SCHOOL OF GRADUATE STUDIES

EFFECT OF SEEDING AND HERBICIDE APPLICATION RATES ON GROWTH AND YIELD OF FOOD BARLEY (*Hordeum vulgare L.*) IN CHEHA DISTRICT, GURAGE ZONE, CENTRAL ETHIOPIA

M Sc. THESIS

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Effect of Seeding and Herbicide Application Rates on Growth and Yield of Food Barley (*Hordeum vulgare L.*) in Cheha District, Gurage Zone, CentraEthiopia

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A thesis Submitted to School of Graduate Studies, in Partial Fulfillment of the Requirements for the Degree of Master in Agronomy

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We here by certify that we have read and evaluated this Thesis titled **“Effect of Seeding and Herbicide application Rates on Growth and Yield of Food Barley (*Hordeum vulgare L.*) in Cheha District, Gurage Zone, Central Ethiopia”** prepared under our guidance by Beharu Bereda Shawye, We recommended that the Thesis shall be submitted as fulfilling the requirements for the award of MSc. degree in Agronomy.

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As members of the Board of Examiners of the Master of Science Thesis open defense examinations, We have read and evaluated this Thesis prepared by Beharu Bereda Shawye and examined the candidate . We here by certify that, the Thesis is accepted for fulfilling the requirements for the award of the degree of **Master of Science** in **Agronomy**.

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Final approval and acceptance of the thesis is contingent upon the submission of its final copy to the Council of Postgraduate Program (CPGS) through the candidate’s department or School Graduate Committee (DGC/SGC).

DEDICATION

I dedicate this thesis to my beloved wife Mihret Fikadu and all my lovely family for the all smoothed and unrestricted support rendered to me for the betterment of my life.

STATEMENT OF THE AUTHOR

By my signature below, I declare that this Thesis is a result of my own work. I have followed all ethical and technical principles of scholarship in the preparation, data collection, data analysis and compilation of this Thesis. Any scholarly matter that is included in the Thesis has been given recognition through citation. This Thesis is submitted in partial fulfillment of the requirements for a Master of Science degree in Agronomy at Wolkite University. The thesis is deposited in Wolkite University Library and is made available to borrowers under the rules of the Library. I solemnly declare that this Thesis has not been submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate. Brief quotations from this Thesis may be made without special permission provided that accurate and complete acknowledgement of the source is made. Requests for permission for extended quotations from or reproduction of the Thesis in whole or in part may be granted by the Head of the School or Department when in his or her judgment the proposed use of the material is the interest of scholarship. In all other instances, however, permission must be obtained from the author.

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BIOGRAPHICAL SKETCH

Mr. Beharu Bereda was born on June 10, 1968, in a village called Luke Kebele in Cheha District, Gurage Zone of the Southern Nation, Nationalities, and Peoples' Regional State (SNNPRS), Ethiopia. His father's name is Bereda Shawye, and his mother's name is Zuriash Bereda. He completed his elementary education at Cheha Jato Primary School from 1975 to 1982 and his senior secondary education from 1983 to 1986 at Wolkite Aberus Senior Secondary High School.

In 1994, he pursued a diploma program in plant sciences at Alage ATVTE College, which he completed in 1996. Following his graduation, he worked as a development agent (extension worker) in Gurage Zone, Gedebano Gutazer Welene District, specifically at K Maranto Kebele, for a period of four years. In September 1999, he enrolled at St. Mary's University to study Rural Development and earned his Bachelor of Arts (BA) degree in Rural Development on April 15, 2010.

Upon graduation, Mr. Beharu Bereda worked as an agronomist in Gurage Zone, Gedebano Gutazer Welene District Agricultural and Rural Development Office until July 10, 2014. From July 11, 2014, he served as the Head of the Crop Development Extension Department in the Agricultural Office of Gurage Zone, Cheha District. In October 2021, he joined Wolkite University to pursue a postgraduate program leading to a Master of Science degree in Agronomy.

