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Full length Research paper

Evaluation of various methods and their combinations for Weed control in Onion (*allium cepa* l.) in the central rift Valley of Ethiopia

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The study was initiated with evaluating the effect of Pendimethalin and Oxyflourfen herbicides with or without supplement of different hand weeding time for control of weeds in onion in the Central Rift Valley of Ethiopia during 2017/2018 under irrigation. The experiment was contained 13 treatments and laid out in randomized complete block design with four replicates. Collected data were analyzed using Statistical Analysis Software version 9.0. The weed density varied significantly with the treatments (P<0.05). At 60 Day after transplanting the lowest weed density (41.875/m^2) was recorded under Hand weeding three week after transplanting followed by Oxyflourfen at 0.5L/ha + Hand weeding six week after transplanting At harvest the lowest weed density (30.875g/m^2) was obtained under Oxyflourfen at 0.5L/ha+Hand weeding six week after transplanting. The lowest weed dry weight was recorded from plot treated with Pendimethalin at 1.5L/ha+Hand weeding nine week after transplanting (293.27g/m^2). The highest weed control efficiency (82.15%) was recorded under Pendimethalin at 1.5L/ha+Hand weeding nine week after transplanting followed by Oxyflourfen at 0.5L/ha+Hand weeding nine week after transplanting (80.48%) after weed free plot.The maximum plant height (43.47cm) was recorded in weed free plot followed by Oxyflourfen at 0.5L/ha+Hand weeding three week after transplanting (40.68cm). Maximum bulb diameter, bulb weight, bulb size (3.51cm, 122.58g, 73.25ml, 29.62ton/ha) were recorded respectively from weed free plot, which were statistically non-significant from Oxyflourfen at 0.5L/ha+Hand weeding nine week after transplanting. The lowest loss in yield (0.03%) was recorded in weed free check followed by plot treated with oxyflourfen at rate of the 0.5 L/ha + Hand weeding six week after transplanting (6.8%) as compared to the highest yield obtained in plot treated with oxyflourfen at rate of the 0.5 L/ha + Hand weeding nine week after transplanting. Weed free check plot resulted in higher cost of protection and gross return but lower in net return and benefit: Cost ratio, whereas Oxyflourfen at 0.5L/ha and pendimethalin at 1.5L/ha showed highest Benefit: Cost ratio (20.34 and 14.65) respectively. The study showed that using herbicides alone or in combination with hand weeding is highly profitable than using hand weeding alone.

Keywords: Effect, Evaluation, Herbicides, Hand weeding, Onion, Weed control

INTRODUCTION

Onion (*Allium cepa*L.) is one of the most economically important and highly cultivated bulbous vegetable crops belonging to the genus Allium, family *Alliaceae* (Hanelt, 1990). It is the second most important crop after tomato in volume of production and area coverage and grown in more than 130 countries in the world. China and India are the world's largest onion producers followed by USA, the Netherland, Egypt and Iran (FAOSTAT, 2017). Onion is used mainly as spices in various cuisines and important in the daily Ethiopian diet for the preparation of traditional foods.

The release of a variety from introduced materials from (Sudan) marked the beginning of extensive production of onion in the country (ET- FRUIT, 1992). Increasing onion production contributes to growth of the rural economy and

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creates many off-farm jobs (MoARD, 2005).

During 2016/17, *Meher season,* 264,849.35ton of onion was produced on a total area 2, 9517.01 ha(CSA, 2017) in Ethiopia. The world average is 19.7 t/ha, in Ethiopia is about 13.3t/ha. The yield estimate in small farmer is about 9.5t/ha, while the average marketable yield in state farms is 14.9 t/ha where as in research condition could reach up to 40t/ha (Desalegn *et al.,* 2004). In this context, average yield is less than world average and even there is a huge gap between researcher and farmers field (Esheteu *et al*, 2006).

