAT + quizalofop Ethyl 5% EC application at 60 DAT came in the second rank after plastic mulch due to supressing in monocot and dicot weed dry biomass. The reduction in weed biomass in herbicidal treatments could be attributed due to the effect of pre-emergence and post-emergence herbicide applications.

Table 3: Efficacy of different weed control methods on monocot weed dry weight, dicot weed dry weight and weed control efficiency in onion

Treatment	*Monocot dry weight (g/m^2)*				*Dicot dry weight (g/m^2)*				*Total dry weight (g/m^2)*				*WCE (%)*			
	2016-17	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*
Oxyflurofen + 1 HW at 40-60 DAT	2.04	7.16	5.56	6.36	2.01	2.86	1.43	2.14	4.05	10.03	6.99	8.51	96.22 (9.83)	88.15 (9.41)	86.69 (9.34)	87.42 (9.37)
Oxyflurofen + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	8.59	7.38	5.30	6.34	1.61	1.05	1.86	1.46	10.20	8.44	7.15	7.79	91.50 (9.59)	90.38 (9.53)	86.42 (9.32)	88.40 (9.43)
Pendimethalin + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	5.30	6.54	4.93	5.73	4.46	0.39	1.73	1.06	9.96	6.93	6.65	6.79	92.39 (9.64)	92.10 (9.62)	87.22 (9.36)	89.66 (9.49)
Plastic mulch	0.00	0.00	1.11	0.55	0.00	0.00	0.94	0.47	0.00	0.00	2.05	1.02	100.0 (10.02)	100.0 (10.02)	96.11 (9.83)	98.06 (9.93)
Organic mulch	1.68	5.39	3.86	4.63	6.57	7.52	2.20	4.86	8.25	12.90	6.06	9.48	95.18 (9.78)	85.06 (9.25)	88.26 (9.42)	86.66 (9.33)
Weedy check	16.88	34.55	28.16	31.35	132.63	52.74	24.91	38.83	149.51	87.29	53.07	70.18	0.0 (0.71)	0.0 (0.71)	0.0 (0.71)	0.0 (0.71)
S.E.m±	0.03	2.56	1.90	1.59	0.61	2.67	2.19	1.73	0.62	2.92	1.88	1.74	0.11	0.12	0.13	1.44
LSD (p=0.05)	0.06	5.46	4.05	3.25	1.30	5.69	4.67	3.53	1.32	6.22	4.01	3.55	0.23	0.26	0.28	2.93

Figures in the parentheses shows square root transformed values

It is one of the best options to farmers to eliminate monocot and dicot weed populations at early and later stages of the crop and to achieve higher weed control efficiency. The post-emergence application of quizalofop ethyl at 60 DAT is the most effective selective herbicide for controlling *Chenopodium album*, *Parthenium hysterophorus* and *Cyperus rotundas* on the basis of weed relative density, while *Cyperus rotundas* could not be controlled completely by any of the herbicide treatments. Quizolofop ethyl inhibits the acetyl CoA carboxylase (ACCase) activity, which is inhibiting the lipid biosynthesis could be possible due to better weed control efficiency (Dhawan et al., 2010). However, the post-emergence application of herbicide showed visual phytotoxic symptoms like leaf chlorosis noticed 10 to 15 days after spraying of herbicides in treatments oxyflurofen 23.5% EC @ 1.5 mL/l at pre-transplanting + one hand weeding at 30 DAT + quizalofop ethyl 5% EC application at 60 DAT and treatment pendimethalin 30 % EC @ 1.5 ml/l at pre-transplanting + one hand weeding at 30 DAT + quizalofop ethyl 5% EC application at 60 DAT, thereafter a declining trend was recorded up to 75 DAT later on the symptoms disappeared. The leaf tip burning symptoms appeared in organic mulch and un-weed control check at 70 DAT. Leaf rosetting symptoms were recorded in treatment un-weed control check from 40 DAT to 70 DAT and an increasing trend was observed in the range of 6.0 to 25.0% (Table 4). In contrast, the maximum dry biomass of monocot, dicot and total weeds were obtained in an un-weeded control check. Channapagoudar & Biradar (2007) and Melo et al. (2019) observed phytotoxicity symptoms in onions after post-emergence herbicide applications. Later on the plant completely recovered from toxicity. The effectiveness of

Table 4: Efficacy of different weed control methods on leaf chlorosis and tip burning in onion

