# ASSESSMENT OF WEED SPECIES COMPOSITION AND THEIR MANAGEMENT PRACTICES IN ONIONAND EFFECT OFDIFFERENT WEED CONTROL METHODS IN ONION (*Allium cepa*L.)IN THE CENTRAL RIFT VALLEY OF ETHIOPIA

**M. Sc Thesis**

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**HAWASSA UNIVERSITY**

**College of Agriculture**

**Hawassa, Ethiopia**

**March, 2019**

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# DEDICATION

This thesis is dedicated to myadvisor, the late Dr. Yibrah Beyene

## STATEMENT OF THE AUTHOR

I declare that this thesis is my real work and all resources of material used for this thesis have been dully acknowledged. This thesis has been submitted in partial fulfillment of the requirement for the Master of Science at Hawassa University and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Place: Hawassa University, Hawassa

Date of submission………………………………..

## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| B: C | Benefit Cost ratio |
| DAS | Day after sowing |
| DAT | Days after transplanting |
| EARO | Ethiopian Agricultural Research Organization |
| EHDC | Ethiopian Horticultural Development Cooperation |
| ET-FRUIT | Ethiopian Fruit and Vegetable Marketing Enterprise |
| FAO | Food and Agricultural Organization |
| EAVIPM-IL | East Africa Vegetable Integrated Pest Management Innovation Lab |
| HW | Hand weeding |
| IWM | Integrated Weed Management |
| LSD | Least Significant Difference |
| M. a. s. l | Meters above sea level |
| MoARD | Ministry of Agriculture and Rural Development |
| PE | Pre- Emergence |
| POE | Post-Emergence |
| RCBD | Randomized Complete Block Design |
| SAS | Statistical Analysis System |
| SPSS | Statistical Package for social Science |
| WAT | Week after transplanting |

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## ABSTRACT

*Farmers have lack of awareness on weed problem on the crop and under take only manual weeding option to control those weeds in their fields. The study identified weed species composition and their management practices in onion (Allium cepa L.) fields of Adami Tulu, Dugda, Lume, and Around Adama woradas, Central Rift Valley of Ethiopia. In addition the effect of different weed control methods in onion were evaluated in Meki woreda during 2017/2018 under irrigation. Primary data were collected from 200 individual farmers using structured questionnaires, face to face interview. Secondary data were collected from different literatures and reports, and analyzed using descriptive statistics, using SPSS version 20. Weed species compositions were determined in a quadrat count of 0.5*$m^2$ *using systematic sampling techniques to obtain representative sample in the fields. The identified individual weed specieswere analyzed using quantitative means. Identified most problematic weed families wereAsteraceae(16 spp.), Poaceae(10 spp.), Solonaceae(2 spp.),Cyperaceae (2spp.)in descending order of 1*$^{st}$*, 2*$^{nd}$*, 3*$^{rd}$*and4*$^{rd}$ *abundant weed families, respectively.The experiment was contained 13 different weed control treatments and laid down in randomized complete block design with four replicates. Collected data were analyzed using SAS version 9.0. The weed density varied significantly with the treatments (*$P<0.05$*). At 60 DAT the lowest weed density (41.875/*$m^2$*) was recorded under HW3WAT followed by Oxyflourfen at 0.5L/ha + HW6WAT. At harvest the lowest weed density (30.875g/*$m^2$*) was obtained under Oxyflourfen at 0.5L/ha+HW6WAT. The lowest weed dry weight was recorded from Pendimethalin at 1.5L/ha+HW9WAT (293.27g/*$m^2$*). The highest weed controlefficiency(82.15%) was recorded under Pendimethalinat 1.5L/ha+HW9WAT followed by Oxyflourfen at 0.5L/ha+HW9WAT (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+HW3WAT (40.68cm). But the number of leaves per plant has shown no significant difference with respect to different treatments (*$P>0.05$*). 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+HW9WAT). 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 + HW6WAT (6.8%) as compared to the highest yield obtained in plot treated with oxyflourfen at rate of the 0.5 L/ha + HW9WAT. 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. Future studies on the use of herbicides with different rates and combinations with other methods, critical period of weed-control and more survey works in different onion production agro-ecologies are recommended.*

**Keywords**: Dominance, Effect, Frequency, Herbicides, Onion, Weeks after transplanting

# 1. INTRODUCTION

## 1.1. Background and Justification

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 among vegetable crops after tomato in volume of production 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. Onion is introduced to Ethiopia in the early 1970s by foreigners (Currah and Proctor, 1990). 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 creates many off-farm jobs (MoARD, 2005).

Agro-climatic conditions of Ethiopia, is suitable for the production of a broad range of commercial crops in general and successful production of onion in particular (Lemma *et al.*, 2006). However, the best growing altitude for onions under Ethiopian condition is between 700 and 1800 m above sea level and under mild climate without extremes of heat or cold and excessive rainfall (Lemma, 2004).

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 and the average yield of onion in the 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 farmersfield (Esheteu*et al*, 2006).

Low yield of onion is the result of various a biotic and bioticsocio economic conditions. These includes lack of appropriate agronomic practices, shortage of improved varieties and complex biotic factors like diseases, insect pests, weeds, poor extension services, high costs of chemicals and sometimes unavailable to small scale farmers (Esheteu*et al*, 2006; Melkamu *et al.*, 2015 and Bewuketu *et al*., 2016).

Weeds often pose serious problem. Weeds are the most underestimated pest in tropicalagriculture, but they have influenced human activities morethan other crop pests like insectsand other pest organisms (Appleby, 1996 and Savary *et al.,* 1997). Weeds are undesirable plants which have negative competitive impact on crops and needed to be controlled in an economical and practical way, in order to produce food, feed, and fiber for humans and animals. Weeds compete with onion for space, nutrients, water, carbon dioxide and light (Dunan *et al*., 1996). Weed infestations also serve as reservoirs of most diseases and insect pests(Jenkinson and Parry, 1994; Ormeno and Sepulveda, 2005; Palumbo, 2013).Due to their slow growth, small stature, shallow roots, and lack of dense foliage, onions cannot withstand the ill effects of weeds and considered as poor competitorsagainst weeds (Menges and Tamez. 1981).

Weed species common in onion field are reported by many authors in different countries of the world (Mishra *et al*., 1986; Nadagouda *et al*., 1996; Dandge and Satao, 1999; Vedprakash *et al*., 2000; Channappagoudar and Biradar, 2007; Sharma *et al*., 2009; Uygur *et al*., 2010), different weed species were reported in Ethiopian Agriculture (Stroud and Parker, 1989). The weed flora of Ethiopia is highly diverse and it is composed of a wide range of perennial and annual grasses and broad leaved weeds, sedges, parasitic and invasive weed species (Fasil, 2006). The nature of crop, cultural practices, cropping system, soil types, moisture availability, location, season, and soil management like fertilizing and previous weed management practices may cause variation in the weed species composition (Mennan and Isik, 2003).A quantitative and qualitative determination of weed species composition is determines, to a large extent, the type of weed management measures to be adopted and may help to predict yield losses and such information helps in deciding whether it is economical to control specific weed problem (Krop and Spitter,1990).

The crop loss due to weeds is variable; it ranged from low to high for different areas and crops. Weed causes about 10% yield loss in the less developed countries and 25% in the least developed (Akobundu, 1987). It causes heavy yield losses in the major crops averagely 25-32%(Fasil, 2006).The study conducted by Taye *et al*. (1996) revealed that competition of *Avena abyssinica*, *Lolium temulentum* L., *Snowdenia polystachya* and *Phalaris paradoxa* L. with bread wheat causes 48-86% a yield loss. Season-long exposure of onion to weedcompetition has been shown to reduce onion yieldup to 96% (Bond & Burston, 1996). There is no report available about the amount of onion crop yield losses due to weeds in Ethiopia.

Weed control has been observed as one of the most important practice in crop production 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 (Vissoh *et al.*, 2004). On small-scale traditional farming systems of developing countries, more than 50% of labor time is devoted to weeding, and is mainly done by the women and children in the farmer's family (Akobundu, 1996).In Africa 69% of farm children between the ages of 5-14 are forced to leave school and are used in the agricultural sector especially at peak period of weeding (Ishaya *et al.,* 2008b). Smallholder farmers spend 50-70% of their total labor time hand weeding (Chikoye *et al.,* 2007a). Defoer and Nieuwkoop (1991) reported, hand weeding costs about $14.6ha$^{-1}$, Whereas in USA, hand weeding costs have been reported to be about $92.59 ha$^{-1}$; five to seven times more expensive than using herbicides alone or in combinations (Appleby, 1996). Several herbicidesare registered for use in onions (Keeling *et al*., 1990). The use of selective herbicides together with mechanical methods for weed control in onion was recommended by Marwat *et al*. (1992), Rapparini (1994) and Hassan and Malik (2001).

Hand weeding is common weed control practice inonion producing areas of Central Rift Valley region of Ethiopia.It is labor intensive and expensive weed control method.Farmers spendmore of their total labor time on hand weeding.Women contribute more of the hand weeding labor by carrying children.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.Therefore, in such situations the herbicidal weed management practices become much more important. The chemical method is though being discouraged worldwide; however, its immediate effect and economic return cannot be ignored totally by the farmers of less developing countries like Ethiopia. As an alternative the ill effects of herbicides can be minimized through the judicious use at recommended doses with supplement of integrated weed management method. Identifying, the type of weeds and their management practices found in the area is prerequisite. However, No previous study conducted related with current problem in our country

Therefore, in view of the farmer's feedback associated with onion crop, weed species composition of the area and the importance of weed management practices, especially herbicidal weed management method, the present study was proposed with the following objectives.

## 1.2. Objectives

1. To determine the species composition of weeds and their management practices in onion fields of Adami Tullu, Dugda, Lume and around Adama woredas, Central Rift Valley Ethiopia.
2. To determine onion yield loss due to weed competition
3. To determine optimum combination of pre emergence and post emergence herbicides with hand weeding time for weed control in transplanted onion crops.
4. To evaluate the economics of using herbicides and hand weeding treatments in onion production

# 2. LITERATURE REVIEWS

## 2.1. Origin, Taxonomy and Distribution of Onion

The primary center of origin of onion is Central Asia with secondary center in Middle East and Mediterranean Region (Zohary and Hopf, 2000, Grubben and Denton, 2004). Onion (*Allium cepa L.*) belongs to the family Alliaceae and the genus Allium (Hanelt, 1990). The genus contains about 750 species, among which Onion (*Allium cepa*), shallot (*Allium ascolonicum*) and garlic (*Allium sativa*) are the most important ones Onion is herbaceous monocot crop cultivated as biennial for seed production; in the first season bulbs are formed while flower stalks and seeds are developed in the second season but for bulb production cultivated as an annual crop (Lemma, 1998).

Morphologically the onion has shallow root system and bulb consists of the thickened bases of leaves attached to a small conical stem. The bulb varies from flat to round in shape. Leaves are long, round and hollow. Flowers are small in size and formed at terminal tip of the stems as umbels (Norman, 1992).

Onions are one of the most important ingredients in the Ethiopian kitchen (MoARD, 2005). Its distinctive pungency is due to the presence of a volatile oil (*allyl propyl disulphide*) (Malik, 1994). The matured bulb contains some starch, appreciable quantities of sugars, some protein, and vitamins A, B, and C and minerals (Malik, 2000). Moreover, onion has medicinal importance because of its anti-carcinogenic and anti-biotic properties and anti-platelet, anti-thrombotic activities Onion is probably cultivated for its bulbs in many countries of tropical Africa such as Chad, Senegal, Mali, Burkina Faso, Ghana, Niger, Nigeria, Sudan, Ethiopia, Kenya, Tanzania, Uganda, Zambia and Zimbabwe (Grubben and Denton, 2004). In Ethiopia, onion was introduced to the agricultural community in the early 1970s through foreigners (Currah and Proctor, 1990). However, it rapidly becomes a popular vegetable crop widely grown in the country (ETFRUIT, 1992).

Studies conducted by Lemma and Shimeles (2003) revealed that onion is produced in many parts of the Ethiopia by smallholder farmers, private commercial growers and state enterprises. The major onion production regions in Ethiopia are Oromia, Amhara, Tigray, Benishngule-Gumuz, Gambela and (SNNP) South Nation Nationalities and Peoples Regions (CSA, 2017). Commercial production of onion is concentrated in central rift valley regions and Amhara Regions around Lake Tana areas and in some extent in Tigary region (Lemma Dessalegn and Shimelis, 2003). It is an important cash crop of Ethiopian farmers that helps them to improve their income. The crop is produced for local as well as regional export market like Djibouti, Somalia, and Sudan (MoARD, 2005). Its production is likely increasing in the near future because of the expansion of irrigable areas in the country (MoARD, 2005).

## 2.2. Agro - ecological Requirements of Onion

Onion is adapted to a wide range of temperatures and relatively frost tolerant. Best production is obtained when cool temperatures prevail over an extended period of time that permit considerable foliage and root development before bulbing starts. Bulb formation is favored by relatively high temperatures (Raemaekers, 2001). An optimum temperature for the production of onion ranges from 18 to 27°C. Temperatures below the optimum ranges caused bolting of plants consequently reducing bulb yield. Similarly, temperatures above 30°C lead to early maturity of the plant and reduced bulb yield (Lemma, 1998).

Onion has specific temperature requirements for seed and bulb production. In Ethiopia, day temperatures ranging from 20 $^0$C – 26 $^0$C and night temperatures of 11 – 15 $^0$C are ideal for bulb production, whereas temperatures between 9$^0$C and 17 $^0$C are favorable for onion seed production since these temperatures induce flower stalk development in onion (Lemma, 1998). Onion grows well in altitudes between 700 to 1800 meters above sea level (Lemma, 2004). Onion can be grown in all types of soils. But for higher yield well drained friable sandy loam soils with high fertility and high of organic matter are preferred (Brewster, 1994). Onion is also sensitive to acid soils and grows best when the pH is between 6.2 and 6.8 (Raemaekers, 2001).

### 2.3. Pest Factors Limiting Onion Production

Due to favorable tropical conditions in Ethiopia which favor the development of pests, onion is suffering from various weeds, diseases and insect pests throughout the country including the study area (Agegnehu*et al*., 2013).Diseases can cause severe losses by reducing yield and quality of marketable onions. Purple blotch, caused by *Alternaria porri*(Cooke and Ellis, 1879),is probably one of the most common diseases of onion and is distributed worldwide. Onion downy mildew, caused by the fungus *Peronospora destructor*(Berkeley, 1960), is very common throughout most areas of the world. Bacterial soft rot, caused by *Erwinia carotovora pv.carotovora* (Cortes, 1990), is a common problem in many vegetables. Bacterial soft usually develops in onions after heavy rains or after irrigation with contaminated water. This disease is primarilyseen on mature onion bulbs during warm humid condition (Lemma and Shimelis, 2003). Among insect pests, thrips, mites and cut worms are the most important ones in farmer`s onion farms. Thrips insects are the primary insect pest of onions. Thrips have rasping mouthparts that cause physical damage to the onion leaf. Damaged leaves are more susceptible to subsequent disease infection and are less efficient at photosynthesis. While these insects can appear in the fall, they are much more common in rain season as temperatures rise. Populations of thrips and the severity of this insect problem on onions can vary considerably from year to year.  Cutworms are the larval stage of many species of moth in the *Noctuidae* family. These caterpillars generally feed at night and hide during daylight hours. Damage generally detected as plants cut off near the soil line. Their nocturnal habits and cryptic coloration make cutworms difficult to observe, which is required for proper diagnosis of the problem (Lemma, 2004).