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ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis Of Variance
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statics Agency
CWAO	Cheha Woreda Agricultural Office
EIAR	Ethiopian Institute of Agricultural Research
FAOSTAT	Food and Agriculture Organization of the United Nations Statistics Division
GLM	General Leaner Model
ICARDA	International Center for Agricultural Research in the Dry Areas
LSD	List Significant Difference
RCBD	Randomized Complete Block Design
SNNP	Southern Nation Nationalities of Peoples
SAS	Statically Analysis System
USDA	United States Department of Agriculture

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EFFECT OF SEEDING AND HERBICIDE APPLICATION RATES ON GROWTH AND YIELD OF BARLEY (*Hordeum vulgare L.*) AT CHEHA DISTRICT, GURAGE ZONE, CENTERAL ETHIOPIA

ABSTRACT

Barley is a major cereal crop in the highlands of Ethiopia and serves as a vital source of food, animal feed, and alcohol. However, weed infestation poses a significant challenge, leading to substantial yield reductions. Hence, to address this issue, a study was conducted during the main cropping season in 2022 in Cheha District. The objective was to assess the effect of seeding and herbicide application rates on the growth and yield of barley. The experimental setup consisted of three seeding rates (75kg/ha, 100kg/ha, and 125kg/ha) and three herbicide rates/AXIS 50EC (0.75l/ha, 1l/ha, 1.25l/ha, twice hand weeding, weed-free, and weedy). The study utilized a randomized complete block design with a factorial arrangement, and each treatment was replicated three times. The study revealed that broad-leaved weed species dominated the study area, accounting for 82.6% of relative density, while grasses constituted 17.4%. The interaction between herbicide application and seeding rates significantly ($p<0.05$) influenced number of days to heading and maturity, total number and productive tillers per plant, thousand grain weight, number of grains per spike, aboveground biomass yield, and grain yield of barley. The highest yield and yield components of barley were observed with a seed rate of 125 kg, combined with two hand weeding and the application of 1.25l/ha AXIS 50EC. Treatments involving the application of 0.75l/ha AXIS 50EC with75 kg seed rate resulted in the highest dry biomass weight for both broad-leaved and grass weed species. The maximum grain yield (5030 kg/ha) was achieved with twice hand weeding when sown with a seed rate of 125 kg. In contrast, the lowest grain yield (1600 kg/ha) was recorded with the application of 0.75l/ha AXIS 50EC and a seed rate of 75 kg. The economic analysis indicated that the combination of a 125 kg seed rate with the application of 1.25l/ha AXIS 50EC produced the highest net benefit and MRR (604.01%)*. In conclusion, sowing barley at a seed rate of 125 kg and applying AXIS 50EC at 1.25l/ha resulted in optimal growth and grain yield for the crop. Since the experiment was conducted in one location and season, it should be repeated over season and location for further recommendation.*

Keywords: Barley, Herbicide, Rate, Seed, Weed

1. INTRODUCTION

Barley *(Hordeum vulgare L.)* is one of the main cereal crops produced in the World. It ranks fourth in the world in production after wheat, maize and rice (FAO, 2018). Global barley production is estimated about 141.7 million tons (USDA, 2017). Many countries grow barley as a commercial crop. Globally European Union, Russia, Canada, USA and Argentina are the top five largest world barley producers where, European Union produces the greatest quantities of barley with an estimated production of 20.5 million tons followed by Russian federations with a production of about 8 million tons, whereas Canada, USA and Argentina barley production was estimated 7.3, 3.1 and 2.8 million tons respectively (USDA, 2017).