Low yield of onion is the result of various a biotic and complex biotic factors like diseases, insect pests, weeds and etc (Esheteu *et al*, 2006; Melkamu *et al.,* 2015).Weeds are one of the pests associated with any agriculture and the most yield reducers that are, in many situations, economically more important than insects, fungi or other pest organisms (Savary et al., 1997) Weeds are undesirable plants, which infest different crops including onion and inflict negative effect on crop yield either through competition for water or nutrients or space or light (Reddy & Reddi, 2011) and by releasing inhibitory chemicals on crop plants (Javaid *et al*., 2007). Weeds may also act as alternate hosts to insect pests and pathogens attacking onion (Palumbo, 2013).

The weed flora of Ethiopia is highly diverse and the crop loss due to these weeds is also variable; it ranged from low to high for different areas and crops (Fasil, 2006).Weed causes about 10% yield loss in the less developed countries and 25% in the least developed (Akobundu, 1987). Weed causes heavy yield losses in the major crops averagely 25-32% (Fasil, 2006). Taye *et al*. (1996) reported that competition of *Avenaabyssinica*, *Loliumtemulentum* L., *Snowdeniapolystachya* and *Phalarisparadoxa* L. with bread wheat causes 48-86% a yield loss. Season-long exposure of onion to weed competition has been shown to reduce onion yield up to 96% (Bond & Burston, 1996). There is no report on the amount of onion crop yield losses due to weeds in Ethiopia.

Onion production is the major activity in the Central Rift Valley of Ethiopia and weed control has been observed as one of the most important practice because good weed control will ensure maximum yield and high quality of farm produce (Njoroge, 1999). Hand weeding is the predominant weed control practice on smallholder farms. However, it is labor intensive and expensive method. Appleby (1996) reported, in USA, hand weeding costs about \$92.59 ha^{-1}; five to seven times more expensive than using herbicides alone or in combinations. Farmers spend more of their total labor time on hand weeding. Most of farmers are too busy during land preparation for main season crops to weed the early planted crops. Most of children are forced to leave school for weeding. In Africa 69% of farm children between the ages of 5-14 are forced to leave school for used in the agricultural sector especially at peak period of weeding (Ishaya *et al.*, 2008b). Therefore, in such situations the herbicidal weed management practices become much more important. Therefore, this study was designed to evaluate the effect of different herbicides with or without supplement of hand weeding for the control of annual grasses and broadleaf weeds in onion and to incorporate the best herbicide in an integrated weed management programme with the following objectives

1. To determine the effect of different herbicides and hand weeding time for weed control in transplanted onion
2. To determine optimum combination of pre- emergence and post- emergence herbicides with hand weeding time for weed control in transplanted onion.
3. To estimate onion yield loss due to weed compition
4. To evaluate the economics of using herbicides and hand weeding in onion production

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at onion production area of Dugdaworeda, East Shoa zone of Oromia Regional State, Central Rift Valley of Ethiopia during 2017/2018 growing season under irrigation. Meki is town of the woreda and located between Latitude $7^0$58’ to $8^0$10’N and Longitude $38^0$43’ to $39^0$57’E at altitude of 564 m. a. s. l. It is found 130km from Addis Ababa. The soil of the area is characterized by sandy loam soil. Weather condition of the study area were recorded (Figure 1)