**2.4. Economic Importance of Weeds**

Weeds are plants growing in a place where it is not desired at a particular time as they are interferewith human activity or welfare (European Weed Research Society, 2011). They are of great menace as they interfere with production of crop and add to the cost of cultivation. The reduction in crop yield has direct correlation with weed competition. Losses inflicted by weeds in agriculture are by far greater than those caused by combined effect of pathogens and insects (Elamin, 1991). Weeds through competition with crops for water, nutrients, space and light lead to serious yield losses. Weeds are also act as an alternative hosts for many diseases and animal pests. They cause damage by reduction in value and reduction in farm lands, loss of quality of crop produce, reduce human efficiency, increase costs of insects and diseases control problems and impair the quality of farm products. Some weeds are poisonous to man and animals. Also weeds reduce the quantity and quality of livestock products, increase the cost of labor and equipment and irrigation. As in many crops, weeds cause yield reduction in onions owing to slow emergence, low initial growth rate, long vegetative period and low competitive ability of the crop. For this reason, onions require absolute early weed control.The annual global economic loss caused by weeds has been estimated at more than $100 billion U.S. dollars (Appleby *et al.* 2000). Season-long exposure of onion to weedcompetition has been shown to reduce onion yieldup to 96% (Bond & Burston, 1996).

**2.5. Common Weed Flora in Onion Field**

Weed flora differ widely in their diversity depending upon location, year, environmental condition, soil conditions, previous management practices and hence the information on the weed spectrum in onion field will be of great use for the formulation of effective weed management practices. The major weed flora of onion in field having vertisols soil composed of monocots such as *Cyperus rotundus*, *Cynodon dactylon, Setaria glauca*, *Digitaria sanguinalis*, *Panicum isachne*, *Commelina benghalensis* while, the predominant dicots are*Parthenium hysterophorus*, *Phyllanthus niruri*, *Hibiscus panduriformis*, *Trianthema monogyna*, *Eclipta alba*, *Amaranthus viridis*, *Portulaca oleraceae*, *Cocculus hirsutus* and *Corchorus trilocularis* (Nadagouda*et al*., 1996).

According to Dandge and Satao (1999) the major weed flora of onion in field having slightly alkaline sandyclay loam soil were *Parthenium hysterophorus*, *Physalis minima*, *Euphorbia* spp., *Chenopodium album*, *Anagalis arvensis*, *Amaranthus viridis* and *Argemone mexicana* among the broadleaved weeds,and *Cyperus rotundus*, *Commelina benghalensis*, *Cynodon dactylon*, *Dinebra retroflexa* and *Panicum* spp., among thenarrow leaved weeds.

The weed flora of onion field having sandy loam soil included *Cyperus rotundus* (28%), *Coronopus didymus* (48%), *Anagallis arvensis* (6%) and other weed (20%) which included *Convolvulus arvensis*, *Melilotus* spp., *Chenopodium album* and *Poa annua. Coronopus didymus* was the dominant broadleaved weedand *Cyperus rotundus* was dominant among sedges and grasses (Chopraand Chopra, 2007). Weed flora such as *Cyperus rotundus*, *Parthenium hysterophorus*, *Phyllanthus niruri*, *Euphorbia geniculata* and *Dinebra retroflexa* were noticed in blackclay soil as reported by Channappagoudar and Biradar (2007).

Studies by Uygur *et al*. (2010) in onion crop revealed that different weeds observed were *Galinsoga parviflora, Nicandra physaloides, Medicago polymorpha, Convolvulus arvensis, Chenopodium album, Cyperus rotundus, Amaranthus retroflexus, Xantium strumarium, Polygonum aviculare, Galium aparine, Digitaria sanguinalis, Chenopodium murale, Amaranthus hybridus and Anagallis arvensis.*

Sharma *et al*. (2009) observed that *Cyperus rotundus* (0.35%), *Rumex dentatus* (2.4%), *Melilotus alba* (0.35%), *Chenopodium album* (0.35%), *Fumaria parviflora* (1.0%), *Anagallis arvensis* (1.25%), *Veronica agrestis* (0.35%), *Spergula arvensis* (20.3%), *Trigonella polycerata* (1.4%), *Medicago denticulata* (1.05%) and *Lepidium sativa* (41.7%) were the predominant weed species of onion field in sandy loam soils. The dominant grassy weed species were *Cynodon dactylon*, *Acrachne racemosa* and *Dactyloctenium aegyptium*. Among the broad leaved weeds *Boerhaavia diffusa*, *Parthenium hysterophorus* and *Digetaria arvensis* were the dominant weeds.

Studies by Mishra *et al*. (1986) revealed a wide range of weeds were *Cyperus rotundus*, *Cynodon dactylon*, *Scirpus moritimus*, *Asphodelus tennifolius*, *Trianthema portulacastrum*, *Melilotus indica*, *Anagallis arvensis*, *Canabis sativa*, *Acalypha indica*, *Euphorbia microphyla*, *Vicia sativa*, *Convolvulus arvensis*, *Amaranthus viridis*, *Cirsium arvensis* and *Launea pinnatiful* in onion raised in sandy loam soil during rabi season. Singh *et al*. (1998) reported that *Chenopodium album*, *Portulaca oleraceae*, *Echinochloa crusgalli* and *Cyperus* spp., were the dominant weeds in onion.

The predominant weed species infesting the rabi season onion were *Galinsoga parviflora*, *Brachiaria ramosa*, *Cyperus rotundus*, *Cannabis sativa*, *Polygonum plebjum*,*Fumaria parviflora*, *Phalaris minor* and *Oxalis latifolia* (Vedprakash *et al.*, 2000).

**2.6. Critical Period of Crop Weed Competition in onion**

The critical period can be defined as "the shortest span of time in the ontogeny of crop growth when weeding will result in higher economic return."A fundamental principle of plant competition is that early occupants on a soil tend to exclude the late comers. This principle finds application in practical weed control. Weeds are capable of accumulating dry weight faster than the crop plants. Thus the duration of weed infestation and time of weed removal has a significant influence on crop growth and economic yield.

Critical period of crop weed competition is the prime factor, which determines the growth and yield of onion. Several workers have reported different critical periods ranging from 30 to 60 DAS and established that critical period of weed competition in between two to eight weeks after sowing. Onion faces weed competition during the early stage of crop growth. So, the field should be kept weed free for a period of 45 days (Bhan *et al*., 1971). According to Roberts (1976) there was no adverse effect on onion bulb yield when maintained a weed free condition for about five weeks after crop establishment. Studies by Labrada (1977) revealed that the critical period of weed competition was between 30 to 40 days after transplanting of onion. Purwito (1978) indicated that a shorter period of 20 to 30 days is the most critical period for weed competition in transplanted onion. Onion crop was susceptible to weed competition between two to ten weeks (Thomas and Wright, 1984).The first one month was apparently the most critical stage of crop weed competition in onion (Mishra *et al*., 1986). Bhalla (1987) observed a longer period of first six to eight weeks or more after crop emergence as critical period and weeds that emerge subsequently did not affect the yield. Babiker *et al*. (1987) reported that unrestricted weed growth reduced crop yield by 98 percent and onion was more sensitive to weed competition between two to six weeks after its emergence. Some studies pointed out that single weed removal at proper time may help in avoiding onion yield losses. This proper time may be 21-56 days after the germination of 50 per cent of onion. According to the findings of several investigators, either singleor repeated weed removal at optimal period helps to avoid the yield decrease in onion (Bondand Burston, 1996).

Weed competition during the first 15 vegetative days does not influence negatively onion crop. If the crop is preserved without weeds only for the first 15 days and later on weeds are not destroyed, the yield decreases was estimated to be 81% (Shuaib, 2001). Weed competition throughout the crop period on an average caused 82.2% reduction in bulb yield. Weed infestation prevailed up to 15, 30, 45 and 60 days after transplanting registered 1.2, 39.8, 56.1 and 69.3% reduction in bulb yield over weedy condition throughout the crop. However, there was no significant difference in bulb yield due to weedy situations up to 60 days and weedy conditions throughout crop season Tewari *et al.*,(2003). Onion is very sensitive to weed competition during the entire vegetative period since luxuriant growth of leaves is arrested, which would otherwise cover inter-rows and prevent weed germination. The competitive power of onion was the weakest one against weeds (Kavaliauskaite, 2009).

## 2.7. Effect of Hand Weeding on Weeds and Onion

It is an established fact that weeds can be controlled manually by hand weeding twice or thrice during the season. Timely cultural operation is one of the important practices of improved onion production package. According to the research recommendation, the number of cultural operations which can be practiced in one growing period of a crop is 2-3 times. The first cultivation should be carried out 15 days after transplanting, while the second after 30 days and the third after 50 days of transplanting to loosen the soil around the root zone (MoARD, 2005).

Hassen and Malik (2002) reported that hand weeding is the best approach for weed control as it provides maximum weed control in tested crop field. In order to reduce crop damage and to allow for the use of mechanical tools such as hoes, removal of large weeds with extensive root systems may damage crop roots or foliage. Hand weeding and herbicide applications provide superior in decreasing weed density.Rahman *et al*. (2012) conducted an experiment in Pakistan to study the relationship between manual weeding intervals and onion yield and observed that onion yield and yield components (bulb diameter, height and weight) increased significantly with increasing frequency of manual weeding, whereas weed density, fresh and dry weed biomass decreased significantly with the increase in frequency of manual weeding.

## 2.8. Effect of Herbicides on Weeds and Onion

Herbicides are chemicals that are used for killing weeds or suppress the plant growth. The practice of weed management using herbicide is called chemical weed control.

### 2.8.1. Pre- emergence herbicides

The dinitroaniline is soil-applied herbicides provide excellentcontrol of annual grasses (Wilcut *et al.,* 1995)Uptake of dinitroaniline herbicides is primarily through roots and emerging shoots (Appleby and Valverde, 1989). The effectiveness is dependent upon several factors, includingmovement of the herbicide into the soil either through water provided by rainfall orirrigation, or by mechanical incorporation (Prostico *et al*., 2001). It is adsorbed more readily and is less mobile in organic soils than in mineral soils (Sharom and Stephenson, 1976).The dinitroaniline herbicides have very low water solubility and are subject to losses due tophotodecomposition and volatilization (Weber, 1990). Therefore, incorporation soon afterherbicide application is important for effective weed control.Pendimethaline (Stomp® 455 CS)is a dinitranalinine herbicide group, a capsule suspension selective herbicide that releases slowly the active ingredient into the soil depending on the amount of moisture in the soil. The mode of action ofpendimethalin is a meristematic inhibitor that interferes with the plant's cellular division or mitosis. It alters chemical composition and several biochemical process of the pant.

Thakral *et al.,* (2003) reported that weed free treatment provided the maximum number of total and healthy seedlings when treated with Pendimethalin at the rate 1 kg ha$^{-1}$ applied as pre-emergence. Marwat *et al.(*2005) recorded the maximum weeds kill percentage (88.6%), size of onion bulbs (78.25gm), onion diameter (5.49 cm) and onion yield (29950 kg ha$^{-1}$) in pendimethalin treatment (1.32 kg ha$^{-1}$), unlike the weedy control which recorded 00.0%, 47.75gm, 4.06 cm, and 13700 kg ha$^{-1}$, respectively. Kumar and Mourya (2006) reported that Pendimethalin at rate of 1kg ha$^{-1}$ along with hand weeding at 45DAP was the most effective and economically viable treatment on the bulb sprouting percentage, plant height, and number of leaves per bulb, length of leaves, and total production.Nargis and Jilani (2006) reported that herbicides applied during pre emergence stage, significantly controlled the weed population. However, the 3.0 $Lha^{-1}$ Pendimethalin treated plot gave the highest yield (40.28$tha^{-1}$) and bulb weight (127.90gm) and was superior to other herbicidal treatments in increasing length, diameter, weight and yield of bulb.Hussain *et al*. (2008) reported that the maximum size of onion bulbs (79 ml), onion count (50 $m^2$) and yield (28730 kg $ha^{-1}$) were recorded in the hand weeded plots followed by pendimethalin (77ml, 49 $m^2$ and 28100 kg $ha^{-1}$) as compared to weedy check (50ml, 40 $m^2$ and11980 kg $ha^{-1}$). Sharma and Khandwe (2008) studying the effects of different weed control measures (alachlor at 1.00 or 1.50 kg $ha^{-1}$, and pendimethalin at 1.00 or 1.25 kg $ha^{-1}$) on weed density, and growth and yield of onion found that the highest plant height, number of leaves per plant, fresh and dry weights per plant, bulb diameter, and marketable bulb yield were recorded for the weed free plot, followed by plots treated with pendimethalin at 1.25kg $ha^{-1}$. Zubair *et al*., (2009) also studied the effect of different weed management practices in onion. For controlling weeds, Stomp 33% was found to be the best. Maximum bulb yield of 9.32 t $ha^{-1}$ was found in weeds free (manual weeding throughout the season) and Stomp 33% with bulb yield of 8.89 t $ha^{-1}$, whereas, minimum bulb yield (5.70 t $ha^{-1}$) was recorded in weedy check plots. Patel *et al.* (2012) reported that application of Pendimethalin at rate 1 kg $ha^{-1}$ followed by one hand weeding produced higher onion bulb yield of 39.3, 36.6 and 38.0 t $ha^{-1}$. Rahman *et al.* (2012) advocated that pendimethalin at rate 2.5 $Lha^{-1}$found to be the best herbicide as compared to control and other herbicides for controlling of weeds. The maximum bulb yield was found in weed free treatment (manual weeding throughout season), followed by pendimethalin, whereas, minimum bulb yield was recorded in control.Khatam *et al.* (2012) reported that pendimethalin at the rate of 2$Lha^{-1}$ was the best herbicide as compared to the other weed management practices used by farmers of the area. The onion bulb yield was highest in the manual weed control followed by pendimethalin at the rate of 2 $Lha^{-1}$.Shinde *et al.* (2013) found that pendimethalin (38.7% CS) at rate 1.75 L/ha exhibited the greatest grass weed control efficiency (90.19%) and resulted in the highest yield (422.58 q $ha^{-1}$), whereas oxyfluorfen (23.5% EC) at rate 1 L $ha^{-1}$ showed the greatest broadleaved weed control efficacy (82.95%). Rathod *et al.* (2014) reported that pre-emergence application of pendimethalin at rate 0.9 kg $ha^{-1}$ showed negative effect on the germination, plant height and dry matter accumulation of indicator plant sorghum (30 DAS), but clearly indicated that there was not any residual phytotoxic effect in the soil.

### 2.8.2. Post- emergence herbicides

Oxyflurofen is a member of the diphenylether group of herbicides used as a selective herbicide applied pre and post-emergence against both types of annual weed in many crops including onion. The mode of action of Oxyflurofen is to inhibit Protoporphyrinogen oxidase. it causes necrosis and sometimes chlorosis when applied to foliage (Mohamed, 1995).