Ethiopia is one of the major producer of barley in Sub-Saharan Africa and the second largest producer in Africa next to Morocco, accounting for about 26 percent of the total barley production in the continent (Shahidur *et al*.,2015). In 2018/19, about 3.5 million smallholder farmers grew barley on more than 0.95 million Meher hectares of land and produce 2.053 million tons (CSA, 2019). The largest barley producer region in Ethiopia is Oromia which covers an area of 386,569.22 ha with production of 932,507.64 ton and yield of 2.412 ton ha^{-1} then south region is ranked 3rd which covers an area of 93,643.58 ha with production of 181,893.869 tons and yield of 1.94 ton ha^{-1} cropping season (CSA,2019). Gurage Zone is also one of the barley producing Zones in SNNPR which covers an area of 7,476.71 ha with production of 17,087.704 tons and yield of 2.28 ton ha^{-1} in 2020 cropping season (CSA, 2021) and barley production in Cheha district locally estimation covers an area of 760 ha with production of 1571.1 ton and yield of 2.21ton ha^{-1} in (CWAO ,2021).Its production in Ethiopia and study area are lower as compared to world the attainable 2.76 ton ha^{-1} and the yield potential of ranges from 3.5 to 5ton ha^{-1} grain yield in research fields.

In Ethiopia, barely is a dependable source of food in the highlands as it is produced during the main and short rainy seasons as well as under residual moisture (Asfaw *et al.*2015). Barley types are predominantly categorized as food and malting barley based on their uses, while in Ethiopia the highest proportion of barley production area is allocated for food barley. Food barley is principally cultivated in the highland areas of Ethiopia where the highest consumption is in the form of various traditional foods and local beverages from different barley types (Zemede *et al.*, 2000). According to (Berhane *et.al.* 2005) barley is used in diversity of recipes and deep rooted in the culture of people's diets.

In Ethiopia, where barley is cultivated, poor weed management, indefinite and below optimum plant population used by the farmers appear to be the major limiting factors resulting in low productivity of barley (Zegeye *et al.,* 2001). In most cases, barley is grown in the country without appropriate seed rate, sometimes farmers use below optimum seed rate that resulted in poor stand establishment encouraging growth of weeds (Abdulkerim *et al.,* 2015).

On the other hand, use of higher seeding rate may exacerbate problems like lodging, insect and disease infestation and damage that harm crop yield (Merga and Ahmed, 2019). Seeding rate, percent viability and germination of seeds usually determine crop density. Normally, the higher the density of a crop, lower is weed competition and vice-verse (Babu *et al.,* 2017).The crop density however, cannot be increased arbitrarily and indefinitely since every crop has an optimum population beyond which intraspecific competition among crop plants may occur. Moreover, economic benefit of using higher seeding rate should also be taken into account. It is also quite important to address plant density with respect to soil fertility, barley variety, and agro-ecology (Babu *et al.,* 2017).

Weeds increase harvesting costs, reduce quality of product (Marwat, 2008). Apart from increasing the production cost, weeds also intensify the disease and insect pest problem by serving as alternative hosts, and uncontrolled weed growth throughout the crop growth caused a yield reduction of 57.6 to 73.2% (Tesfaye *et al.,* 2014).Farmers in the country are aware of weed problem in their fields but often they cannot cope-up with heavy weed infestation during the peak-period of agricultural activities because of labor shortage, hence, most of their fields are weeded late or left un-weeded (Bekele *et al.,* 2018). Such ineffective weed management is considered as the main factor for low average yield of barley resulting in average annual yield loss of 35% (Esheteu *et al.,* 2006). They can also control those weeds which survive through mimicry, but the choice of the best herbicide, its proper time of application and proper dose are important considerations for lucrative returns (Marwat *et al.,* 2005). In addition, the use chemical weed control has becoming popular worldwide and in Ethiopia in particular mainly due to scarcity or expensive labor during peak of growing season and relatively the higher weeding cost (Haile and Girma, 2010). However, the choice of most appropriate herbicide, proper time of application and proper dose is an important consideration for lucrative returns (Tigabu and Asfaw, 2016).

Hence, a research has to be conducted to increase the effectiveness of weed management practices. This requires the use of herbicide due to shortage of labor and high labor cost during the peak periods. The weeds together with inadequate seed rate is the most important factors contributing to the reduced productivity of barley. Farmers of the research area did not practice weeding and sowing of optimum seed rate. The major reason for farmers not to practice weeding is their fatalistic attitude towards weeds, they assume that losses due to weeds are not high and they did not know that, in most cases early germinating weeds can cause greatest yield decrease. It is clear that proper weed management and sowing the crop at optimum seed rate can increase productivity of the crop in general. However, no investigations have been made in the district to evaluate or determine the effect of different weed management options and optimum seed rate on weed control and grain yield of barley. Therefore, the present study was conducted to investigate the effects of seed and herbicide rates on weed management, and yield of food barley (*Hordeum vulgare* L.) at Cheha district, Gurage Zone Central Ethiopia.