Treatment	*Leaf chlorosis % at 63 DAT*	*Leaf chlorosis % at 67 DAT*	*Leaf chlorosis % at 70 DAT*	*Leaf chlorosis % at 75 DAT*	*Tip burning % at 40 DAT*	*Tip burning % at 50 DAT*	*Tip burning % at 60 DAT*	*Tip burning % at 70 DAT*
Oxyflurofen + 1 HW at 40-60 DAT	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
Oxyflurofen + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	8.25 (2.93)	13.00 (3.67)	9.00 (3.05)	7.00 (2.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
Pendimethalin + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	10.50 (3.31)	14.00 (3.80)	10.50 (3.30)	9.00 (3.07)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
Plastic mulch	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
Organic mulch	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	7.00 (2.70)	8.00 (2.91)	6.50 (2.61)
Weedy check	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	4.00 (1.98)	10.00 (3.22)	8.00 (2.85)	4.50 (2.19)
S.Em±	0.11	0.08	0.13	0.11	0.17	0.11	0.10	0.14
LSD (p=0.05)	0.23	0.15	0.27	0.23	0.34	0.22	0.20	0.29

Figures in the parentheses shows arcsin transformed values

Table 5: Efficacy of different weed control methods on phenological parameters in onion

Treatment	*Plant height (cm)*				*No. of leaves/ plant*				*Neck thickness (cm)*			
	2016-17	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*
Oxyflurofen + 1 HW at 40-60 DAT	52.70	60.20	66.15	63.18	8.55	8.55	9.75	9.15	1.32	1.41	1.64	1.53
Oxyflurofen + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	55.45	57.85	66.00	61.93	9.25	8.20	9.90	9.05	1.39	1.40	1.79	1.59
Pendimethalin + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	57.80	60.25	65.75	63.00	8.90	8.55	9.90	9.23	1.51	1.45	1.79	1.62
Plastic mulch	56.95	61.90	68.75	65.33	8.80	9.05	10.15	9.60	1.34	1.51	1.85	1.68
Organic mulch	57.80	59.95	71.15	65.55	9.55	8.40	10.85	9.63	1.46	1.46	1.78	1.62
Weedy check	54.95	49.15	49.05	49.10	6.95	6.55	7.10	6.83	1.03	1.04	1.17	1.11
S.E.m±	1.12	1.96	2.00	1.40	0.21	0.51	0.49	0.36	0.03	0.06	0.08	0.05
LSD (p=0.05)	2.39	4.18	4.26	2.86	0.45	1.09	1.04	0.73	0.06	0.13	0.17	0.10

Table 6: Efficacy of different weed control methods on yield attributing parameters in onion

Treatment	*Bulb equatorial diameter (cm)*				*Bulb polar diameter (cm)*				*Bolters (%)*				*Doubles (%)*			
	2016-17	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*	*2016-17*	*2017-18*	*2018-19*	*Pooled*
Oxyflurofen + 1 HW at 40-60 DAT	5.72	5.58	5.88	5.73	3.95	3.90	4.00	3.95	1.05 (1.25)	1.37 (1.36)	4.59 (2.22)	2.983 (1.79)	4.30 (2.19)	3.54 (2.01)	4.68 (2.27)	4.109 (2.14)
Oxyflurofen + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	5.77	5.65	5.87	5.76	4.24	4.12	3.99	4.12	1.12 (1.27)	0.90 (1.18)	3.89 (2.06)	2.396 (1.62)	3.55 (2.01)	2.90 (1.84)	3.30 (1.89)	3.098 (1.87)
Pendimethalin + 1 HW at 30 DAT + uizalofop Ethyl at 60 DAT	5.78	5.75	5.87	5.80	4.23	4.17	3.89	4.10	1.83 (1.52)	2.36 (1.69)	4.37 (2.17)	3.368 (1.93)	3.89 (2.09)	4.56 (2.25)	5.79 (2.50)	5.178 (2.38)
Plastic mulch	5.84	5.76	6.0	5.87	4.32	4.21	4.21	4.25	0.20 (0.84)	0.94 (1.20)	6.83 (2.68)	3.881 (1.94)	3.95 (2.11)	3.95 (2.11)	6.59 (2.65)	5.269 (2.38)
Organic mulch	5.82	5.65	6.07	5.85	4.11	4.11	4.26	4.16	1.61 (1.45)	1.08 (1.25)	4.33 (2.17)	2.701 (1.71)	5.15 (2.38)	3.54 (2.00)	3.85 (2.08)	3.694 (2.04)
Weedy check	4.33	4.51	4.16	4.33	3.19	3.00	3.37	3.19	2.09 (1.61)	1.03 (1.23)	1.87 (1.53)	1.449 (1.38)	10.15 (3.26)	4.53 (2.24)	2.65 (1.77)	3.593 (2.01)
S.E.m±		0.14	0.17	0.11		0.14	0.11	0.09	0.03	0.11	0.30	0.16	0.03	0.09	0.19	0.11
LSD (p=0.05)		0.30	0.36	0.22		0.30	0.23	0.18	0.06	0.23	0.64	0.32	0.06	0.19	0.40	0.23