Mondal *et al.* (2005) observed that the lowest weed density at 30 DAT with the treatment oxyfluorfen (200$gha^{-1}$), while that at 60 days after transplanting was observed with the treatment oxyfluorfen along with hand weeding. Bulb yield was highest with oxyfluorfen (100$gha^{-1}$) along with hand weeding treatment.Qasem (2006) used 14 herbicides for control of weeds in seed bed sown onion (*Allium cepa* L. cv. Geza 20) and the effect of different herbicides on onion seedlings and weed growth were investigated. Out of 14 herbicides tested in 16 treatments, post emergence application oxyfluorfen treatment was the best of all herbicides used.Mother bulb yield was significantly higher (121.9 $qha^{-1}$) with the application of oxyfluorfen at rate 0.15 $kgha^{-1}$ a day after transplanting and was found to be efficient with higher bulb diameter (4.0 cm). Higher dose of oxyfluorfen (0.30 kg $ha^{-1}$) was not efficient in achieving higher yields (Chopra and Chopra, 2007).Dalavai *et al.* (2009) reported that oxyfluorfen (150 g $ha^{-1}$) and pendimethalin (750 g $ha^{-1}$) exhibited the greatest weed control efficiency (62.9 and 60.4 respectively) in onion and oxyfluorfen gave the highest bulb yield.Murthy *et al.* (2009) used pre-emergence application of herbicides viz., oxyfluorfen at rate 0.09 kg $ha^{-1}$, pendimethalin at rate 0.75 kg $ha^{-1}$ and metolachlor at rate 0.75 kg $ha^{-1}$ in combination with one hand weeding at 45 DAS resulted in higher bulb yield of onion(148.91, 147.25 and 146.50 q$ha^{-1}$, respectively) due to maintenance of weed free condition during initial stages with pre-emergence application of herbicides and control of late emerged weeds as a result of one hand weeding at 45 days after sowing. The weed control efficiency was more than 80 and 95 % at 45 days after sowing and at harvest. A field experiment carried out by Bharathi *et al. (*2011) revealed that oxyflourfen at rate 0.15 kg $ha^{-1}$ with one hand weeding at 45 DAT recorded highest bulb yield and was at par with pendimethalin at rate 1 kg $ha^{-1}$ with one hand weeding at 45 DAT. Saini and Walia (2012) studied the effect of land configuration and weed management in onion (*Allium cepa* L.). Application of oxyflourfen gave the highest bulb yield, which was at par with pendimethalin and two hand weeding. A field experiment were conducted for two years by Ramalingam *et al.* (2013) showed that application of new formulation of oxyfluorfen (23.5% EC) at 200 g $ha^{-1}$ as pre-emergence herbicide can keep the weed density and dry weight below the economic threshold level and increase the bulb weight (42.56 and 43.87 g) and yield (15940 and 15610 kg $ha^{-1}$) in onion.An experiment conducted by Tripathy *et al.* (2013) to study the weed management strategies in onion (*Allium cepa* L.). It was observed that plant height was greatest with the use of pendimethalin 30 EC (5 m$lL^{-1}$) applied before planting and at 30 DAS and the number of leaves per plant, marketable bulb yield and total bulb yield were highest for oxyfluorfen 23.5 EC (2ml$L^{-1}$) applied before planting and hand weeding at 40-60 DAT.

**2.9. Effect of Integrated Weed management on Weed and Onion**

Integrated weed management (IWM) refers to the system of combining two or more weed management systems at low input level to keep weed interference in a given cropping system below economic threshold level. Vegetables including onion respond significantly to integrated weed management strategies being its short duration crops.

Bhutia *et al.* (2005) reported that the highest bulb yield was obtained with weed free treatment followed by oxyfluorfen + hand weeding at 45 DAT which was at par with twice hand weeding at 25 & 45 DAT while the season long crop-weed competition (control) reduced the bulb yield by 38.26%. Pre-emergence application of pendimethalin at 0.75 kg$ha^{-1}$ was found to be the most effective treatment among herbicidal treatments. Ghadage *et al*., (2006) studied the effect of herbicides (pendimethalin at 1 kg$ha^{-1}$ and oxyfluorfen at 0.2 kg $ha^{-1}$), alone and in combination with hand weeding (20 and 40 days after transplanting) and reported that pendimethalin at 1 kg $ha^{-1}$+ hand weeding 40 days after transplanting and two weeding at 20 and 40 days after transplanting proved to be the superior integrated weed control approach control weeds and increase weed control efficiency. Oxyfluorfen at 0.15 kg $ha^{-1}$followed by hand weeding in the mother bulb onion production resulted in higher weed control efficiency of 81.4% and was comparable with the hand weeding at 20, 40 and 60 days after transplanting (Chopra and Chopra, 2007).Kathepuri *et al.* (2007) observed that the application of pendimethalin at 1.0 kg $ha^{-1}$as pre-plant with one hand weeding at 40 DAT were most effective in reducing the weed density and weed dry weight significantly in irrigated onion under Maharashtra conditions.A field experiment was conducted by Shete *et al.* (2008) and results revealed that the significantly lowest dry weight of weeds at harvest (18.67 gm$^{-2)}$ was observed in the weed free plots up to 60 DAT which was followed by pendimethalin application at 1.5 kg ha$^{-1}$ (PE) along with one hand weeding at 45 DAT. The highest weed control efficiency was observed in weed free plots up to 60 DAT (79.09%) followed by application of pendimethalin at 1.5 kg ha$^{-1}$ (PE) along with one hand weeding at 45 DAT (64.33%).Pre-emergence application of oxadiargyl at 120 gha$^{-1}$, oxyfluorfen at 250 gha$^{-1}$, trifluralin at 1000 gha$^{-1}$and pendimethalin at 1000 gha$^{-1}$supplemented with one hand weeding at 45 DAT result significant reduction of weed population and higher bulb yield in onion (Yadav *et al.*,2009). Khokhar *et al.* (2010) reported that the application of pendimethalin at 0.825 Lha$^{-1}$, or oxadiazon at 0.240 Lha$^{-1}$ 2 DAT alone and in combination with one manual hand weeding found to have significant effects on weed competition and bulb yields.A field experiment was conducted by Kathepuri *et al.* (2011) during *Rabi* season to study the effect of different weed control practices on growth, yield and yield attributes of onion. The results indicated that the application of two hand weeding at 20 and 40 DAT was significantly superior for weed control followed by spraying of pendimethalin 30 EC at 1 kgha$^{-1}$ as pre plant incorporation along with one hand weeding at 40 DAT.A field experiment was conducted by Kalhapure and Shete (2012) to find out practically convenient and economically feasible weed managementpractice in onion. Different combinations of hand weeding with application ofpendimethalin at 1.0 kg ha$^{-1}$ (pre-planting) and oxyfluorfen at 0.25 kgha$^{-1}$ (post - emergence)were used in onion. Weed free check treatment (three hand weeding at 20, 40 and 60DAS) recorded significantly lowest weed density, dry weight of weed and higher weedcontrol efficiency. All the growth attributes of onion viz., plant height, neck thickness,bulb weight and diameter were recorded maximum in weed free plots. Kaur *et al.*

(2013) reported that in onion the application of oxyfluorfen gave the highest bulb yield in Punjab which was at par with pendimethalin and two hand weeding.Sankar *et al*. (2015) reported that the application of oxyflurofen 23.5 % EC at 1.5 $mlL^{-1}$ before planting and one hand weeding at 40-60 days after transplanting recorded the higher marketable bulb yield (43.5 $tha^{-1}$) with maximum weed control efficiency of 78.4%.

## 2.10. Economics of Herbicidal Weed Control in Onion

The final choice of any weed management method depends upon the cost of herbicides and their relative efficacy. Higher money value and less cost of cultivation are desirable traits for getting higher returns.

Ravinder Singh *et al*. (1998) obtained maximum net return during both the year of study from oxyfluorfen at 0.25 $kgha^{-1}$ + hand weeding at 40 DAP (\$871.27$ha^{-1}$ and \$891.64$ha^{-1}$, respectively) which was followed by oxyfluorfen at 0.37 $kgha^{-1}$ (\$579.26$ha^{-1}$ and \$739.08$ha^{-1}$, respectively) as compared to weedy check (\$56.43$ha^{-1}$ and \$20.01 $ha^{-1}$, respectively). Yadav *et al*. (2000) suggested that use of chemicals such as oxyfluorfen and pendimethalin was a better option for getting higher bulb yield and net income in onion. Ranpise and Patil (2001) recorded maximum cost benefit ratio with oxyfluorfen 0.40 $kgha^{-1}$ followed by oxyfluorfen 0.20 kg $ha^{-1}$. Ravinder Singh *et al*. (2001) recorded highest bulb yield and net return from treatment having oxyfluorfen 0.25 $kgha^{-1}$ + hand weeding at 40 DAP followed by oxyfluorfen 0.37 $kgha^{-1}$. Kolhe (2001) found that pre-emergence application of oxyfluorfen at 0.15 $kgha^{-1}$ + hand weeding at 35 DAT recorded higher net return (\$1350.04$ha^{-1}$) and benefit cost ratio owing to lower cost of weed control as compared to hand weeding.The pre-emergence application of pendimethalin at 1.5 $kgha^{-1}$ supplemented with one hand weeding gave the highest net return of \$1213.08$ha^{-1}$ which was 43.4 percent higher than farmers practice as noticed by Rameshwar *et al*. (2002).Nandal and Ravinder Singh (2002) observed higher net return when oxyfluorfen at 0.25 kgha$^{-1}$ was supplemented with hand weeding at 40 DAT (\$876.85ha$^{-1}$) followed by oxyfluorfen at 0.75 kgha$^{-1}$(\$79.80 ha$^{-1}$) and pendimethalin at 1.00 kgha$^{-1}$ plus hand weeding at 40 DAT (\$745.26ha$^{-1}$) and net loss of \$38.22ha$^{-1}$ where weeds were not controlled under weedy check in onion. According to Mondal *et al.*(2005) report higher net monetary returns were obtained with pre-emergence application of oxyfluorfen at 100 gha$^{-1}$ supplemented with one hand weeding on 25 DAT (\$490.17ha$^{-1}$) followed by fluchloralin at 750gha$^{-1}$ + hand weeding (\$465.88ha$^{-1}$), pendimethalin at 750 gha$^{-1}$ + hand weeding (\$458.12ha$^{-1}$) and oxyfluorfen at 200 gha$^{-1}$ (\$457.39 ha$^{-1}$). There was net loss of \$56.81ha$^{-1}$under weedy check. Pre-emergence application of pendimethalin at 1.00 kgha$^{-1}$ supplemented with one hand weeding in onion gave the higher net return of 747.21ha$^{-1}$ with maximum benefit cost ratio of 8.77 (Channappagoudar and Biradar, 2007). Economic analysis by Patel *et al.* (2011) revealed that higher net profit (\$3924.57ha$^{-1}$) in onion crop was obtained with application of pendimethalin at rate of the 1.0 kgha$^{-1}$ + hand weeding on 40 DAT with the B:C ratio of 7.85 followed by oxyfluorfen at 1.0 kgha$^{-1}$ + hand weeding on 40 DAT(\$3669.48ha$^{-1}$) and weed free control. Saini and Walia (2012) studied the effect of land configuration and weed management in onion (*Allium cepa* L.). Application of oxyflourfen gave the maximum net returns of \$2703.57ha$^{-1}$ and B: C ratio (7.63). Weedy control treatment recorded the lowest net returns of \$1373.63ha$^{-1}$ and B: C ratio (4.10).Kumar *et al*., (2013) reported that the pendimethalin at rate of the 0.75kgha$^{-1}$ + Hand weeding gave highest net return due to weed control. Pendimethalin at rate of the 1.5kgha$^{-1}$gave highest marginal benefit cost ratio of 40.7 followed by pendimethalin at 0.75 kgha$^{-1}$ + hand weeding

# 3. MATERIALS AND METHODS

## 3.1 Description of Study Areas

The study was conducted in four districts of East Shoa zone of Oromia Regional State, Central Rift Valley (CRV) in Ethiopia (Ziway, Meki, Koka and around Adama) (Figure 1).The area is known by high potential irrigated vegetable production (Moti. 2002).

The area has an arid to semi arid climate with minimum and maximum temperatures of 12.6 $^{0}$C and 28.5 $^{0}$C respectively. The area is characterized by a bi- modal rainfall pattern ranging from 500 – 850mm with long rainy season extending from June to September(Jansen *et al*., 2007). The soils are largely volcanic in origin, sandy loam texture with pH ranging from slightly acidic to very alkaline (Jansen *et al*., 2007).

The potential irrigation lands were owned majorly by the farmers' association and large scale private investors. There are also a few individual farmers engaged on using their own irrigation land. Most of the lands owned by the individual farmers and farmers association have been transferred to small scale investors through contractual agreement for one year to several years due to the rise of production cost that small scale farmers can't pay for.

This approach made the crop pests including weed and soil fertility management very problematic. Especially those producers producing on land of short period contractual agreement were found only giving main concern for productivity of that season without considering the issue of pest resistance development and soil fertility degradation. The area has severe invasive weed species problem with *Eichhornia crassipes*, the water Hyacinth (Firehun *et al*, 2007).