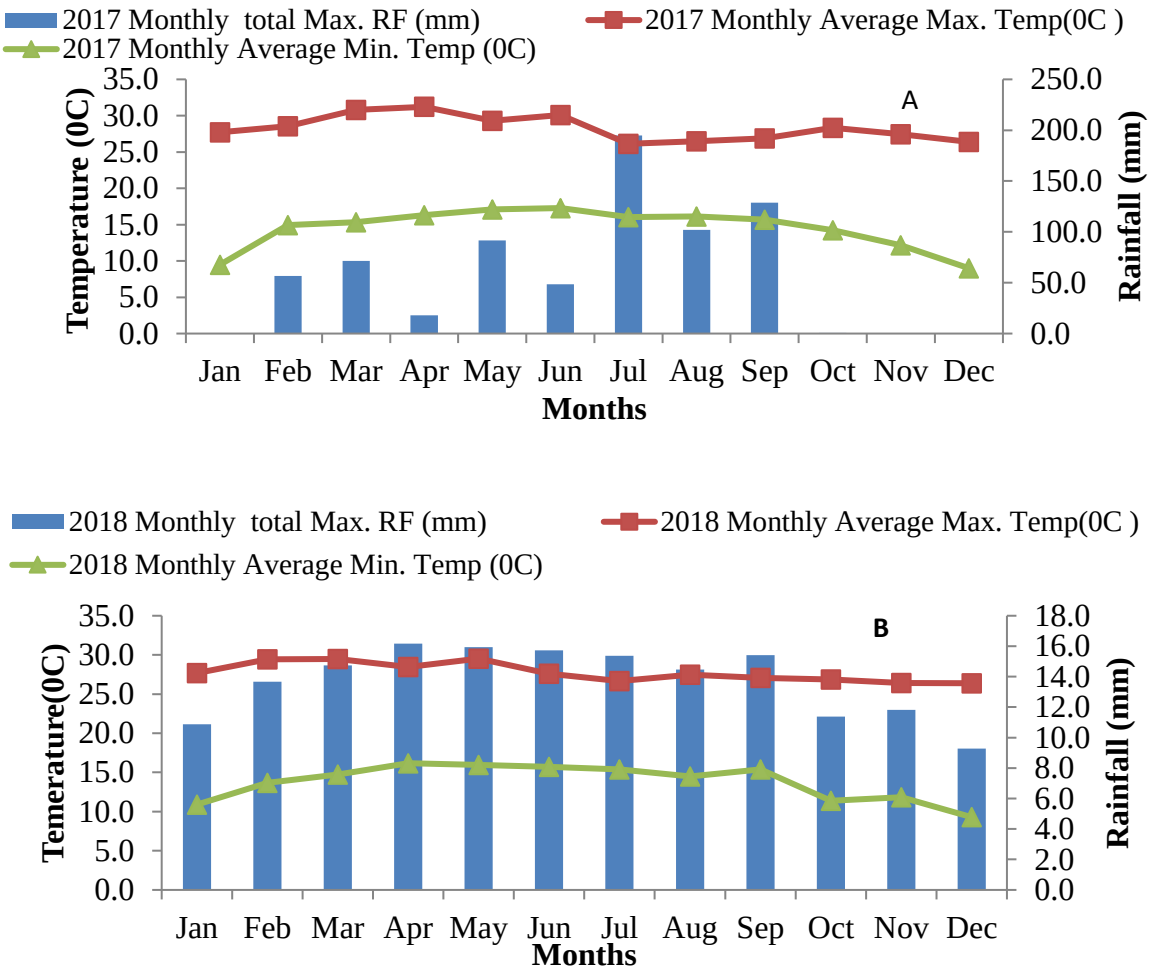

Figure1: Metrological observations during field experimental period of 2017/2018

Treatments and Experimental Design

The experiment consists of thirteen treatments: two herbicides (pendimethaline 455CS as pre emergence and oxyflorfen 240EC as Post emergence) with or without supplement of hand weeding (3WAT, 6WAT and 9WAT), one weed free check and one weedy as control (Table 1). The treatments were laid down in randomized complete block design (RCBD) with four replications.

Table 1: Experimental treatments used in the study area

Treatment number	Weed control treatments
1	Pendimethaline at rate of 1.5L/ha pre - emergence of weeds
2	Pendimethaline at rate of 1.5L/ha PE + Hand Weeding (3WAT)
3	Pendimethaline at rate of 1.5L/ha PE+ Hand Weeding (6WAT)
4	Pendimethaline at rate of 1.5L/ha PE+ Hand Weeding (9WAT)
5	Oxyfluorfen at rate of 0.5L/ha Post - emergence of weeds
6	Oxyfluorfen at rate of 0.5L/ha POE + Hand Weeding (3WAT)
7	Oxyfluorfen at rate of 0.5L/ha POE + Hand Weeding (6WAT)
8	Oxyfluorfen at rate of 0.5L/ha POE + Hand Weeding (9WAT)
9	Hand weeding(3WAT)
10	Hand weeding(6WAT)
11	Hand weeding(9WAT)
12	Weed free check
13	Weedy check