Figures in the parentheses shows square root transformed values

Table 7: Efficacy of different weed control methods on yield parameters and economics of onion

Treatment	Gross Yield (q/ha)				Marketable yield (q/ha)				Net monetary return (₹)				Benefit : Cost ratio			
	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled	2016-17	2017-18	2018-19	Pooled
Oxyflurofen + 1 HW at 40-60 DAT	271.36	256.08	227.46	251.63	229.50	233.13	173.72	212.12	1,35,900	1,86,156	1,66,980	1,63,012	2.45:1	2.99:1	2.78:1	2.74:1
Oxyflurofen + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	298.70	263.11	246.41	269.41	252.36	249.50	185.00	228.95	1,56,702	2,03,742	1,81,842	1,80,762	2.64:1	3.13:1	2.90:1	2.89:1
Pendimethalin + 1 HW at 30 DAT + Quizalofop Ethyl at 60 DAT	295.03	280.06	255.22	276.77	251.17	255.23	183.31	229.90	1,54,872	2,09,978	1,78,667	1,81,172	2.61:1	3.18:1	2.86:1	2.88:1
Plastic mulch	314.00	309.63	329.26	317.63	261.33	282.62	258.07	267.34	1,28,480	2,06,294	2,54,255	1,96,343	1.97:1	2.55:1	2.91:1	2.48:1
Organic mulch	271.19	259.64	284.86	271.90	224.79	240.51	228.84	231.38	1,04,990	1,68,812	2,23,460	1,65,754	1.88:1	2.41:1	2.87:1	2.38:1
Weedy check	171.54	156.41	168.38	165.44	134.98	123.75	116.07	124.93	54,980	68,500	94,105	72,528	1.69:1	1.86:1	2.18:1	1.91:1
S.Em±	6.67	3.36	12.65	6.55	5.71	5.78	10.24	5.84	-	-	-	-	-	-	-	-
LSD (p=0.05)	14.22	7.16	26.96	13.37	11.53	12.32	21.83	11.94	-	-	-	-	-	-	-	-

various herbicides against different weed species in onion crops has been previously reported by Vishnu et al. (2015) and Islam et al. (2020).

Effects on growth and yield attributes

Chemical and non-chemical weed management methods caused significant variations pertaining to the growth and yield attributes. The highest plant height (65.55 cm) and number of leaves (9.63/plant) were recorded in the treatment organic mulch and the results were found at par with treatment plastic mulch and herbicide treatments (Table 5). The maximum plant growth and development could be due to less weed competition and higher exposure to sunlight. The minimum plant growth and development in the un-weeded control check was due to continuous competition of weeds, poor exposure to sunlight, and competition for nutrients and water, by which reduced the growth of plants. The findings are in close approximation to Channappagoudar & Biradar (2007), Vishnu et al. (2015) and Chattopadhyay et al. (2017). The yield is the final index of the experiment, indicating the success or failure of any weed management treatments. The highest bulb equatorial size (5.87 cm) and polar size (4.25 cm) were recorded in treatment plastic mulch, while the lowest bulb size (4.33cm and 3.19cm) was recorded in un-weeded control check (Table 6). The highest gross yield (317.63q/ha) and marketable yield (267.34q/ha) were recorded in treatment plastic mulch (Table 7). This might be vigorous growth of the crop, due to the control of weeds resulted in less crop and weed competition throughout the crop growth stage and enhanced the availability of nutrients, water, light and space, which accelerated the photosynthetic rate, thereby increasing the supply of carbohydrates and overall improvement in vegetative growth, which favorably influenced the bulb development and ultimately resulted into increased bulb yield. In addition, plastic mulch showed a positive effect on soil moisture, heat and aeration, thereby restricting moisture evaporation (Kaur *et al*., 2020). While in the weedy check reverse trend happened due to the adverse effect of weeds. The bulb yield was drastically reduced by 62.18% and due to poor growth lowest bolters and lowest doubles were obtained. The variability in plant growth, development and yield is due to the effectiveness of weed control methods, which ultimately increase the nutrient availability for the crop. The results are in agreement with Vishnu et al. (2015), Chattopadhyay et al. (2016) and Islam et al. (2020).