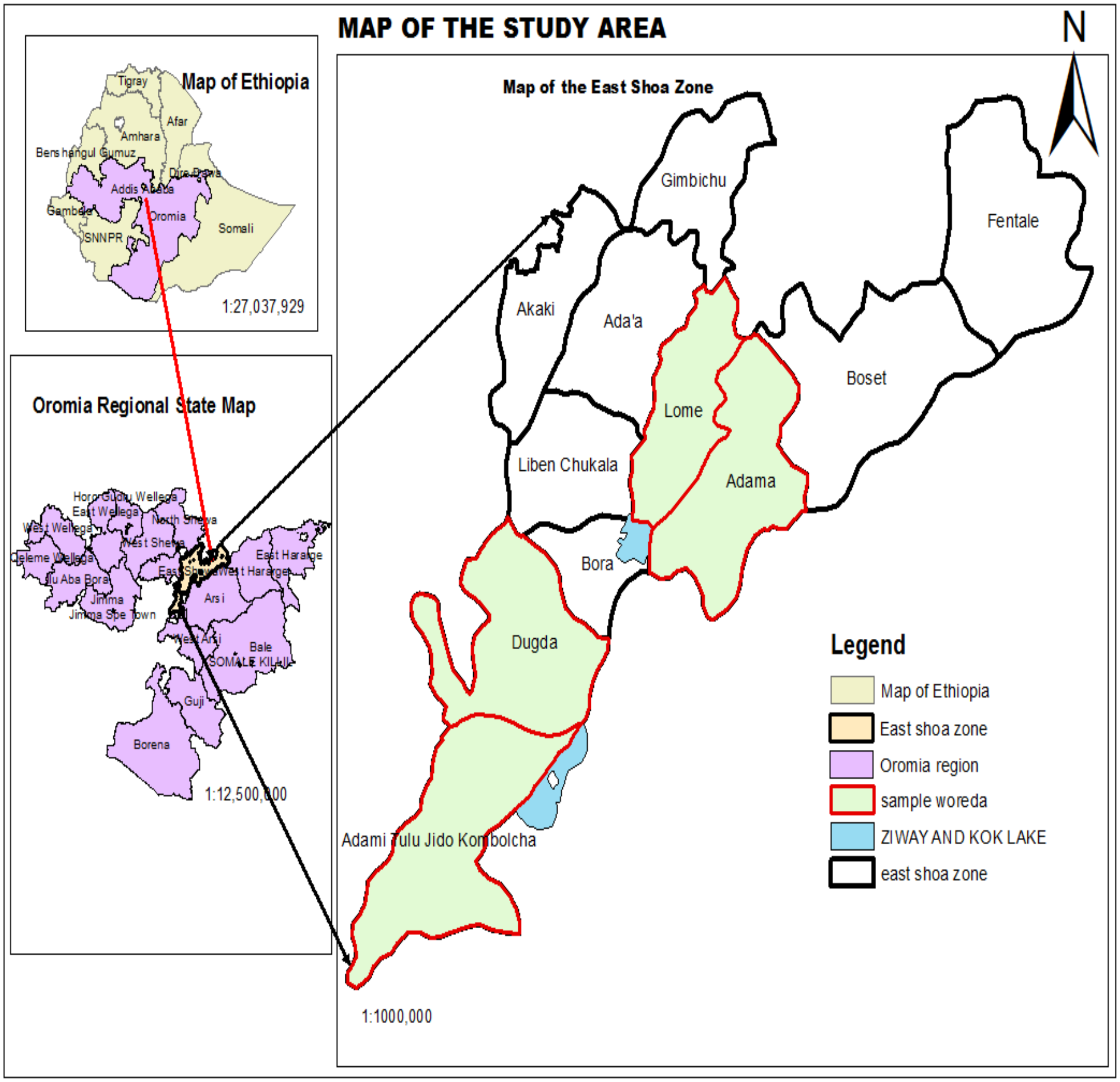


Figure 1.Map of the study areas

Table 1.Geographical description of the study areas

| Location | Altitude (m. a. s. l) | Longitude | Latitude |
|---|---|---|---|
| Adami Tullu | 1500-2300 | $38^{0}$01’ to $39^{0}$30’ | $7^{0}$ 15’ to $8^{0}$30’ |
| Dugda | 1636-2200 | $38^{0}$01’ to $39^{0}$30’ | $7^{0}$ 15’ to $8^{0}$30’ |
| Lume | 1500-2300 | $38^{0}$25’ to $39^{0}$09’ | $7^{0}$57’ to $8^{0}$28’ |
| around Adama | 1500-2300 | $38^{0}$01’ to $39^{0}$30’ | $8^{0}$06’ to $8^{0}$18’ |

### 3.2. Assessment of Weed Management Practices in Onion Farms

#### 3.2.1. Sampling procedure, data collection and analysis

To achieve the objective of the study relevant data were gathered from both primary and secondary sources. Primary data were collected from 200 individual farmers where, 163 (82.5 %) male and 37(17.5%) female by using structured questioners, face to face interview. The farmers were interviewed following two stage sampling methods. In the first stage, four woredas of the region were selected and in the second stage from each woredasfive kebeles were purposively selected based on irrigationsupply potential. Sample farmer was selected from each kebele using non- probabilistic judgment sampling technique.The survey design team spent several days on interviewing farmers in the four woredas. The duration of each interview was about 15-20 minutes. Farmers were given all basic information needed to answer the questions, assuring them that individual information will remain confidential. Survey team also explained the purpose of the interview, the objectives of survey and any potentially confusing technical terminology.Secondary data were collected from different sources like literatures and reports. The collected data included demographic features of respondents, farmers practices associated with weed, the type of weed species according to farmers and weeds considered to cause serious problems, types of weed management methods practiced and their cost of management. Particularly, farmer's experience of herbicide usage on onion was investigated. Collected data were analyzed using descriptive statistics, using SPSS version 20, and presented in tables and graphs with detail explanation

### 3.3. Assessment of Weed Flora Composition in Onion Farms

#### 3.3.1. Sampling procedure and data analysis

The survey was carried out in 2017/2018growing season in fields which were not yet weeded with area ranging between 1-1.5hectares of land about harvest stage of onion and the harvested field. Onion production requires intensive management and fields were regularly weeded in the study area. Thus, it was difficult to get and identify many weeds. Weeds were sampled using 0.5 $m^2$quadrate thrown in systematic way to obtain representative sample in the fields. In each field a pattern of an inverted W (Thomas, 1985) was followed continuously for every 5-7 meters. At each field 7-13 sample quadrats were taken based on field size and species distribution.

The first quadrat sample was taken following the procedure of Kevine *et al*., (1991), where the surveyor walks 50 paces along the edge of the field, turns at right angle and walks 50 paces into the field, throws the quadrant and starts taking sample. Ten fields were surveyed in each kebele. Weed specimen in the field were identified using weed identification guides (Ciba-Geigy, 1980; Terry &Michieka, 1987; Stroud and Parker, 1989; McIntyre, 1991; Naidu, 2012), literatures(Esayas *et al.,* 2012;Terfa, 2018)with experts. The data on weed species were analyzed using quantitative means formula described by Taye and Yohannis (1989).

**Frequency:** $F = \frac{X}{N} X100$………...………………………………………..……………. (1)

Where, F = frequency,X = number of occurrences of a weed species, N = sample number.

**Abundance:** $A = \frac{\sum W}{N}$..………………………………………...………………………. (2)

Where, A = abundance, W = number of individuals of a weed species, N = sample number.

**Dominance:** $D = \frac{A}{\sum A} X100$……………………....…………………………..................…… (3)

Where, D = dominance, ∑A = total abundance of all species.

**Similarity index:**$SI = \frac{(Epg)}{(Epg + Epa + Epb + Epc + Epd)} X100$ ……………………………………... (4)

Where, SI= similarity index; Epg = number of weed species found in all locations (around Adama, Lume, Dugda and Adami Tullu); Epa = number of species only in location a (around Adama); Epb = number of species only in location b (Lume); Epc= number of species only in location c (Dugda); Epd = number of species only in location d (Adami Tullu).

### 3.4. Effect of Different Weed Control Methods on Weed Flora and Yield of Onion

#### 3.4.1. Experimental site description

The experiment wasconductedtwo times at onion production area of Dugda woredaduring 2017/2018 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.

### 3.4.1.1. Weather condition of the study area

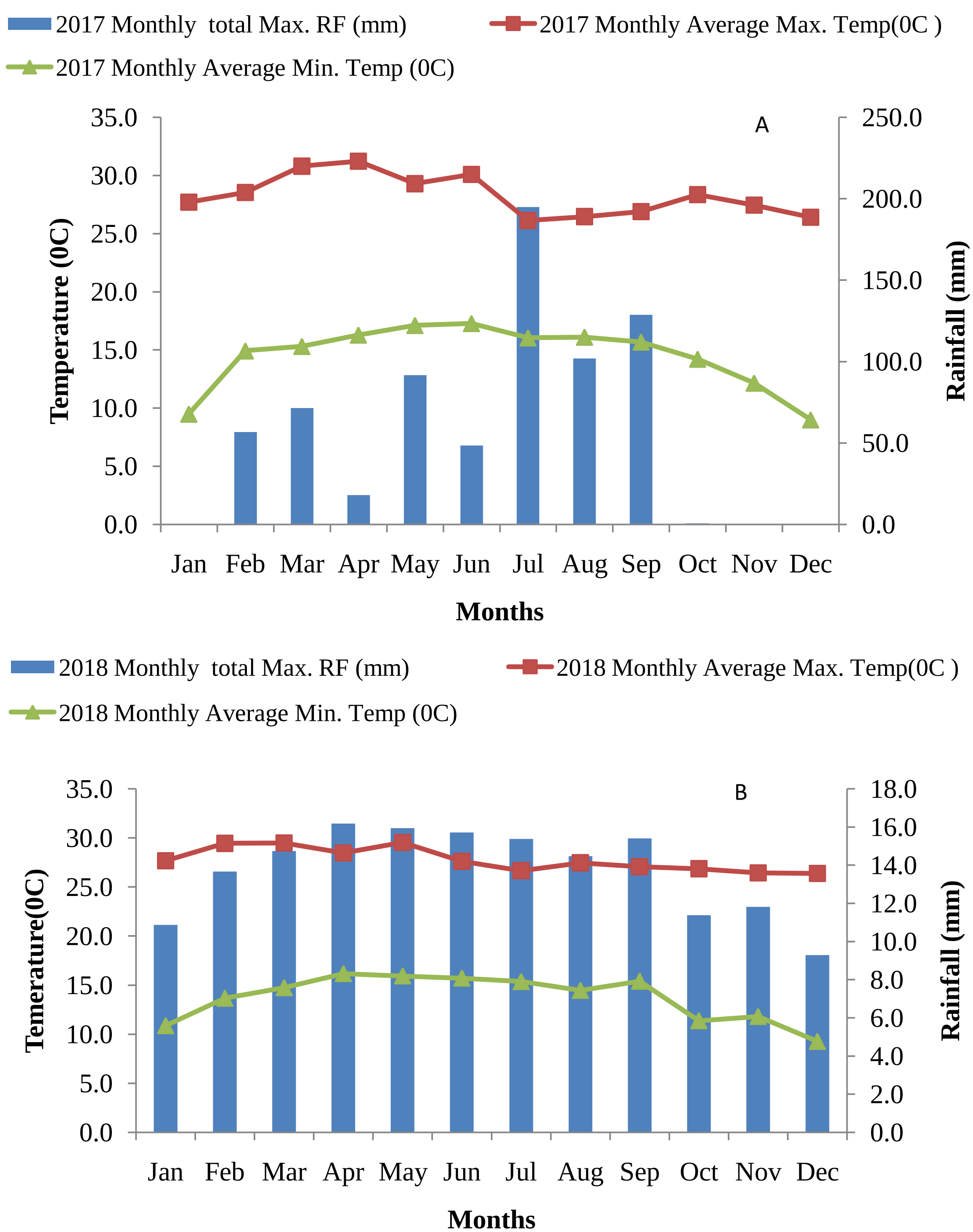


Figure 2. Metrological observations during field experimental period of 2017/2018

### 3.4.2. Treatments and experimental design

The experiment consisted of thirteen treatments: two herbicides (pendimethaline 455CS PE and oxyflorfen 240EC POE) with or without supplement of hand weeding (3, 6 and 9WAT), one weed free check and one weedy as control (Table 2). The treatments were laid down in randomized complete block design (RCBD) with four replications.

Table 2..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

### 3.4.3. Management of the Experimental Plots

Onion variety "Bombay red" was used in both experiments. Healthy seedlings with 3 to 4 leaf stage were purchased from Ziway local nursery growers. Seedlings were transplanted to the experimental plots (one seedling per hole) on December 10/04/2017 and May 21/9/2018 for the first and second experiment, respectively. 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 7.28$m^2$ (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 on 17 December 2017 and 30 May for first and second experiment, respectively. 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).Insect pests like thrips were observed on both experimental plots and cutworms were observed only in the second experimental plots. However, they were successfully controlled by spaying karate (Lambda-cyhalothrin).

#### 3.4.3.1. Application of the treatments

The pre- emergence herbicide (pendimethaline 455CS) were applied to soil a day before transplanting on 9 December 2017 and 20May2018 at rate of 1.5L/ha for first and second experiment, respectively. The post transplant herbicide (oxyfluorfen 240EC) were foliar sprayed four weeks after transplanting on 8 January 2018 and 20 June at rate of 0.5L/ha first and second experiment respectively. All herbicide applications were applied with 20 liters capacity knapsack sprayer. 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.

Table 3.Common name, trade name, chemical name, rate of application, amount of water used and application time of used herbicides

| Common name | Trade name | Chemical name | Rate (L/ha) | Amount of water used (L/ha) | Application time |
|---|---|---|---|---|---|
| Pendimethalin | Stomp 455%CS | N (1-ethylpropyl) -3, 4-di-methyl – N-2, 6-dinitrobenzene amine | 1.5 | 200 | PE |
| Oxyflourfen | Goal 240%EC | 2-Chloro-4-(trifluro-methyl – Phenyl-3 – ethoxy-4 nitrophenyl Ether | 0.5 | 200 | POE |

### 3.4.4. Data Collection

#### 3.4.4.1. Weed parameters

**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).

$$\text{WCE} = \frac{\text{Weed biomass of unweeded control} - \text{Weed biomass of a treatment}}{\text{Weed biomass of unweeded control}} \text{X100}$$

**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

#### 3.4.4.2. Crop growth and yield parameters

**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 (Guesh, 2015).

### 3.4.5. 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).

### 3.4.6. Economic Analysis of Treatments

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)

**Cost of treatments (ETB)**

Price of the herbicides and application costs were recorded. The labor cost for the various hand weeding treatments were also recorded. Cost of protection was calculated by adding all the costs involved in each treatment.

**Gross returns (ETB)/ha**

The bulb yield was converted into gross returns in birr based on the prevailing market prices.

**Net returns (ETB)/ha**

The treatment wise net returns were obtained by subtracting the cost oftreatment inputs from the gross returns.

**Benefit: Cost ratio (B: C) =** Net return (ETB)/Cost of treatments (ETB)

### 3.4.7. Crop Yield loss due to weeds

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

$$\text{Yield loss} = \frac{\text{Maximum yield from a treatment} - \text{Yield from a particular treatment}}{\text{Maximum yield from a treatment}} \text{x100}$$

# 4. RESULTS AND DISCUSSIONS

## 4.1. Assessment of Weed Management Practices in Onion farms

### 4.1.1. Demographic characteristics of the respondents

#### 4.1.1.1. Gender of the respondents

About 82.5 % of the interviewed farmers were male and the remaining 17.5% of the households were female (Table 4). Mulugeta (2000) reported that gender differentials among the farm households positively influenced the adoption of package including weed management package that a male headed household increases than a female headed household.

#### 4.1.1.2. Age of the respondents

The age distribution of the study farmers showed that the majority of onion producers (67.5%) were between the ages of 30-50 and about 17.5% of onion producers were greater than 50 years and the remaining 15% onion producers were between 18–30 years old(Table 4). The majorities (67.5%) of onion producers in the study area were matured and at working ages and this can be coupled with availability of labor requirements for weed management in onion production.

#### 4.1.1.3. Family size of the respondents

Concerning to family size, about 82.5% of the respondents have a family size of greater than five persons. About 17.5% of the interviewed onion producers had one up to five family members. Large family size can be associated with high labor requirement for weed management in onion production (Table 4).

Table 4.Sex, age and family size of respondent in the study area

| Description | Adami Tullu (N=50) | Dugda (N=50) | Lume (N=50) | Around Adama (N=50) | Total (N=200) |
|---|---|---|---|---|---|
| | Percent (%) | Percent (%) | Percent (%) | Percent (%) | Percent (%) |
| **Gender** | | | | | |
| Male | 70 | 90 | 90 | 80 | 82.5 |
| Female | 30 | 10 | 10 | 20 | 17.5 |
| **Age** | | | | | |
| 18-30 | 20 | 20 | 10 | 10 | 15 |
| 30-50 | 40 | 70 | 70 | 90 | 67.5 |
| >50 | 40 | 10 | 20 | 0 | 17.5 |
| **Family size** | | | | | |
| 1-5 | 10 | 30 | 20 | 10 | 17.5 |
| >5 | 90 | 70 | 80 | 90 | 82.5 |

#### 4.1.1.4. Educational status of the respondents

According to the survey results, about 92.5% of the interviewed were able to read and write while 7.5% of the respondents were illiterate and 75% of farmer's household has attended 1-8 grade and the remaining 7.5% have attended 8-10 grade (Fig.3).