WAT= Week after transplanting, PE=Pre- emergence, POE=Post- emergence

Management of the Experimental Plots

Onion variety "Bombay red" was used in experiment. Healthy seedlings with 3 to 4 leaf stage were transplanted to the experimental plots (one seedling per hole) Each plot had gross plot size 12 m^2 (4m x 3m) and four furrows with eight rows and spacing 30cm between rows, 10cm between plants and 40cm between furrows (Lemma and Shimeles 2003). Net plot size was 7.28m^2 (2.6 m x 2.8 m) with six central rows were harvested. Plots and replications were separated by one meter. Gap filling was done a week after transplanting. UREA and DAP applied as recommended. 200 kg DAP/ha applied to the experimental plot as basal application during transplant 100kg/ha Urea was applied as split. The first half was applied during transplanting and the remaining half was the applied as side dressing six weeks after transplanting. Irrigation was applied for the first two weeks after transplanting at four days interval. Then after, experimental plots were irrigated at six days interval using furrow irrigation system (Lemma and Shimeles, 2003). Diseases like purple blotch and bulb rot were occurred and successfully controlled by spraying fungicides. Also Insect pests like thrips and cutworms were observed. However, they were successfully controlled by spaying insecticides.

The pre- emergence herbicide (pendimethaline 455CS) were applied to soil a day before transplanting at rate of 1.5L/ha. The post- transplant herbicide (oxyfluorfen 240EC) were foliar sprayed four weeks after transplanting at rate of 0.5L/ha. All herbicide applications were applied with 20 liters capacity knapsack sprayer. 200L/ha used for both herbicides. Hand weeding was carried out as per treatment by manual laborers (at 3WAT, 6 WAT and 9 WAT). Weed free plot was hand weeded regularly as and when the weeds emerged out throughout the crop season. Weedy control treatment kept unweeded throughout harvest.

Data Collected

Weed density (Plants/m^2) at 60DAT and at the time of harvesting

Weed density were recorded in five randomly selected area of the plot using the 0.5 m^2 quadrate. The area in the quadrate was marked in each net plot and weeds were counted at 60 days after transplanting and at the time of harvesting

Weed biomass (g/m^2) - weeds present inside the quadrate were harvested, dried and weighted

Weed control efficacy (%)-Weed control efficacy (WCI) was worked out based on the formula given by Patel *et al*. (1987).

$$\text{WCE} = \frac{\text{Weed biomass of unweeded control} - \text{Weed biomass of a treatment}}{\text{Weed biomass of unweeded control}} \text{X}100$$

Weed competition index (%)- Weed competition index (WI) was calculated after the crop harvested using the formula by Gill and Kumar (1969).

$$\text{WI} = \frac{\text{X} - \text{Y}}{\text{X}} \text{ x } 100$$

Where, X = Yield of weeded check; Y = yield of treatment

Plant height (cm)– Plant height of ten plant which randomly selected from each net plotfrom each replication was measured from ground level up to tip of longest leaf with the help of ruler at physiological maturity and the mean values were computed for further analysis.

Number of leaves (leaf/plant) - All the photo- synthetically active green leaves of ten randomly selected plants in each net plot was counted and the mean values were computed for further analysis.

Average bulb diameters (cm) - The diameter of ten bulbs were recorded from randomly selected plants of each plot by using caliper (Lemma and Shimeles, 2003).

Average bulb size (ml) -Size of onion bulbs were recorded by volume method using a graduated beaker. A random sample of ten bulbs were immersed in the graduated beaker, containing known amount of water, and the water displaced by onion bulbs was considered as the size of ten bulbs. Later on the values were converted to the size of a single bulb by taking the average of the ten bulbs for further analysis.

Average bulb weights (gm) - The average weight of ten bulbs were recorded from randomly selected plants of each net plot by using weighing balance (Guesh, 2015).

Bulb yield (ton/ha)- The onion bulbs from the inner rows excluding the border were harvested and bulbs of each net plot was weighted by using weighting balance.