Consequently, information on influence of different seed rate and hand weeding, herbicidal weed management practices on weeds, yield components and yield of barley is limited in Gurage Zone in general and at Cheha district in particular (CWAO ,2021).

General objectives

To investigate the effects of seed and herbicide rates on weed management, and yield of food barley (*Hordeum vulgare* L.) at Cheha district, Gurage Zone Central Ethiopia.

Specific objectives

To evaluate the effect of seed and AXIS 50 EC rates on grass and annual broad leave weeds and yield of barley.

To determine economical combinations of seed and AXIS 50 EC rates for weeds management, and yield of barley.

2. LITERATURE REVIEW

2.1. Origin and Distribution of Barley

Ethiopia is a center of origin and diversity for many cultivated crops and their wild relatives. Although the barley crop is distributed throughout the world, it's supposed progenitor, *Hordeum vulgare* L. ssp. *spontaneum* C. Koch, occurred in a more restricted area, namely the Middle East and adjacent regions of North Africa (Ellis, 2002). After domestication, unrecorded migration and trade would have rapidly distributed the barley crop outside the region of its origin. The result is the development of landraces adapted to northern and western European environments and later to North American, Australian, and Southern African environments (Ellis, 2002). Barley has a long history of cultivation in Ethiopia and it is reported to have coincided with the beginning of plow culture (Zemede, 2000). In Ethiopia, barley types are predominantly categorized as food and malting barley based on their uses while the highest proportion of barley production area is allocated for food barley. Food barley is principally cultivated in the highland where the highest consumption in the form of various traditional foods and local beverages from different barley types (Zemede, 2000).

2.2. Importance of Barley in Ethiopia

Barley is a major cereal grain grown for food, animal feed and alcohol. In many countries like Ethiopia and Tibet, it is a major food crop. Farmers also use barley straw as animal feed in West Asia, North Africa, Ethiopia, Eritrea, Yemen, the Andes region and East Asia (Akar *et al.,* 2004). Barley is used as a food and beverage in more than 20 different ways in the country. Bread and Injera (pancake-like bread) are among the major types of barley products to consume. The grain is roasted and consumed as kolo (snack bread). Roasted or cooked grain is also consumed alone or mixed with beans and peas. The powder is made to porridge either boiled or raw. Kinche (a type of bulgur) is another type of food prepared from semi-milled grains of barley (Shewayrga and Sopade, 2011). The existence of genetic diversity has special significance for improving productivity and maintenance of diversity in a country like Ethiopia (Worede *et al.,* 2000).

2.3. Production Status of Barley in Ethiopia

Barley is among the major cereal crops in Ethiopia and accounts for about 8% of the total national cereal production. In the 2020/21 growth season, 951,993.15 hectares of land was covered by barley in peasants' farms in Ethiopia with a total harvest of 2,052,996.4 tons (CSA, 2021).

Ethiopia is considered as a centre of diversity of barley with the widest morphological diversity (Lakew *et al.,* 1997). Barley is believed to be the oldest domesticated crop long before other cereals were known in recorded history (Bekele *et al.,* 2005). The existence of extremely variable climatic and edaphic conditions in Ethiopia allowed barley to be cultivated from 1400 to over 4000 meters above sea level (m.a.s.l) (Asfaw, 2000).

2.4 Morphology of Barley

Barley is an annual grass that stands 60–120 cm tall. Barley has two types of root systems, seminal and adventitious. The depth the roots reach depends on the condition, texture and structure of the soil, as well as on the temperature. The deepest roots are usually of seminal origin and the upper layers of the soil tend to be packed with the later developing adventitious roots. If the grain is deeply planted a 'rhizomatous stem' is formed, which produces leaves when it reaches the surface. The 'rhizome' may be one or several internodes in length, and may carry adventitious roots (Briggs, 1978).