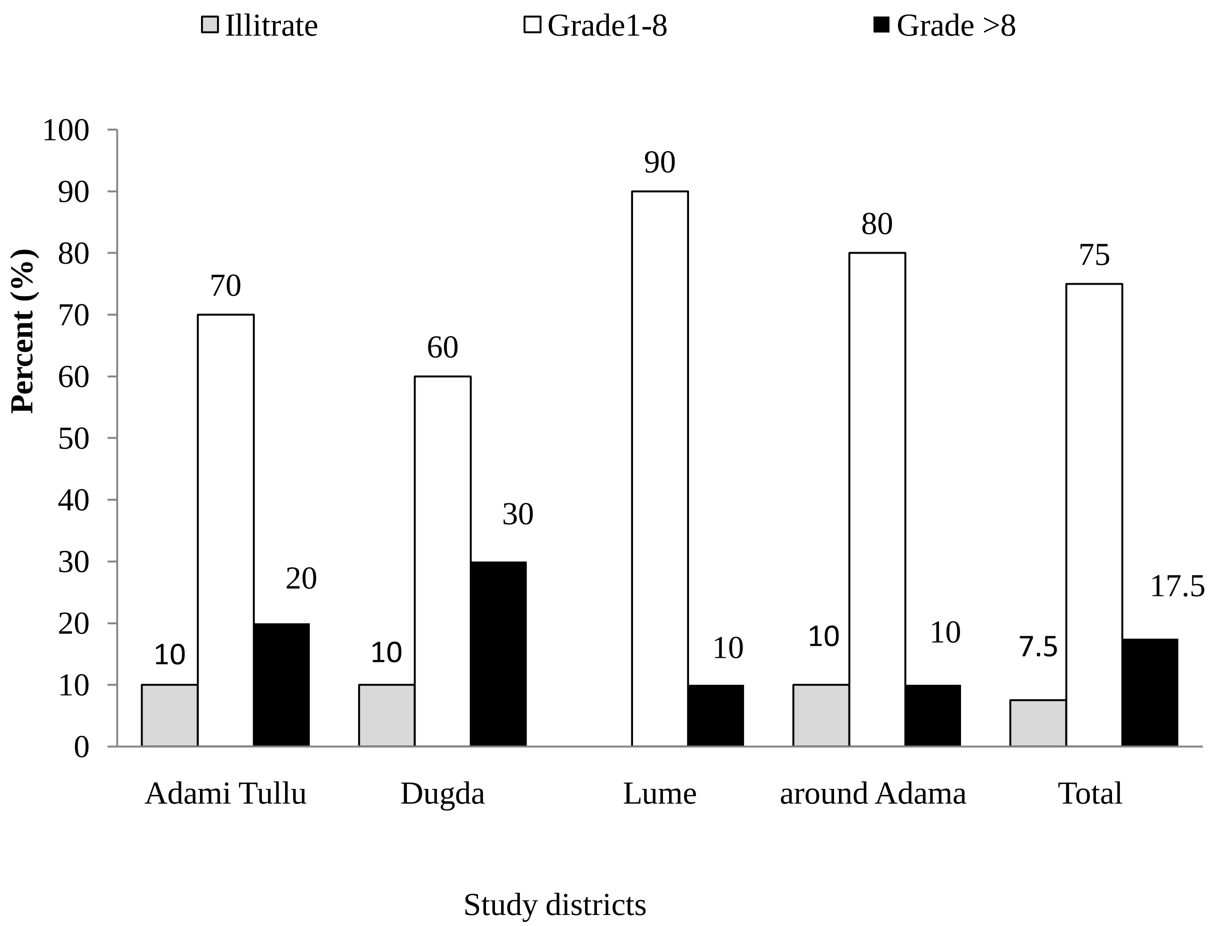


Figure 3.Educational statuses of the respondents in the study area

#### 4.1.1.5. Onion production experience of the respondents

The majority (55%) of onion producers had 5-10 years onion production experiences, about 30% and 15% of them had more than ten and less than five years production experience, respectively (Fig4).

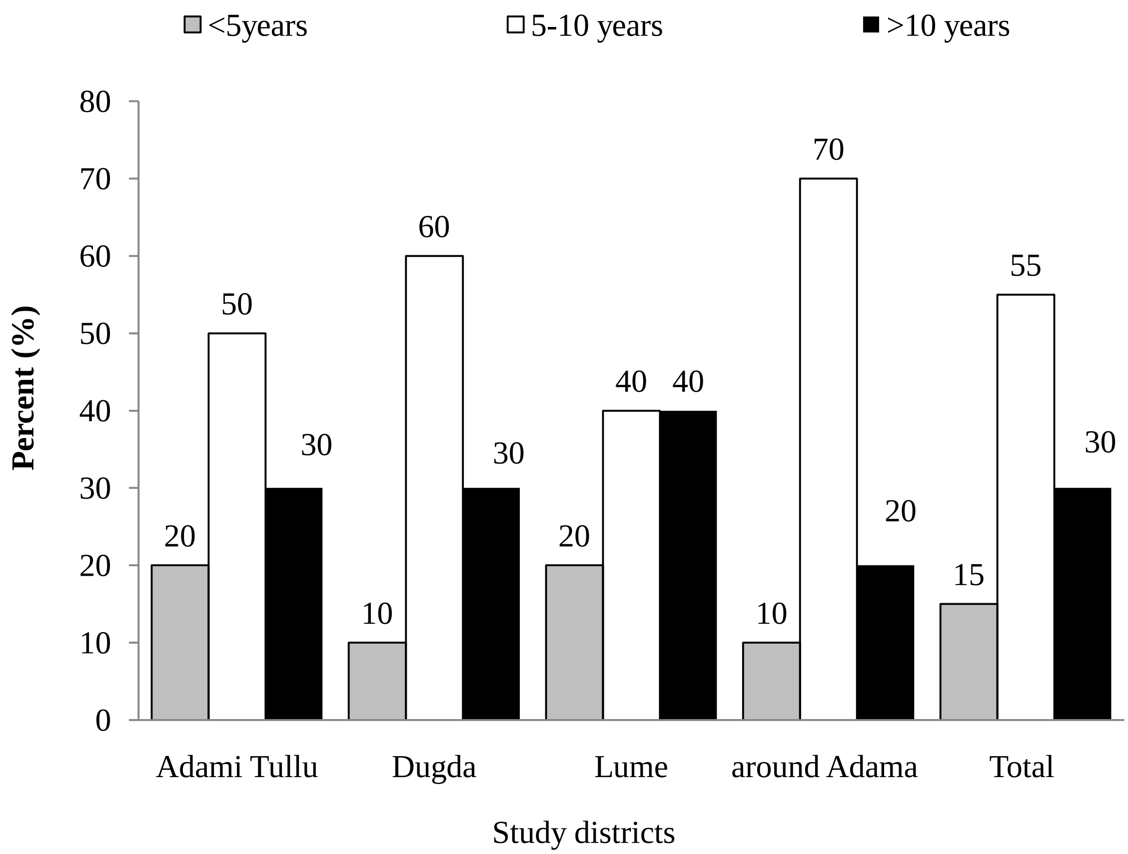


Figure 4.Onion production experiences of the respondents in the study area

### 4.1.2. Onion production system and its planting methods in the study area

Vegetables are usually grown in two seasons, namely in the wet season (locally known as *meher* season) using rainfall with supplemental irrigation or under full irrigation during the dry season. Majority (87.5%) of the respondents produce vegetables under irrigation system, 12.5% produce under rain fed production system **(**Table 5**)**. Farmers explained that they schedule production pattern to avoid periods of high weed, pest and disease infestation.

Major crop establishment method found in the study area was transplanting (100%) of seedling to well prepared fields so that to allow crop seedling to establish before weeds emerge and to facilitate crop seedlings dominate the weeds. If the time of germination coincides with the emergence of first flush of weeds, it leads to intense weed-crop competition. Usually the longer the interval between emergence of crop and weeds, the lesser will be the weed-crop interference. Transplanting of 40-45 days of onion seedling to well-prepared field make faces lesser weed-onion interference and results in high bulb yield (Lemma and Shimeles (2003).

About 83% of the respondents of the study areas planted onion seedlings at non-recommended spacing due to lack of skill and knowledge and 17% of them used the recommended spacing of 10cm x 20cm x 40 cm **(**Table5**)**.Spacing determines the quantity and quality of crop environment available to the growth of weeds. Wide row spacing with simultaneous high intra row plant population may induce dense weed growth. In addition, from the point of weed – crop competition, square method of planting is ideal to reduce intra row competition.

Table 5.Onion production system and its planting methods

| Description | Adami Tulu (N=50) | Dugda (N=50) | Lume (N=50) | Around Adama (N=50) | Total (N=200) |
|---|---|---|---|---|---|
| | Percent (%) | Percent (%) | Percent (%) | Percent (%) | Percent (%) |
| **Production system** | | | | | |
| Rain fed | 10 | 10 | 20 | 10 | 12.5 |
| Irrigation | 90 | 90 | 80 | 90 | 87.5 |
| **Planting methods** | | | | | |
| Direct sowing | 0 | 0 | 0 | 0 | |
| Transplanting | 100 | 100 | 100 | 100 | 100 |
| **Planting spacing** | | | | | |
| Without space | 20 | 22 | 30 | 32 | 32.5 |
| 10x10 x30cm | 66 | 60 | 50 | 42 | 54.5 |
| 10x20x40cm-recommended | 14 | 18 | 20 | 16 | 17 |

### 4.1.3. Types, rates, times, and methods of fertilizers application in the study area as reflection on the factor of onion - weed competition

Respondent farmers in the study area applied chemical fertilizers such as DAP and UREA and organic fertilizer like manure to improve the soil fertility so that to increase production of onion. While 82.5% of the interviewed farmer used DAP, about 17.5% of them did not used DAP for onion production (Table 6). All DAP user respondents applied DAP below its blanket recommendation (200 kg DAP/ha) which is recommended by EIAR (2007). About 55% of the respondents applied DAP at the time of planting/or weeding which is in agreement with the recommendation of (Lemma, 2004). However, 25% of the farmers applied DAP both before and after transplanting/ or weeding and 20% of the respondent farmers applied DAP after planting/ or every interval weeding due to lack of knowledge. This inappropriate use of fertilizer may cause weed more competitive than the crop and made weed control worse.

In the same way, about 70% of the respondents applied urea for onion production in the study area. Especially in Around Lume woreda about 80% of the onion growers use urea fertilizer for onion production which may cause weed more competitive than crop in the woreda. Among the urea users in the study woredas, 32.5% used below the recommended rate which is 150 kg/ha EIAR (2007). Most of them (67.5%) applied the whole quantity of urea at one time during transplanting or after transplanting which is not the correct time of urea application for onion. About 32.5% of the respondents applied urea by split application method where one half of urea was applied at the time of planting/or weeding and the remaining half urea after planting/or weeding (Table 6).

According to the recommendation, the whole quantity of DAP (200 kg/ha) should be applied at the time of planting or 7-10 days after transplanting. The quantity of urea (150 kg/ha) should be divided into two and one half should be applied during transplanting and the remaining one half 45 days after transplanting (Lemma and Shimeles, 2003).

However, the rate and time of application of DAP and urea fertilizers were not according to the recommendation for onion production as indicated above which may contribute to the more competiveness of weeds resulting in low level of productivity of onion in the study area. In general, limited and elevated soil fertility usually stimulates weeds more than the crop, reducing thus crop yields. Method and time of application of fertilizers to crop determining whether added fertilizer will suppress or invigorate weed growth in fields. As reported by many authors weeds usually absorb mineral nutrients faster than crop plants and they accumulate relatively larger amounts of nutrients than crop plants. *Amaranthus* spp accumulate over 3% N in their dry matter; *Digetaria* spp accumulates more phosphrous content of over 3.36%. *Chenopodium* spp and *Portuluca oleracea* are potassium lovers, with over 4.0% $K_2O$ in their dry matter. For this reason application of fertilizer at recommended rate and proper time is important for reducing onion- weed competition. In case of organic fertilizer, all interviewed households (100%) used manure as a source of organic fertilizer and applied before planting by broadcasting. This may give enough time for decomposition processes that should be completed ahead of time.

Table 6. Types, rates, times, and methods of fertilizers application in the study area

| Description | Adami Tulu (N=50) | Dugda (N=50) | Lume (N=50) | Adama (N=50) | Total (N=200) |
|---|---|---|---|---|---|
| | Percent (%) | Percent (%) | Percent (%) | Percent (%) | Percent (%) |
| **Amount of DAP used** | **(kg/ha)** | | | | |
| 10 | 10 | 10 | 10 | 0 | 7.5 |
| 25 | 10 | 10 | 20 | 20 | 15 |
| 50 | 30 | 40 | 40 | 30 | 35 |
| 100 | 30 | 30 | 20 | 30 | 27.5 |
| Non –users | 20 | 10 | 10 | 20 | 17.5 |
| **Time of application** | | | | | |
| Before weeding | 70 | 50 | 40 | 60 | 55 |
| After weeding | 10 | 20 | 30 | 20 | 20 |
| Both | 20 | 30 | 30 | 20 | 25 |
| **Amount of Urea used** | **(kg/ha)** | | | | |
| 10 | 20 | 0 | 30 | 0 | 10 |
| 25 | 20 | 30 | 0 | 40 | 22.5 |
| 50 | 30 | 30 | 50 | 30 | 35 |
| Non- users | 30 | 40 | 20 | 30 | 30 |
| **Time of application** | | | | | |
| During weeding | 30 | 20 | 30 | 30 | 27.5 |
| After weeding | 30 | 40 | 50 | 40 | 40 |
| Both | 40 | 40 | 20 | 30 | 37.5 |
| **Application of manure** | | | | | |
| Yes | 100 | 100 | 100 | 100 | 100 |

### 4.1.4. Methods and frequency of irrigation used among respondents of the study area as reflection on the factor of onion weed competition

Most of the respondents (85%) in the study area applied water through furrow irrigation while 15% used surface flooding method (Table 7). However, the majority (60%) of the respondents in around Adama preferred surface irrigation as a method of irrigation water application which is not appropriate for most of vegetables including onion. Surface flooding moisturizes all space and facilitates many weed germination and competition. In case of furrow irrigation water reaches only around square method planted onion and small area moisturized and few weed germinate. Therefore, most important irrigation method, furrow irrigation is dominant in the onion production area of Rift valley of Ethiopia.

The frequency of irrigation is very important in onion weed competition and its production which differs with the weather conditions, type of soil and the developmental stages of the crop. Onion requires generally frequent irrigation since the crop has shallow root system (MoARD, 2005). The majority (50%) of the onion growers in the study area irrigate onion fields every one week interval throughout the growing periods without considering the soil type and the stage of the crop (Table 7). About 32% of the respondents applied water every two weeks. The recommended frequency for onion is two times a week for the first three weeks after transplanting and at 5-7 days interval then after depending on the type of soils and weather conditions (MoARD, 2005). The frequency of irrigation may influence and cause weeds to be more competitive than the crop.