Yield loss estimation due to weeds

Crop yield loss due to weeds were calculated in percent (%) by using the following formula

$$\text{Yield loss} = \frac{\text{Maximum yield from a treatment} - \text{Yield from a particular treatment}}{\text{Maximum yield from a treatment}} \text{x}100$$

Economic Analysis

After taking into consideration all weed control inputs and their corresponding rates, the cost incurred on each treatment was worked out as follows (CIMMYT, 1988)

Statistical Analysis

Average values of various parameters were subjected to analysis of variance (ANOVA) using SAS (Statistical Analysis System) version 9.0 and significant differences were separated using Tukey's HSD (honestly significant differences) test at 5% independence level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Table 2: Weed density (Number/m^2), weed biomass (g/m^2), weed control efficiency (%) and weed index (%) as affected by different weed control treatments

Treatments	Weed density (Number/m^2)		Weed biomass at harvest (g/m^2)	WCI (%) at harvest	WI (%) at harvest
	At 60 DAT	At harvest			
Pendimethalin	102.13^{b}	64.750^{bc}	617.42^{bc}	61.01	44.32
Pendi +HW3WAT	64.625^{cd}	74.250^{b}	487.32^{bc}	69.98	37.08
Pendi +HW 6WAT	49.125^{d}	54.625^{bcd}	425.07^{cd}	74.50	22.38
Pendi +HW 9WAT	82.000^{bc}	38.625^{cd}	293.27^{cd}	82.15	22.84
Oxyflourfen	49.125^{d}	35.625^{cd}	659.42^{bc}	57.33	30.51
oxyfl +HW3WAT	48.125^{d}	32.375^{d}	431.62^{cd}	72.05	24.01
oxyfl +HW6WAT	42.750^{d}	34.500^{cd}	460.58^{cd}	72.25	7.23
oxyfl + HW9WAT	47.625^{d}	30.875^{de}	320.32^{cd}	80.48	0.014
HW3WAT	41.875^{d}	82.500^{b}	954.29^{b}	40.38	67.37
HW6WAT	44.500^{d}	53.000^{bcd}	745.69^{bc}	54.19	60.89
HW9WAT	94.125^{b}	39.625^{cd}	552.88^{bc}	63.40	71.74
Weed free check	0.0000^{e}	0.0000^{e}	0.0000^{d}	100	0
Weedy control	134.38^{a}	126.75^{a}	1515.7^{a}	-	98.88
CV	16.10	25.15	32.85	-	-
P-value (5%)	31.78	32.17	557.95	-	-

Means in the same column followed by similar letters are not statistically significant
CV= Coefficient of variation, WCI= Weed control efficiency, WI=Weed index

Weed density (Number/m^2)

All weed control treatments caused significant reduction in weed population compared with weedy check plot (Table 2). However, the level of reduction was varied among the treatments. The lowest weed density (41.88/m^2) was recorded under hand weeding three weeks after transplanting followed by oxyflourfen at the rate of 0.5L/ha + Hand weeding six week after transplanting, pendimethalin at the rate of 1.5 L/ha + Hand weeding six week after transplanting, oxyflourfen at the rate of 0.5L/ha + Hand weeding three week after transplanting and oxyflourfen at the rate of 0.5L/ha treated plots, which were not significant from each other.

Whereas, maximum weed density (134.38/m^2) was recorded from weedy check plot followed by plot treated with pendimethalin at rate of the 1.5L/ha and hand weeding nine weeks after transplanting.

The weed density at harvest significantly varied among the different treatments (Table 2). The lowest weed density (30.875/m^2) was recorded from oxyflourfen at the rate of 0.5 L/ha + Hand weeding nine weeks after transplanting, whereas weedy check plot had the highest weed density (126.75/m^2). Weed population at 60 DAT were higher as compared to that at harvest stage. Probably, due to the dominance of some weed species suppressing other weed species through time when some weed species might have finished their life cycle. Sampat *et al.* (2014) reported maximum weed density from weedy check plot in garlic farm.

Weed biomass (gm^{-2})

The weed biomass was found to be significantly affected by the treatments (Table 2). The lowest weed biomass were recorded from pendimethalin at the rate of 1.5 L/ha+ hand weeding nine weeks after transplanting (293.27g/m^2) followed by oxyflourfen at the rate of 0.5 L/ha + hand weeding nine weeks after transplanting, pendimethaline at the rate of 1.5 L/ha+ hand weeding six weeks after transplanting, oxyflourfen at the rate of 0.5 L/ha + Hand weeding three weeks after transplanting, oxyflourfen at the rate of 0.5 L/ha + hand weeding six weeks after transplanting, respectively which were not significantly different from each other. Weedy check plot had the highest (1515.7g/m^2) weed biomass/m^2.