Benefit-cost analysis

In view of the economics of weed management in onion, the highest gross monetary return was obtained in plastic mulch due to the highest yield, while the cost of cultivation is higher side as compared with herbicide treatments. Therefore, lower net monetary return and benefit: cost ratio, i.e., ₹1,28,480 & 1.97:1.0 and ₹2,062,94 & 2.55:1.0 recorded during the first and second years, respectively, however during the third year, higher net monetary return and benefit: cost ratio (₹2,54,255 & 2.91:1.0) recorded in the same treatment. While the pooled results revealed that the highest benefit: cost ratio (2.89:1.0) was recorded in integrated weed management treatment oxyfluorfen 23.5% EC @ 1.5 ml/l at pre-transplanting + one hand weeding at 30 DAT + quizalofop ethyl 5% EC application at 60 DAT due to lowest cost of cultivation and is very effective weed management practice at critical stages. Due to poor yield lowest cost-benefit ratio (1.91:1.0) was found in the un-weeded control check.

Conclusion

The chemical and non-chemical methods significantly reduced weed population and increased bulb yield. The highest yield and weed control efficiency were recorded in the treatment of plastic mulch but this method is an un-economical method. However, in onion organic farming, a farmer certainly depends on plastic mulching and organic mulching is safe and efficient instead of using chemical weed management methods. In chemical weed management methods, the treatment oxyflurofen 23.5% EC @ 1.5 ml/l at pre-transplanting + one hand weeding at 30 DAT + quizalofop ethyl 5% EC application at 60 DAT recorded highest benefit: cost ratio followed by treatment pendimethalin 30% EC application before planting + one hand weeding at 30 days after transplanting + quizalofop Ethyl 5% EC application at 60 days after transplanting and these treatments are economical and affordable by farmers under integrated weed management approach.

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सारांश

प्याज और लहसुन पर अखिल भारतीय नेटवर्क अनुसंधान परियोजना के तहत प्याज में रासायनिक और गैर-रासायनिक खरपतवार प्रबंधन विधियों की प्रभावकारिता की तुलना करने के लिए एक एकीकृत खरपतवार प्रबंधन प्रयोग आयोजित किया गया था। तीन वर्षों के संयुक्त परिणामों से पता चला कि सभी खरपतवार प्रबंधन विधियों ने खरपतवार घनत्व पर महत्वपूर्ण प्रभाव डाला। प्लास्टिक मल्च के उपचार में सबसे कम मोनोकोट, डायकोट, कुल खरपतवार आबादी, खरपतवार बायोमास और उच्चतम खपतवार नियंत्रण दक्षता दर्ज की गई। प्लास्टिक मल्च के उपचार में उच्चतम बल्ब भूमध्यरेखीय व्यास (5.87 सेमी), ध्रुवीय व्यास (4.32 सेमी), सकल उपज (317.63 क्विंटल प्रति हेक्टेयर) और विपणन योग्य उपज (267.34 क्विंटल प्रति हेक्टेयर) दर्ज की गई। हालाँकि, सबसे अधिक लाभ: लागत अनुपात (2.89:1.0) शाकनाशी उपचार ऑक्सीफ्लूरोफेन 23.5% ईसी @ 1.5 मिली/लीटर पूर्व-प्रत्यारोपण + 30 डीएटी पर एक हाथ से निराई + 60 डीएटी पर क्विज़ालोफॉप इथाइल 5% ईसी अनुप्रयोग में दर्ज किया गया था। खरपतवार प्रतिस्पर्धा के भारी संक्रमण के कारण खराब वृद्धि और विकास दर्ज किया गया, उपचार के बिना खरपतवार जांच के परिणाम में 49.0 से 88.80% उपज में कमी दर्ज की गई।