Table 7. Methods and frequency of irrigation used among respondents of the study area

| Description | Adami Tulu (N=50) Percent (%) | Dugda (N=50) Percent (%) | Lume (N=50) Percent (%) | Around Adama (N=50) Percent (%) | Total (N=200) Percent (%) |
|---|---|---|---|---|---|
| **Methods of Irrigation** | | | | | |
| Furrow irrigation | 90 | 90 | 90 | 70 | 85 |
| Surface flooding | 10 | 10 | 10 | 30 | 15 |
| **Irrigation Frequency** | | | | | |
| Every three day | 40 | 40 | 50 | 0 | 32.5 |
| Every week | 50 | 40 | 50 | 60 | 50 |
| Every two week | 10 | 20 | 0 | 40 | 17.5 |

### 4.1.5. Major problematic weeds according to farmers of the study area

Onion is affected by various weeds in the study area. Survey results revealed that Sedges are the major problematic weed group in the area (Table 8). Among the sedge weeds species, *Cyperus rotundus* is the top ranker which is considered critically harmful in onion fields according to the farmers as it is difficult to suppress. Second most problematic weed group in the study area are grasses. Among grasses *Echinochloa collona*, *Eleusine indica*, *Cynodon dactylon*, *Setaria verticillata* and*Phalaris paradoxa* are the most critical grass species in the onion fields in the study area. Third most problematic weed group in the study area is broadleaf weeds. According to the farmers it causes significant harmful impact on onion due to its high dense foliage and fast grows.As information obtained fromfarmers, *Portulaca oleraceae* are among noxious weeds difficult to control because of their fast growth rate once infested the field and field infested with this weeddemandregular weeding as compared to the other weeds.Information obtained from farmers indicated laborersare not willing to work fields infested by *Amaranthus spinosus* and *Xanthiumspinosum* weeds because of their shock appearance they have.

Table 8.Local name, common name and scientific name of major weeds of the study area

| Local name | Common name | Scientific name | Ranks based on their problem |
|---|---|---|---|
| **Broadleaved weeds** | | | **3rd** |
| Cululuka | Purslane | *Portulaca oeraceae* | |
| - | Chinese lantern | *Nicandra physaloides* | |
| Nechi lebashi | Mexican thistle | *Argemone mexicana* | |
| Abadebo | Gallant soldier | *Galinsoga parviflora* | |
| Amedmado | Lambs-quarters | *Chenopodium* spp | |
| Mangi | Thorn apple | *Datura stramonium* | |
| Ye mogne feqer | Spiny cochlebur | *Xanthium spinosum* | |
| Adaa, Anamale | Golden crown beat | *Verbesina encloides* | |
| Rafu, Aluma | Pigweed | *Amaranthus* spp | |
| Banda, xorserawit | Rough cochlebur | *Xanthium strumarium* | |
| Kurinchit | Puncturivine | *Tribulus* spp | |
| **Grassy weeds** | | | **2nd** |
| Wodeldhufisa | Goose grass | *Eleucine indica* | |
| Qilo | Barnyard grass | *Echinocoloa* spp | |
| | Bermuda grass | *Cynodon* spp | |
| Metagoye,Asendabo | Canary grass | *Phalaris* spp | |
| Marga sare | Foxtail | *Setaria* spp | |
| | Crabgrass | *Digitaria* spp | |
| **Sedges** | | | **1st** |
| Quni, Engicha | Nutsedges | *Cyperus* spp | |

### 4.1.6. Source and cause of weed infestation in the study area

A sound knowledge of the mode of propagation and dispersal of weeds is essential to plan on effective prevention and control measures. Majority of the respondents (45.5%) revealed that weeds emerged from soil seed bank before and after planting the crop, (39.5%) responded that weed seeds and propagules come from field edge and some of them (15%) of respondents indicated that they might be dispersed with manures (Table 9). Their knowledge on this issue is limited. Obviously, weeds are dispersed in many ways including by falling near mother plant, move out of the fields with crop harvest, dispersed with agents like wind, water, transport system, animal, man and manure to short or long distance. Careless cultivation of land is also the important factor in the dispersal of vegetative propagules of weeds such as rhizomes, root stocks and tubers and drags them to uninfected areas where they grow into new colonies.

### 4.1.7. Management actions undertaken by farmers of the study area

Prevention is the most effective method of dealing with weeds. Once a weed has entered an area and become established, eradication is more expensive and it is likely that greater resources will be required to control its further spread and reduce its impact (Weeds in Australia, 2012).Weed removal by hand, including hoeing, is a good method for selective removal of weeds without disturbing the surrounding desirable crop including onion. In the study area, almost all of the farmers practiced hand weeding (90%) to reduce invasion. The frequency hand weeding ranges 3 to5 cycles along with the crop establishment. The remaining (10%) use pre planting non-selective herbicides. Some land owner farmers responded that, hand weeding is advantageous due shortage of money and use of family or relatives through non-cash exchange. In contrast, those growing onion with contractual agreement said that hand weeding is intensive and expensive methods as they have to pay laborers doing the job. Farmers of the area required 20 laborers per hectare for weeding onion field. The daily payment was 100 ETB/person (Table 9). Therefore, to increase onion production and to reduce the time and cost of weeding there is an urgent need to improve and develop hand-weeding practices such as with the use of effective herbicides. Regarding to crop rotation, most of the respondents do not have planned scheme of crop rotation although some rotate crops.

Table 9.Source of weed infestation and their management practices in the study area

| Description | Adami Tullu (N=50) | Dugda (N=50) | Lume (N=50) | around Adama (N=50) | Total (N=200) |
|---|---|---|---|---|---|
| | Percent (%) | Percent (%) | Percent (%) | Percent (%) | Percent (%) |
| **Source of infestation** | | | | | |
| Field edge | 40 | 42 | 36 | 40 | 39.5 |
| Animals/Manures | 20 | 10 | 0 | 30 | 15 |
| Soil seed bank | 40 | 48 | 64 | 30 | 45.5 |
| **Weed control used** | | | | | |
| Using Chemicals | 10 | 10 | 10 | 10 | 10 |
| Using Cultural method | 90 | 90 | 90 | 90 | 90 |
| **Frequency of tillage** | | | | | |
| Two times | 20 | 12 | 34 | 40 | 26.5 |
| Three times | 60 | 68 | 36 | 20 | 46 |
| Four times | 20 | 20 | 34 | 40 | 28.5 |
| **Frequencyof weeding** | | | | | |
| Two times | 20 | 10 | 30 | 40 | 25 |
| Three times | 60 | 70 | 40 | 40 | 52.5 |
| Four times | 20 | 20 | 30 | 20 | 22.5 |
| **Labors per hectare** | | | | | |
| 20 man per hectare | 100 | 100 | 100 | 100 | 100 |
| **Cost per person** | | | | | |
| 100birr/ person | 100 | 100 | 100 | 100 | 100 |

### 4.1.8. Herbicide application and experiences among farmers of the study area

A few (10%) farmers of the study have started using only non - selective herbicides in onion field before planting the crop (Table 10). Herbicide dosage is important factor related to the herbicide efficacy. Generally, farmers (85%) use higher dosage of herbicides than the recommendation, while the remaining used the recommended dosage. Farmers believe that high dose means better control of weeds. However, application of high or low dosage of herbicides leads to high selection pressure and could lead to the development of resistant weed species. Farmers prefer to apply herbicide once to reduce the cost of application. They have little knowledge and training on compatibility of pesticides to apply them as mixtures.

Hand operated knapsack sprayers are the most popular application equipment although farmers apply pre planting non- selective post emergence herbicides to control all grasses, sedges and broadleaved weeds in their field they achieve poor weed control after planting onion. Poor efficacy of herbicides might be due to combining effect of the lack of selection of proper pre and post planting herbicides, improper use and practices of herbicides, lack of awareness on available post-planting selective herbicides and other management practices including hand weeding adopted by the farmers. Farmers get information on control of weeds in onion with herbicides from the three sources. Mainly the information comes from agrochemical dealers, and few depend on information from colleague farmers and agricultural extension officers. Farmers partly depend on the instructions in the label prefer to rely on herbicide sellers.

Table 10.Herbicide usage practices among farmers of the study area

| Herbicide use practices | Variables | Percentage |
| --- | --- | --- |
| Herbicide type | Pre- planting and Non-selective | 100 |
| | Post- planting selective herbicides | 0 |
| Herbicide spraying equipment | Knapsack sprayer | 100 |
| | Power sprayer | 0 |
| Dosage of application | Higher dose | 85 |
| | Recommended | 10 |
| | Lower dose | 5 |
| Frequency of application | One time | 100 |
| | Two times | 0 |
| Source of information | Agrochemical dealers | 80 |
| | Co-workers farmer | 15 |
| | Agricultural Extension | 5 |

## 4.2. Assessment of Weed Species Composition in Onion Farms

### 4.2.1 Weed species composition of the study area

The assessment was conducted in onion farms of Adami Tulu, Dugda, Lume and around Adama woreda of East Shewa zone, Central Rift Valley of Ethiopia. Most of fields were weeded at the time of data collection. Forty three weed species from 16 plant families were recorded (Table 11). Most of the species were erect annual herbs and grasses, the rest were perennials that had vegetative propagules, viz. rhizomes, stolons or tubers, annual prostrate herbs, annual or perennial climbers or perennial shrubs. *Asteraceae* (16 spp.), *Poaceae* (10 spp.), and *Solonaceae* (2 spp.) were the 1$^{st}$, 2$^{nd}$, 3$^{rd}$ abundant weed families, respectively (Table11). Pulschen (1990) described that a botanical family is regarded as highly diversified if contains more than five species. Therefore, *Asteraceae* (16spp.)and *Poaceae* (10 spp.) families are the most diverse species of weeds in onion fields of the study area.

As it was reported in results of weed surveys on different crops in other places (Kedir*et al*., 1999 a, b; Taye and Yohannes, 1998) there was a positive and significant relationship among the weed species abundance, dominance and frequency. It was recognized that the dominance level of individual weed species varied across locations and the crop growth stages. Some weed species with high infestation levels at some localities might not occur at similar level and might not be important weeds at other locations. The frequency of occurrence of individual species ranged from 4 to 96, while the infestation level based abundance is ranged from 0.24 to 40.4 whereas based on dominance ranged from 0.15 to 19.52 (Tables 12 - 15). According to Taye and Yohannes (1998), weed species having frequency and dominancy levels below 5.0% and 0.05%, respectively, occur rarely, not significantly distributed and are at low density.

Table 11.Number of weed families identified and number of species they contain

| No- | Family | Number of species |
|---|---|---|
| 1 | Asteraceae | 16 |
| 2 | Poaceae | 10 |
| 3 | Solanaceae | 2 |
| 4 | Cyperaceae | 2 |
| 5 | Amaranthaceae | 1 |
| 6 | Portulaceae | 1 |
| 7 | Chenopodiaceae | 1 |
| 8 | Plantagaceae | 1 |
| 9 | Commelinaceae | 1 |
| 10 | Euphorbaceae | 1 |
| 11 | Convolvolaceae | 1 |
| 12 | Paparavaceae | 1 |
| 13 | Zygophyllaceae | 1 |
| 14 | Brassicaceae | 1 |
| 15 | Pontederiaceae | 1 |
| 16 | Oxalidaceae | 1 |
| | Total | 43 |

#### 4.2.1.1. Weed species frequency, Abundance and dominance in Adami Tulu onion-growing areas

Onion fields in Adami Tulu, out of 19 weed species recorded, ten were broadleaved weeds, eight grassy weeds and one sedge. The frequency and infestation levels of individual weed species based on abundance ranged from 4 to 96% and0.4 up to 40.4%, respectively. Dominance value ranged from 0.19 up to 19.52. *Argemone Mexicana, Nicandra physaloides, Portulaca oleraceae, Cyperus rotundus Amaranthus hybridus*, *Sonchus arvensis*, *Eleusine indica*, *Echinochloa colona*, *Datura stramonium*, *Galinsoga parviflora* and *Chenopodium album*are the most frequent in descending order of their frequency values respectively. *Cyperus rotundus, Portulaca oleraceae, Nicandra physaloides, Amaranthus hybridus, Argemone Mexicana* and *Chenopodium album* are the most abundant and dominant respectively based on their descending order of their abundance and dominance value (Table12).*Nicandra physaloides* wasthe most frequent (96%)and dominantweedspecies contributing to 9.78%of infestationoftheonionfields.Themostdominantweedspecieswas*Portulaca oleraceae*, contributingupto19.52%oftheinfestationintheonionfields.

Table12.Weed species composition, Frequency, Abundance and dominance of delimited areas of Adami Tulu woreda

| Botanical name | Family name | Features | Frequency | Abundance | Dominance |
|---|---|---|---|---|---|
| *Argemone Mexicana* | Paparavaceae | d p | 96 | 14.08 | 6.80 |
| *Nicandra physaloides* | Asteraceae | d a | 90 | 20.24 | 9.78 |
| *Portulaca oleraceae* | Portulaceae | m p | 88 | 40.4 | 19.52 |
| *Cyperus rotundus* | Cyperaceae | m p | 86 | 32 | 15.46 |
| *Amaranthus hybridus* | Amaranthaceae | d a | 84 | 15.52 | 7.50 |
| *Echinochloa colona* | Poaceae | m a | 78 | 7.12 | 3.44 |
| *Sonchus arvensis* | Asteraceae | d p | 76 | 8.8 | 4.25 |
| *Eleusine indica* | Poaceae | m a | 70 | 8.64 | 4.18 |
| *Phalaris paradoxa* | Poaceae | m a | 70 | 8.16 | 3.94 |
| *Datura stramonium* | Solanaceae | d a | 68 | 7.36 | 3.56 |
| *Raphanusraphanistrum* | Brassicaceae | d a | 64 | 7.84 | 3.79 |
| *Plantago lanceolata* | Plantaginaceae | d a | 58 | 7.74 | 3.74 |
| *Chenopodium album* | Chenopodaceae | d a | 56 | 10.24 | 4.95 |
| *Galinsoga parviflora* | Asteraceae | d a | 48 | 7.36 | 3.56 |
| *Agropyron repen* | Poaceae | m a | 42 | 4 | 1.93 |
| *Digitaria spp* | Poaceae | m a | 30 | 1.92 | 0.93 |
| *Gnaphaliumuliginosum* | Asteraceae | d a | 28 | 3.6 | 1.74 |
| *Senecio vulgaris* | Asteraceae | d p | 18 | 1.52 | 0.73 |
| *Bromus pectinatus* | Poaceae | m a | 4 | 0.4 | 0.19 |

Where, m = monocot; d=dicot; a=annual; p=perennial

#### 4.2.1.2. Weed species frequency, Abundance and dominance in Dugda onion- growing areas

According to the survey results, out of 18 weed species recorded in Dugda, ten were broad leaved weeds, seven grassy weeds and one sedge. The frequency and infestation levels based on abundance of individual weed species ranged from 20 to96% and1.68 up to 31.44%, respectively. Dominance value ranged from0.68 up to 14.88%. Based on frequency *Nicandra physaloides, Amaranthus hybridus Galinsoga parviflora, Cyperus rotundus, Polygonum nepalense, Plantago lanceolata and Datura stramonium* are the most frequent weed species in descending order of their frequency values respectively. (Table13).Based on abundance and dominance value, the most abundant and dominant weed species were*Portulaca oleraceae, Cyperus rotundus, Chenopodium album, Galinsoga parviflora, Nicandra physaloides, Amaranthus hybridus, Polygonum nepalense and Guizotia scabra* are the most in terms of descending order of their abundance and dominance values, respectively. *Galinsoga parviflora* was the most frequent (96%) and dominant weed species contributing to7.88% of infestation of the onion fields. *Portulaca oleraceae* contribute up to17.3 % of the infestation in the onion fields.