Weed control efficiency (%)

Among herbicide treatments, the highest weed control efficiency (82.15%) was recorded under pendimethaline at the rate of 1.5L/ha + hand weeding nine week after transplanting followed by oxyflourfen at the rate of 0.5L/ha + hand weeding nine week after transplanting (80.48%) after weed free plot. The lowest (40.38%) weed control efficiency was recorded from Hand weeding three week after transplanting (Table 2). Kalhapure and Shete (2012) reported highest weed control efficiency from weed free check on onion.

Weed index (%)

Weed index is the indicator in yield loss due to presence of weeds. The study showed differences among different weed control treatments (Table 2). The lowest weed index was obtained in plot applied with oxyflourfen at the rate of 0.5L/ha + HW9WAT(0.14%), oxyflourfen at the rate of 0.5L/ha + hand weeding six week after transplanting (7.23%), pendimethalinat the rate of 1.5L/ha + HW6WAT (22.38%), pendimethalin at the rate of 1.5L/ha + HW9WAT (22.84%) and oxyflourfen at the rate of 0.5L/ha + hand weeding nine week after transplanting (24.01%) respectively. The highest weed index (98.88%) was recorded under weedy check treatment likely due to severe weed - crop competition, suppression of crop plants by the emerging weeds and more utilization of water and nutrients by the weed canopy. Kolse *et al.,* 2010 reported maximum weed index from weedy check plot on onion

Table3: Growth parameters of onion as affected by different weed control treatments

Treatments	Plant height	Number of leaves per plant
Pendi	39.460^{abc}	8.7787 ^{a}
Pendi +HW3WAT	38.479^{abc}	9.0500 ^{a}
Pendi +HW 6WAT	39.741^{abc}	9.2312 ^{a}
Pendi +HW 9WAT	39.055^{abc}	9.0763 ^{a}
Oxyfl	34.688^{bcd}	8.6850 ^{a}
Oxyfl +HW3WAT	40.681^{ab}	9.2225 ^{a}
Oxyfl +HW6WAT	37.040^{abcd}	9.4300 ^{a}
Oxyfl + HW9WAT	38.694^{abc}	9.1050 ^{a}
HW3WAT	32.529^{cd}	8.6650 ^{a}
HW6WAT	35.165^{bcd}	9.1612 ^{a}
HW9WAT	35.354^{bcd}	9.3538 ^{a}
Weed free check	43.472^{a}	9.6750 ^{a}
Weedy control	30.494^{d}	8.5575^{a}
CV	8.18	6.22
P-value (5%)	8.63	1.34

Means in the same column followed by similar letters are not statistically significant
CV= Coefficient of variation

Plant height (cm)

The treatments had effect on the plant height and the highest plant height was recorded in weed free plot (Table 3). Among the treatment with herbicides, the highest height (43.472cm) was recorded in weed free plots followed by oxyflourfen at rate 0.5 L/ha + hand weeding three week after transplanting (40.681cm), pendimethalin at rate 1.5 L/ha + hand weeding three week after transplanting, pendimethalin at the rate 1.5 L/ha + hand weeding nine week after transplanting and oxyflourfen at the rate 0.5 L/ha + hand weeding nine week after transplanting had higher plant height which were not significantly different from each other. The lowest plant height (30.5cm) was recorded from weedy check plo.t The higher plant height from weed free plot was due to favorable environment created around root zone resulting in more absorption of water and nutrients from soil and also good control of weeds throughout the crop period helps in good penetration of solar radiation and greater photosynthetic rate resulting in more plant height of the crop. Similar results were observed by Kalhapure and Shete (2012). Lower plant height under weedy check treatment is because of high infestation of weeds which leads to lack of solar radiation penetration and lesser photosynthetic rate of the crop resulting in less vegetative growth of the crop.

Number of leaves per plant

The number of leaves per plant was not affected by the treatments (Table 3).