The stems are erect and made up of hollow, cylindrical internodes, separated by the nodes, which bear the leaves (Gomez-Macpherson, 2017). A mature barley plant consists of a central stem and 2–5 branch stems, called tillers. The apex of the main stem and each fertile tiller carries a spike. At, or near, the soil surface, the part of the stem carrying the leaf bases swells to form the crown. It is from the crown that the adventitious roots and tillers develop (Briggs, 1978).

Barley leaves are linear, 5–15 mm wide, and are produced on alternate sides of the stem (Briggs, 1978). The leaf structure consists of the sheath, blade, auricles and ligule. The sheath surrounds the stem completely. The ligule and auricles distinguish barley from other cereals as they are smooth, envelope the stem and can be pigmented with anthocyanins (Gomez-Macpherson, 2017).

2.5. Environmental and Agronomic Requirements of Barley

Barley is a crop of cool climate, and can also be grown successfully in tropical and subtropical regions. There are winter and spring types of barley. Winter types require vernalaization for completion of the life cycle (Ahlawat, 2012; Oser, 2015). Barley can grow from near sea level to an elevation up to 4500 m.a.s.l. It performs best in areas of relatively high rainfall, low relative humidity and cool temperature at maturity. A mean daily temperature of 12-15oC and 30oC during growth and ripening phase respectively are best for barley cultivation (Ahlawat, 2012). Generally, it is a cool season crop that will yield the best under conditions in which the vegetative and early reproductive growth coincide with moderate temperatures (Oser, 2015). It can grow under rain fed and drought prone conditions. A well distributed 200-250 mm rainfall can support barley crop, however, the crop does best with 400-500 mm annual rainfall. Barley being a long day plant would prefer a photoperiod of 10-12 and 12-14 hours during vegetative and reproductive stages respectively (Ahlawat, 2012).

Soil texture is very essential to the performance of barley. It favors well-drained, fertile loam or clay loam soils. Soils heavy in clay may become waterlogged, which restrict root growth and results in poor- yielding, low-quality barley crops. If soil texture is too sandy, soil water supply may become inconsistent. This leads to a decrease in plant growth and reduced grain fill. Barley is very tolerant of alkalinity and salinity. It is less tolerant of acidic soils, preferring a soil pH of 6.0 to 8.5. Barley responds negatively to soil pH levels of 5.5 or lower, and fields should be limed according to soil analysis results (Ashley *et al.*, 2014).

Agronomic practices also influence the yield, protein content and other quality parameters of barley grain which have a direct bearing on the malt quality. Early planting reduces the risk from drought stress, high temperatures later in the season, diseases, and insect infestations (McVay *et al.*, 2008). Delayed planting increases the risk of high protein content in the grain and can result in decreased yields. Reduced grain quality can ultimately lead to rejection at the elevator (Oser, 2015).

2.6. Barley Production Constraints in Ethiopia

Despite, the importance of barley and its many useful characteristics, there are several constraints that affecting its production and productivity. The most important factors that affect the yield of barley in Ethiopia are poor soil fertility, water logging, drought, frost, soil acidity, diseases and insects and weed competition (ICARDA, 2008). Scarcity of soil fertility and soil acidity are the major problem that threatens barley production in Ethiopia. Barley production is constrained by both a biotic and biotic factors such as low soil fertility, weed, diseases, insect pests, poor management practices, in adjustable barley cultivars with durable resistance to diseases, inappropriate sowing patterns, inadequate seed rate, lack of improved variety, rate of fertilizers, climatic condition, sowing time. Among the several factors responsible for low yield in study area, use of unbalanced seed rate and poor weed management are important agronomic practice and research on these limiting factors will enhance yield (FAO, 2017).

Since shortage of appropriate production system biotic stresses like disease, insect pest, weed declined grain yield by 21-67% and 25-34%respectively (Bekele, 1983). Barley shoot fly may decline yield by more than 56% and aphids may cause 4% to79% (Haile and Ali 1986).