Table 13. Weed species composition, Frequency, Abundance and dominance of delimited areas of Dugda woreda

| Botanical name | Family name | Features | | Frequency | Abundance | Dominance |
|---|---|---|---|---|---|---|
| *Nicandra phaseoloides* | Solanaceae | d | a | 96 | 14.32 | 6.78 |
| *Galinsoga parviflora* | Asteraceae | d | a | 92 | 16.64 | 7.88 |
| *Amaranthus hybridus* | Amaranthaceae | d | a | 88 | 14.32 | 6.78 |
| *Cyperus rotundus* | Cyperaceae | m | p | 86 | 31.44 | 14.88 |
| *Polygonum nepalense* | Poaceae | m | a | 84 | 14.16 | 6.70 |
| *Gnaphaliumuliginosum* | Poaceae | d | m | 82 | 4.16 | 1.97 |
| *Plantago lanceolata* | Plantagnaceae | d | a | 80 | 6.8 | 3.22 |
| *Datura stramonium* | Solanaceae | d | a | 80 | 9.12 | 4.32 |
| *Chenopodium album* | Chenopodiaceae | d | a | 76 | 22.72 | 10.75 |
| *Eleusine indica* | Poaceae | m | a | 72 | 2 | 0.95 |
| *Digitaria ischaemum* | Poaceae | m | a | 70 | 5.2 | 2.46 |
| *Senecio vulgaris* | Asteraceae | d | a | 68 | 1.44 | 0.68 |
| *Bidens pilosa* | Asteraceae | d | a | 52 | 10 | 4.73 |
| *Commelinabenghalensis* | Commelinaceae | m | a | 42 | 3.36 | 1.59 |
| *Tribulus terrestris* | Zygophyllaceae | d | a | 42 | 5.04 | 2.39 |
| *Guizotia scabra* | Asteraceae | d | a | 34 | 12.32 | 5.83 |
| *Portulaca oleraceae* | Portulaceae | m | p | 32 | 36.56 | 17.30 |
| *Echinochloa colona* | Poaceae | m | a | 20 | 1.68 | 0.80 |

Where, m = monocot; d=dicot; a=annual; p= Perennial

#### 4.2.1.3. Weed species frequency, Abundance and dominance in Lume onion- growing areas

According to the survey results, out of 24 weedspeciesrecordedinLume,12 were broad leaved weeds, eleven grassy weeds and 1sedge. The frequency and infestation levels of individual weed species based on dominance ranged from 4 to 88%and0.17 up to12.08%, respectively. The major weed species found in the area based on their frequency were, *Portulaca oleraceae, Galinsoga parviflora, Eleusine indica, Tagetes minuta, Phalaris paradoxa Datura stramonium,Cyperus rotundus, Amaranthus hybridus, Nicandra physaloides, Argemone Mexicana* and *Commelina benghalensis*. were the most frequent weed species based on their descending frequency value(Table 14).*Cyperus rotundus, Portulaca oleraceae, Commelina benghalensis*, *Galinsoga parviflora*, *Amaranthus hybridus* and *Argemone Mexicana* are the most abundant and dominant weeds in descending order of abundance and dominance value. *Portulaca oleraceae* was the most frequent (88%) and dominant weed species contributing to9.55% of infestation of the onion fields. The most dominant weed species was *Cyperus rotundus*, contributing up to12.08% of the infestation in the onion fields.

Table 14.Weed species composition, Frequency, Abundance and dominance of delimited areas of Lume woreda

| Botanical name | Family name | Features | | Frequency | Abundance | Dominance |
|---|---|---|---|---|---|---|
| *Galinsoga parviflora* | Asteraceae | D | a | 88 | 10.16 | 7.31 |
| *Portulaca oleraceae* | Portulaceae | M | p | 88 | 13.28 | 9.55 |
| *Phalaris paradoxa* | Poaceae | M | a | 86 | 4.96 | 3.57 |
| *Datura stramonium* | Poaceae | D | a | 86 | 7.28 | 5.24 |
| *Eleusine indica* | Poaceae | M | a | 86 | 9.28 | 6.67 |
| *Cyperus rotundus* | Cyperaceae | M | p | 82 | 16.8 | 12.08 |
| *Amaranthus hybridus* | Amaranthaceae | D | a | 80 | 10.88 | 7.83 |
| *Argemone mexicana* | Papavaraceae | D | p | 76 | 9.12 | 6.56 |
| *Commelinabenghalensis* | Commelinaceae | M | a | 76 | 11.68 | 8.40 |
| *Digitaria ischaemum* | Poaceae | M | a | 76 | 12.16 | 8.75 |
| *Tagetes minuta* | Asteraceae | D | a | 72 | 3.52 | 2.53 |
| *Bidens pilosa* | Asteraceae | D | a | 60 | 5.36 | 3.86 |
| *Galium aparine* | Rubiaceae | D | a | 46 | 2.72 | 1.96 |
| *Cynodon dactylon* | Poaceae | M | p | 44 | 4.64 | 3.34 |
| *Nicandra phaseoloides* | Asteraceae | D | a | 38 | 1.76 | 1.27 |
| *Cirsium arvense* | Asteraceae | D | p | 38 | 2.48 | 1.78 |
| *Xanthium strumarium* | Asteraceae | D | a | 36 | 4.08 | 2.93 |
| *Lactuca serriola* | Asteraceae | M | p | 28 | 1.28 | 0.92 |
| *Echinochloa colona* | Poaceae | M | a | 26 | 1.52 | 1.09 |
| *Polygonum nepalense* | Poaceae | M | p | 26 | 1.68 | 1.21 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Eichhornia crassipes* | Pontederiaceae | D | p | 12 | 3.28 | 2.36 |
| *Euphorbia hirta* | Euphorbiaceae | D | p | 6 | 0.88 | 0.63 |
| *Convulvulus arvensis* | Convulvulaceae | D | p | 4 | 0.24 | 0.17 |

Where, m = monocot; d=dicot; a=annual; p=Perennial

#### 4.2.1.4. Weed species frequency, abundance and dominance in around Adama onion-growing areas

In around Adama, 18 weed species were recorded out of which, ten were broad leaved weeds, eight grassy weeds and one sedge. The frequency of individual weed species ranged from 6 to 96%.Abundance value ranged from 0.32 to 24.64%. Their dominance level ranged from 0.15 to 11.14% In terms of their descending frequency value major weed species were *Tagetes minuta*, *Echnochloa colona*, *Polygonum nepalense*, *Galinsoga parviflora*, *Eleucine indica. Bidens pilosa*, *Taraxacum officinales* and *Chenopodium album* are most frequent ones (Table1 5 ). *Echnochloa colona*, *Bidens pilosa*, *Tagetes minuta and Amaranthus hybridus* are the most abundant and dominant weed species in the onion field of the areas in descending order of their abundance and frequency value. The most dominant weed species was *Echinochloa colona*, contributing up to 11.14% of the infestation in the onion fields.*Echinochloa colona and Tagetes minuta* was the most frequent (96%).

Table 15.Weed species composition, Frequency, Abundance and dominance of delimited areas of around Adama woreda

| Botanical name | Family name | Features | | Frequency | Abundance | Dominance |
|---|---|---|---|---|---|---|
| *Tagetes minuta* | Asteraceae | d | a | 96 | 16 | 7.42 |
| *Echinochloa colona* | Poaceae | m | a | 96 | 24 | 11.14 |
| *Polygonum nepalense* | Poaceae | d | p | 88 | 10.64 | 4.94 |
| *Taraxacum officinales* | Asteraceae | d | p | 88 | 12 | 5.57 |
| *Eleusine indica* | Poaceae | m | a | 88 | 14.64 | 6.79 |
| *Galinsoga parviflora* | Asteraceae | d | a | 88 | 16.96 | 7.87 |
| *Chenopodium album* | Chenopodiaceae | d | a | 86 | 14.8 | 6.87 |
| *Bidens pilosa* | Asteraceae | d | a | 86 | 18.4 | 8.54 |
| *Cyperus rotundus* | Cyperaceae | m | p | 84 | 11.2 | 5.20 |
| *Plantago lanceolata* | Plantaginaceae | d | a | 84 | 13.36 | 6.20 |
| *Oxalis latifolia* | Oxalidaceae | d | a | 82 | 13.36 | 6.20 |
| *Amaranthus hybridus* | Amaranthaceae | d | a | 76 | 16.08 | 7.46 |
| *Chenopodium album* | Chenopodiaceae | d | a | 60 | 9.2 | 4.27 |
| *Agropyron repens* | Poaceae | m | p | 46 | 1.84 | 0.85 |
| *Argemone mexicana* | Paparavaceae | d | p | 42 | 2.64 | 1.22 |
| *Commelina benghalensis* | Commelinaceae | n | a | 40 | 3.12 | 1.45 |
| *Datura stramonium* | Solanaceae | d | a | 40 | 3.76 | 1.74 |
| *Senecio vulgaris* | Asteraceae | d | p | 32 | 1.92 | 0.89 |
| *Nicandra phaseoloides* | Asteraceae | d | a | 32 | 5.44 | 2.52 |
| *Convolvolus arvensis* | Convolvulaceae | d | p | 30 | 2.96 | 1.37 |
| *P. hystherophorus* | Asteraceae | d | a | 8 | 0.56 | 0.26 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Rumex abyssinicus* | Polygonaceae | d | P | 8 | 0.72 | 0.33 |
| *Guizotia scabra* | Asteraceae | d | a | 6 | 0.32 | 0.15 |
| *Cynodon dactylon* | Poaceae | m | p | 6 | 1.6 | 0.74 |

Where, m = monocot; d=dicot; a=annual; p=Perennial

#### 4.2.1.5. Similarity index (SI)

The study showed that in all four study locations similar weed communities were observed (>60%) (Table16). According to Taye *et al.* (1998) similarity having similar weed community (SI > 60%) will find similar weed management activity.

Table 16.Similarity Index (Percent) of four woredas

| Locations | Adami Tulu | Dugda | Lume | around Adama |
|---|---|---|---|---|
| Adami Tulu | 100 | 90.2 | 60.3 | 80.5 |
| Dugda | 90.2 | 100 | 60.4 | 80.6 |
| Lume | 60.3 | 60.4 | 100 | 90.3 |
| around Adama | 80.5 | 80.6 | 90.3 | 100 |

### 4.3. Effect of Different Weed Control Methods on Weed Flora and Yield of Onion

#### 4.3.1. Weed parameters

#### 4.3.1.1. Common weeds species found in both experimental areas

Results of the weed survey from weedy control of both experiments revealed a total of 25 weed species. Dominant weeds associated with experimental area are Chinese lantern (*Nicandra physaloides)*, Golden crown beat *(Verbesina encloides)*, Mexican thistle(*Argemone mexicana*), *Bermuda grass*(*Cynodon nfluensis)*, Purple nutsedge *(Cyperus rotundus)*, Purslane(*Portulaca oleraceae)*,Gallant soldier *(Galinsogaparviflora)*, Thorn apple *(Datura stramonium)*, Spiny amaranth*(Amaranthus spinosum)*, Pigweed*(Amaranthus hybridus)*, Spiny cochlebur *(Xanthium spinosum)*, Crowsfoot Grass (*Eleucine indica)*, Lambs- quarters (*Chenopodium album)*, Stink grass*(Eragrostis cilianensis)*, Nettle leaved goose foot *(Chenopodium murale)*,Foxtail *(Setaria verticellata)*, Rough cochlebur *(Xanthium strumarium)*, Puncturivine *(Tribulus cistoides)*, Barnyard grass*(Echnochloa colona)*, Sow-thistle *(Sonchus oleraceae)*, *Orobanche minor*, Wild Radish *(Raphanas raphanistrum)*, Dandelion *(Gnaphalium uliginosum)* and Wandering jew *(Commelina* spp*).*

#### 4.3.1.2. Weed density at 60DAT and at the time of harvesting harvest

All weed control treatments caused significant reduction in weed population compared with weedy check plot (Table 17). 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 17). 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 60DAT 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.

#### 4. 3.1.2. Weed biomass ($gm^{-2}$)

The weed biomass was found to be significantly affected by the treatments (Table 17). 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/$m^2$.

#### 4.3.1.3. 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 17). Kalhapure and Shete (2012) reported highest weed control efficiency from weed free check on onion.

#### 4.3.1.4. 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 17). 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 highestweed 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

Table 17.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 |
| Grand Mean | 61.567 | 51.346 | 574.12 | - | - |
| CV | 16.10 | 25.15 | 32.85 | - | - |
| SE(m) | 6.8568 | 9.1326 | 133.36 | - | - |
| 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, SE(m)= Standard error of mean, WCI= Weed control efficiency, WI=Weed index

### 4.3.2. Cropgrowth parameters

#### 4.3.2.1. Plant height (cm)

The treatments had effect on the plant height and the highest plant height was recorded in weed free plot (Table 18). 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 plot

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.

#### 4.3.2.2. Number of leaves per plant

The number of leaves per plant was not affected by the treatments (Table 18).

Table 18.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] |
| Grand Mean | 37.296 | 9.0763 |
| CV | 8.18 | 6.22 |
| SE(m) | 2.1565 | 0.3993 |
| P-value (5%) | 8.63 | 1.34 |

Means in the same column followed by similar letters are not statistically significant

CV= Coefficient of variation, SE (m) = Standard error of mean

### 4.3.3. Yield parameters

#### 4.3.3.1. 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 19). 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.

#### 4.3.3.2. 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 19). The lowest (3.34g) average bulb weight was recorded on weedy check plot.

#### 4.3.3.3. 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 19). 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.

#### 4.3.3.4. 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 plot (Table 19).

Table 19.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] |
| Grand Mean | 2.83 | 85.93 | 54.58 | 18.75 |
| CV | 6.66 | 8.05 | 8.64 | 24.40 |
| SE(m) | 0.13 | 4.89 | 3.33 | 3.23 |
| 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

### 4.3.4. Crop Yield loss due to weeds

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 20)

Table 20.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 |

### 4.3.5. Economics of treatments

#### 4.3.5.1. Cost of protection (ETB/ha)

Among all weed control treatments, the weed free check plot incurred the highest cost of protection (8000ETB/ha) (Table 21).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.

#### 4.3.5.2. 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) (Table21). The lowest gross return (462ETB/ha) was from weedy check treatment.