Table 4: Bulb yields of onion as affected by different weed control treatments

Treatments	Average bulb diameter(cm)	Average bulb weight(g)	Average bulb size(ml)	Bulb Yield(ton/ha)
pendimethalin	2.91^{bcd}	83.29^{ef}	60.00^{b}	16.49^{bcde}
pendi +HW3WAT	3.15^{abc}	87.15^{cde}	59.50^{b}	21.60^{abc}
pendi +HW 6WAT	3.15^{abc}	92.96^{cde}	65.50^{ab}	22.99^{abc}
pendi +HW 9WAT	3.08^{abc}	85.66^{de}	70.75^{ab}	22.85^{abc}
Oxyflourfen	2.85^{bcd}	102.30^{bcd}	60.25^{b}	20.58^{abc}
oxyfl +HW3WAT	3.10^{abc}	103.50^{bc}	59.00^{b}	22.50^{abc}
oxyfl +HW6WAT	3.18^{abc}	114.04^{ab}	68.00^{ab}	27.62^{ab}
oxyfl + HW9WAT	3.31^{ab}	113.74^{ab}	62.75^{ab}	29.62^{a}
HW3WAT	2.57^{d}	64.39^{g}	41.50^{c}	9.66^{def}
HW6WAT	2.71^{cd}	77.25^{efg}	42.75^{c}	11.58^{cdef}
HW9WAT	2.79^{cd}	66.82^{fg}	46.25^{c}	8.37^{ef}
Weed free check	3.51^{a}	122.58^{a}	73.25^{a}	29.61^{a}
Weedy control	0.46^{e}	3.34^{h}	0.00^{d}	0.33^{f}
CV	6.66	8.05	8.64	24.40
P-value (5%)	0.52	16.85	11.49	11.46

Means in the same column followed by similar letters are not statistically significant
CV= Coefficient of variation, SE (m) = Standard error of mean

Average bulb diameter (cm)

The weed control treatments significantly affected the average onion bulb diameter. The highest average bulb diameter (3.5062cm) was recorded from weed free treatment followed by oxyflourfen at the rate of 0.5 L/ha + hand weeding nine week after transplanting (3.3088cm) (Table 4). Among herbicidal treatments maximum bulb diameter were recorded in post application of oxyflourfen at the rate of 0.5 L/ha + hand weeding nine week after transplanting due to early inhibition of emerged weeds like broad leaf weeds, grass weeds and to some extent sedges and hand weeding of late emerged weeds in the crop. Oxyflourfen disturbs chlorophyll and photosynthesis pathways of susceptible weeds and also causes breakdown of cell membrane of leafs of susceptible weeds and then resulting death of weeds and hand weeding supplemented late in the crop growth facilitates favorable condition for better crop growth and bulb diameter. The results are inconformity with Kalhapure and Shete (2012). The lowest (0.46cm) bulb diameter was recorded on weedy check plot.

Average bulb weight (g)

Among all the treatments the highest (122.58g) average bulb weight were recorded on weed free check followed by oxyflourfen at the rate of 0.5L/ha + hand weeding six week after transplanting (114.04g) and oxyflourfen at the rate of 0.5L/ha+ hand weeding nine week after transplanting) (113.74 g) which were not significantly different from each other (Table 4). The lowest (3.34g) average bulb weight was recorded on weedy check plot.

Average bulb size (ml)

Among all the treatments the highest (73.250ml) average bulb size were recorded on weed free check followed by pendimethalin at the rate of 1.5 L/ha + hand weeding nine week after transplanting (70.75ml), oxyfluorfen at the rate of 0.5 L/ha + hand weeding six week after transplanting (68.00 ml), pendimethalin at the rate of 1.5 L/ha + hand weeding six week after transplanting (65.500ml) and oxyflourfen at the rate of 0.5 L/ha + hand weeding six week after transplanting (62.75ml) which were not significantly different from each other (Table 4). Pendimethalin alters chemical composition and biochemical processes of susceptible weeds and finally resulting in death of weeds and at the end resulting in large bulb size. The lowest (0.0ml) and (41.500ml) average bulb weight was recorded on weedy check plot and Hand weeding (3WAT) as a result of high weed infestation.