#### 4.3.5.3. 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.

#### 4.3.5.4. 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.

Table 21.Economic analysis of different treatments

| Treatments | BY(t/ha) | GR(birr/ha) | a. CHW | b. CH | c. CHA | TVC(a+b+c)(birr/ha) | NR(birr/ha) | B:C ratio |
|---|---|---|---|---|---|---|---|---|
| Pendimethalin | 16.49 | 23086 | - | 1275 | 200 | 1475 | 21611 | 14.65 |
| Pendi +HW3WAT | 21.60 | 30240 | 2000 | 1275 | 200 | 3475 | 26765 | 7.70 |
| Pendi +HW6WAT | 22.99 | 32186 | 2000 | 1275 | 200 | 3475 | 28711 | 8.26 |
| Pendi +HW9WAT | 22.85 | 31990 | 2000 | 1275 | 200 | 3475 | 28515 | 8.21 |
| Oxyfluorfen | 20.58 | 28812 | - | 1150 | 200 | 1350 | 27462 | 20.34 |
| Oxyfl +HW3WAT | 22.50 | 31500 | 2000 | 1150 | 200 | 3350 | 28150 | 8.40 |
| Oxyfl +HW6WAT | 27.62 | 38668 | 2000 | 1150 | 200 | 3350 | 35318 | 10.54 |
| Oxyfl + HW9WAT | 29.62 | 41468 | 2000 | 1150 | 200 | 3350 | 38118 | 11.38 |
| HW3WAT | 9.66 | 13524 | 2000 | - | - | 2000 | 11524 | 5.76 |
| HW6WAT | 11.58 | 162112 | 2000 | - | - | 2000 | 14212 | 7.11 |
| HW9WAT | 8.37 | 11718 | 2000 | - | - | 2000 | 9718 | 4.86 |
| Weed free check | 29.61 | 41454 | 8000 | - | - | 8000 | 33454 | 4.18 |
| Weedy control | 0.33 | 462 | - | - | - | - | 462 | - |

BY= Bulb yield, GR= Gross return, CHW= Cost of hand weeding, CH= Cost of herbicides, CHA= Cost of herbicide application, TVC= Total variable costs, NR= Net return. B: C= Benefit cost ratio. Price of onion bulb 14birr/kg, Price of pendimethaline (Stomp 455CS) = 1275Birr $ha^{-1}$; Price of oxyflourfen 240 EC = 1150Birr $ha^{-1}$; labor costs for spraying= 2Mandays $ha^{-1}$, Birr 100$man^{-1}$; Hand weeding: 20 mandays $ha^{-1}$, Birr 100$man^{-1}$.

# 5. SUMMARY AND CONCLUSION

Weeds are the most important pests that influencing human activities more than other crop pests. The study was conducted to determine weed species composition and their management practices and to evaluate the effect of different weed control methods in onion (*Allium cepa* L.) in Adami Tulu, Dugda, Lume and around Adama woredas, Central Rift Valley of Ethiopia during 2017/2018 under irrigation. Information on weeds and their management practices were collected from 200 individual farmers and analyzed using descriptive statistics. Weed species compositions were determined in a quadrate count of 0.5 $m^2$ using systematic sampling. Identified weed species were presented in terms of their frequency, abundance and dominance value. Experimental part was used13 different weed control treatments and laid down in randomized complete block design with four replicates and analyzed using SAS software.

Total forty three (43) weed species from sixty (16) plant families were identified. *Asteraceae* (16 spp.), *Poaceae* (10 spp.), *Solonaceae* (2 spp.) and *Cyperaceae* (2spp) were $1^{st}$, $2^{nd}$, $3^{rd}$ and$4^{th}$ abundant weed families respectively.In Adami Tulu Woreda: *Argemone Mexicana, Nicandra physaloides, Portulaca oleraceae, Cyperus rotundus* and *Amaranthus hybridus* are the most frequent in descending order of their frequency values respectively. *Cyperus rotundus, Portulaca oleraceae, Nicandra physaloides, Amaranthus hybridus, Argemone Mexicana* and*Chenopodium album* are the most abundant and dominant ones. In Dugda woreda: *Nicandra physaloides, Amaranthus hybridus, Galinsoga parviflora, Cyperus rotundus, Polygonum nepalense, Plantagolanceolata* and*Datura stramonium* are themost frequent weed species in descending order of their frequency values respectively. *Portulaca* *oleraceae, Cyperus rotundus, Chenopodium album, Galinsoga parviflora, Nicandra physaloides, Amaranthus hybridus, Polygonum nepalense* and *Guizotia scabra* are the most in terms of descending order of their abundance and dominance values respectively. In Lume Woreda: *Galinsoga parviflora, Portulaca oleraceae,Eleucine indica, Tagetes minuta* and *Datura stramonium* are most frequent ones. *Cyperus rotundus, Portulaca oleraceae, Commelina benghalensis, Galinsoga parviflora* and *Amaranthus hybridus* are the most abundant and dominant weeds.In around Adama woreda*: Tagetes minuta, Echnochloa colona, Polygonum nepalense, Galinsoga parviflora, Eleucine indica. Bidens pilosa and Taraxacum officinales* are most frequent ones. *Echnochloa colona, Bidens pilosa, Tagetes minuta* and *Amaranthus hybridus* are the most abundant and dominant ones. Survey of weed flora composition in each location showed some variation infrequency, abundance and dominance of some weed species and the causes for variation might be due to variability of irrigation types and frequencies, previous cropping and crop management system, frequency of cultivation, tillage, weeding and use of fertilizers were the major factors. But in all woradas weed communities were similar (SI>60%). Thus, the frequent, abundant and dominant weeds of the areas should be considered while devising management strategies.

Thefarmers of the study area, even though they didn't appreciate the existence of weeds in their farm; they have beendoing less effort to control the weeds. There is no adapted field sanitation practice after harvest. All farmers were trying weed clearing only when the land has been required for cultivation. After harvest the field is left abandoned and the weeds complete their lifecycle and shed their seed to the soil and weeds and multiply next season. Most of the farmers do not have planned scheme of crop rotation. Weed removal by hand, including hoeing, is common practice of the farmers. Some farmers start to use pre- planting non-selective herbicides. Hand weeding is labor intensive and expensive methods. Therefore, to increase onion production and to reduce the time and cost of weeding there is an urgent need to improve and develop hand-weeding practices such as with the use of effective herbicides.

Among the Experimental treatments the weed free treatment had significantly higher plant height, bulb diameter, bulb weight and bulb yield than other treatments except oxyflourfen at the rate of 0.5L/ha POE recorded higher average bulb yield, which was not significantly different from weed free check plot. Weedy check plot had the lowest value for all onion parameters and had the highest weed population, weed biomass and weed index. Among the herbicidal treatments, post emergence application of oxyflourfen at the rate of 0.5L/ha +Hand weeding 9WAT and oxyflourfen at the rate of 0.5L/ha +Hand weeding 6WAT performed better than the other control treatments and had higher weed control efficiency and yield parameters compared to the other treatments. The lowest yield loss (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. The highest (98.9%) loss in yield due to the weed was recorded from weedy check plot. The highest gross return (41468 ETB/ha) and net return (38118 ETB/ha) were recorded for the Post emergence application of oxyflourfen at the rate of 0.5L/ha + Hand weeding 9WAT. However, highest Benefit: cost ratio was recorded in Post-emergence application of oxyflourfen at the rate of 0.5L/ha followed by pre-emergence application of pendimethaline at the rate of 1.5L/ha. The weedy check had the lowest net income and benefit: cost ratio.

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. More survey works in different onion production agro-ecologies are recommended to identify the weed species composition and the most important species and monitor population shifts.

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# 7. APPENDICES

Appendix: Table1. ANOVA Table for Weed density at 60 DAT

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 248.2 | 82.72 | | |
| Trt | 12 | 42530.8 | 3544.23 | 20.94 | <0.0001 |
| Error | 36 | 6092.9 | 169.25 | | |
| Total | 51 | 48871.9 | | | |
| Grand Mean | 61.567 | | | | |
| CV | 16.10 | | | | |
| SE(m) | 6.8568 | | | | |
| Pvalue(5%) | 31.78 | | | | |

CV= Coefficient of variation, SE(m)= Standard error of mean

Appendix: Table2. ANOVA Table for Weed density at harvest

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 3113.8 | 1037.94 | | |
| Trt | 12 | 48458.5 | 4038.21 | 42.95 | <0.0001 |
| Error | 36 | 3385.1 | 94.03 | | |
| Total | 51 | 54957.4 | | | |
| Grand Mean | 51.346 | | | | |
| CV | 25.15 | | | | |
| SE(m) | 9.1326 | | | | |
| P value (5%) | 32.17 | | | | |

CV= Coefficient of variation, SE(m)= Standard error of mean

Appendix: Table3. ANOVA Table for total weed biomass

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 674113 | 224704 | | |
| Trts | 12 | 6423923 | 535327 | 15.05 | <0.0001 |
| Error | 36 | 1280469 | 35569 | | |
| Total | 51 | 8378505 | | | |
| Grand Mean | 574.12 | | | | |
| CV | 32.85 | | | | |
| SE(m) | 133.36 | | | | |
| P value (5%) | 557.95 | | | | |

CV= Coefficient of variation, SE(m)= Standard error of mean

Appendix: Table4. ANOVA Table for plant height

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 132.69 | 44.2293 | | |
| Trts | 12 | 603.59 | 50.2995 | 5.41 | <0.0001 |
| Error | 36 | 334.82 | 9.3006 | | |
| Total | 51 | 1071.11 | | | |
| Grand Mean | 37.296 | | | | |
| CV | 8.18 | | | | |
| SE(m) | 2.1565 | | | | |
| P value (5%) | 8.63 | | | | |

CV= Coefficient of variation, SE(m)= Standard error of mean

Appendix: Table5. ANOVA Table for Leaf number

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 0.6044 | 0.20145 | | |
| Trt | 12 | 5.1785 | 0.43154 | 1.35 | 0.2331 |
| Error | 36 | 11.4790 | 0.31886 | | |
| Total | 51 | 17.2618 | | | |
| Grand Mean | 9.0763 | | | | |
| CV | 6.22 | | | | |
| SE(m) | 0.3993 | | | | |
| P value (5%) | 1.34 | | | | |

CV= Coefficient of variation, SE (m)= Standard error of mean

Appendix: Table6. ANOVA Table for Bulb Diameter

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 0.4096 | 0.13654 | | |
| Trt | 12 | 27.4234 | 2.28528 | 64.41 | <0.0001 |
| Error | 36 | 1.2772 | 0.03548 | | |
| Total | 51 | 29.1102 | | | |
| Grand Mean | 2.8274 | | | | |
| CV | 6.66 | | | | |
| SE(m) | 0.1332 | | | | |
| P value (5%) | 0.52 | | | | |

CV= Coefficient of variation, SE(m)= Standard error of mean

Appendix: Table7. ANOVA Table for Bulb Weight

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 61.9 | 20.64 | | |
| Trt | 12 | 45067.9 | 3755.65 | 78.54 | <0.0001 |
| Error | 36 | 1721.4 | 47.82 | | |
| Total | 51 | 46851.2 | | | |
| Grand Mean | 85.925 | | | | |
| CV | 8.05 | | | | |
| SE(m) | 4.8896 | | | | |
| P value (5%) | 16.85 | | | | |

CV= Coefficient of variation, SE(m)= Standard error of mean

Appendix: Table8. ANOVA Table for Bulb Size

| Source of variation | D.F. | S.S. | M.S. | F- cal | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 29.2 | 9.72 | | |
| Trt | 12 | 17763.2 | 1480.27 | 66.58 | <0.0001 |
| Error | 36 | 800.3 | 22.23 | | |
| Total | 51 | 18592.7 | | | |
| Grand Mean | 54.577 | | | | |
| CV | 8.64 | | | | |
| SE(m) | 3.3341 | | | | |
| P value (5%) | 11.49 | | | | |

CV= Coefficient of variation, SE (m)= Standard error of mean

Appendix: Table9. ANOVA Table for Bulb yield(ton/ha)

| Source of variation | DF | SS | MS | F | Significance |
|---|---|---|---|---|---|
| Rep | 3 | 129.72 | 43.241 | | |
| Trts | 12 | 3844.37 | 320.364 | 15.31 | <0.0001 |
| Error | 36 | 753.43 | 20.929 | | |
| Total | 51 | 4727.52 | | | |
| Grand mean | 18.75 | | | | |
| CV | 24.40 | | | | |
| SE(m) | 3.23 | | | | |
| P value (5%) | 11.455 | | | | |

CV= Coefficient of variation, SE (m)= Standard error of mean

Appendix: Table10. Economic analysis of different treatments

| Treatments | GR(ETB/ha) | a. CHW | b. CH | c. CHA | NR(ETB /ha) | B:C ratio |
|---|---|---|---|---|---|---|
| Pendimethalin | 23086 | - | 1275 | 200 | 21611 | 14.65 |
| Pendi +HW3WAT | 30240 | 2000 | 1275 | 200 | 26765 | 7.70 |
| Pendi +HW6WAT | 32186 | 2000 | 1275 | 200 | 28711 | 8.26 |
| Pendi +HW9WAT | 31990 | 2000 | 1275 | 200 | 28515 | 8.21 |
| Oxyfluorfen | 28812 | - | 1150 | 200 | 27462 | 20.34 |
| Oxyfl +HW3WAT | 31500 | 2000 | 1150 | 200 | 28150 | 8.40 |
| Oxyfl +HW6WAT | 38668 | 2000 | 1150 | 200 | 35318 | 10.54 |
| Oxyfl + HW9WAT | 41468 | 2000 | 1150 | 200 | 38118 | 11.38 |
| HW3WAT | 13524 | 2000 | - | - | 11524 | 5.76 |
| HW6WAT | 162112 | 2000 | - | - | 14212 | 7.11 |
| HW9WAT | 11718 | 2000 | - | - | 9718 | 4.86 |
| Weed free check | 41454 | 8000 | - | - | 33454 | 4.18 |
| Weedy control | 462 | - | - | - | 462 | - |

GR= Gross return, CHW= Cost of hand weeding, CH= Cost of herbicides, CHA= Cost of herbicide application, NR= Net return. B:C= Benefit cost ratio. Price of onion bulb 14birr/kg, Price of pendimethaline (Stomp 455CS) = 1275Birr $ha^{-1}$; Price of oxyflourfen 240 EC = 1150Birr $ha^{-1}$; labor costs for spraying= 2Mandays $ha^{-1}$, Birr $100man^{-1}$; Hand weeding: 20 mandays $ha^{-1}$, Birr $100man^{-1}$.

## SKETCH OF BIOGRAPHY

The Author was born in 1986 at Jeldu worada, West shewa zone of Oromia regional state. He attended Elementary education (Grade 1-8) at Falo Elementary School. After completion of his elementary class, He joined Regassa Bulto secondary school, where he completed $9^{th}$ and 10th grades. He completed his preparatory school at Jeldu preparatory school. He then joined Adama Science and Technology University in 2014 and graduated with the Degree of Bachelor of Science in Plant Science in July 2016. Immediately following graduation, he was assigned by Federal Democratic Republic of Ethiopia Ministry of education (FDRE-MoE) to Hawassa University to pursue a study leading to the degree of Master of Science in Crop Protection.

## ANNEX

*Argemone mexicana* *Verbecina encelioides* *Amaranthus hybridus* *Xanthium strumarium*

*Sonchus oleraceae* *Eragrostis cilianensis* *Cynodon nfluensis* *Chenopodium murale*

*Nicandra physaloides* *Eleucine indica* *Cyperus rotundus* *Xanthium spinosum*

*Datura stramonium* *Portulaca oleraceae* *Galinsoga parviflora* *Tribulus cystoides*

Figure 5.Photography of dominant weed species found in the experimental field