Bulb Yield (ton/ha)

The treatments significantly affected the bulb yield of onion and the highest yield (29.62ton/ha) was from the treatment oxyflourfen at the rate of 0.5L/ha + hand weeding nine week after transplanting and weed free check plot (29.61ton/ha) which was more than the weed free check treatment, might be because of oxyflourfen ability to inhibit early emerged all types of weeds. The lowest bulb yield (0.33 ton/ha) was recorded on weedy check (Table 4).

Table 5.Crop Yield loss due to weeds

Treatments	Relative Yield loss (%)
Pendimethalin	44.3
Pendi +HW3WAT	27.1
Pendi +HW6WAT	22.4
Pendi +HW9WAT	22.9
Oxyfluorfen	30.5
Oxyfl +HW3WAT	24.0
Oxyfl +HW6WAT	6.8
Oxyfl + HW9WAT	0.0
HW3WAT	67.4
HW6WAT	60.9
HW9WAT	71.7
Weed free check	0.03
Weedy control	98.9

While comparing the loss in yield due to the weed control practices, the lowest loss in yield (0.03%) was recorded in weed free check followed by plot treated with oxyflourfen at rate of the 0.5 L/ha + hand weeding six week after transplanting(6.8%) and oxyflourfen at rate of the 0.5 L/ha + hand weeding three week after transplanting(24.0%) as compared to the highest yield obtained in plot treated with oxyflourfen at rate of the 0.5 L/ha + hand weeding nine week after transplanting. Whereas, highest (98.9%) loss in yield due to the weed was recorded from weedy check (Table 5)

Cost of protection (ETB/ha)

Among all weed control treatments, the weed free check plot incurred the highest cost of protection (8000ETB/ha)

(Table 6). The cost of combination treatments pendimethalin at the rate of 1.5L/ha + each time hand weeding (3475 ETB/ha) and combination of oxyflourfen at the rate 0.5L/ha + each time of hand weeding (3350 ETB/ha) were also higher following the weed free plot, whereas the lowest cost of weed protection (2000 ETB/ha) was recorded for single time hand weeding conducted at three week after transplanting, six weeks after transplanting, and nine weeks after planting.

Gross return (ETB/ha)

The highest gross return (41468 ETB/ha) was recorded in oxyfourfen at the rate 0.5L/ha+ HW9WAT followed by weed free treatment (41454 ETB/ha), Oxyfourfen at the rate 0.5L/ha+ HW6WAT (38668 ETB/ha) and Pendimethalin at the rate 1.5L/ha + HW6WAT (32186 ETB/ha) (Table 6). The lowest gross return (462ETB/ha) was from weedy check treatment.

Net return (ETB/ha)

The highest net return was obtained from post emergence application of oxyfourfen at the rate 0.5 L/ha + hand weeding (9WAT) (38118 ETB/ha) followed by Oxyfourfen at the rate of 0.5 L/ha+ hand weeding (6WAT) (35318 ETB/ha). This may be due to better control of weeds in these treatments resulting increased yield attributes, gross returns and thereby increasing the net return. The lowest (116.08 ETB/ha) net return was recorded in weedy check plots.

Benefit: Cost ratio

The highest benefit: cost ratio (20.34) was for post emergence application of oxyflourfen at the rate of 0.5L/ha followed by pendimethalin at the rate of 1.5L/ha (14.65). This could be attributed to lower cost of protection in this treatments in compared with weed free plot. In weed free plot cost of protection increased due to regular weeding operation (four times) followed by clean cultivation. The weedy check plot had the lowest Benefit: Cost ratio (0.0) due to no bulb yield owing to more weed crop competition. This is in line with Kalhapure (2013) who recorded the lowest benefit: cost ratio from weedy check plot.

CONCLUSION AND RECOMMENDATION

The study showed that using pre emergence and post emergence herbicides alone or in combination with hand weeding in onion is highly profitable than using hand weeding alone. Future studies on the use of herbicides in onion with different rates and combinations with other methods are recommended. In conclusion, as the experiment was of a short duration it is necessary to repeat the study to further investigates and draws a comprehensive recommendation for onion cultivation in the study area.
Determine critical period of weed control is recommended.

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