2.7. Effect of Seed Rate on Yield and Yield Components of Barely

Seed rate is the quantity of seed required for sowing or planting in unit area. The seed rate for a particularly the crop would depends not only on its seed size test weight, but also on its desired population, germination percentage and purity percentage of seed (Sekaran *et al*., 2010). Practically the seed rate of crops is depends on the factors such as seed bed preparation, seed size, viability, seedling survival, planting methods and moisture availability(Tanner *et al.*,1991). High seed rates are required for poor seedbed, and for a grain with reduced germination capacity and vice versa (Gooding and Davies, 1997).

According to Lockhart and Wiseman (1983) reported that seed rate generally, increases for cultivars on larger seed size and low tillering capacity. Moreover, late, sowing, broadcasting seeds and heavy clay soils requires higher seeding rates. Normally, plant population increases yield also increases proportionally.

According to Sekaran *et al.* (2010) factors that influence seed rates are categorized under mechanical and biological factors. Mechanical factors such as depth of sowing, emergence nature, seed size and weight, soil texture, seed soil contact, soil fertility, soil moisture etc. biological factors also Seed size and seed weight Heavy and bold seeds produce vigorous seedlings. Application of fertilizer to large size seeds tends to encourage the seedlings than the seedlings from small size seeds.

2.8. Effects of Seed Rates on Weed Management and Productivity of Barley

Optimum seeding rate is important in determining the size of weed infestation in the field. The ideal numbers of barley plants per unit area allow the highest yield and persistent of the weed. It is well established that yield increased with seeding rate up to a certain rate level after which no more increase obtained per plant basis, while increasing rate per unit area is greatly lower or kept steady or unchanged after certain plant density. Optimum seeding rate minimize the space available between plants and rows which may be occupied by weeds. Therefore, farmers should not exceed this rate in order to avoid any intraspecific competition effects of crop plants (Rao and Nagamani, 2010).

Planting lower seeds rates may increase weed growth and also the high seeding rates should be increased when seeding is delayed beyond the optimum dates to compensate for reduced tillering (Shah *et al*., 1994). Row spacing has directly related with seeding rate and availability of water and nutrients. Under low soil moisture and fertility level planting distance between plants and rows may be increased to allow enough space to be exploited by individual crop plant. This however, opens the way for weed invasion and occupation of space available.

Weed control by hoeing or herbicides should be implemented between rows. Wide rows associated with low seeding rate allows more crop tillering and preferable mechanical weed control. The removed weeds vegetation may be laid into between rows (soil cover) to prevent any subsequent weed seed germination or growth. However when moisture and nutrients are unlimited, narrow rows and increased crop density offer advantages for weed control. Emerged weed seedling strongly suffered from both shading and competition effects of tall growing barley plants. Narrow row spacing can improve weed control during the fallow periods because weeds are smaller and more easily controlled with herbicides than they are in wide row (Derksen *et al*., 2002).

2.9. Effects of Herbicide Application on Weed Management and Productivity of barley

Weed control is always easier and less disruptive to the crop when done at an early growth stage on the weeds. Decreasing the water carrier volume can increase the danger of spray drift result in inadequate coverage of the weed species and cause yield damage. According to Tanner and Grief (1991) reported that broadleaf herbicides in the first decade of research as the phenoxy compounds provided adequate control. And also subsequent to the shift in the weed spectrum towards phenoxy tolerant broadleaf species, broadleaf herbicide screening increased in the early 1980s.

On the other hand, reliance solely the chemical weed control involves excessive use of herbicides, resulting in pollution of the environment and inter and intra-specific shifts (Hassan and Marwat, 2001) due to the development of more competitive herbicide-resistant biotypes within a plant population and community (Shrestha *et al.,* 2010).In addition, herbicide use reduces N-uptake in barley (Azad, 1997) leading to the lower growth and yields. This is especially true in the case of non-selective herbicides as reported by (Malhi *et al.*2007) who observed that significant reduction of plant N uptake in barley by applying a mixture of non-selective (glyphosate) and selective (2,4-D) herbicides. For most infestations of the selective use of herbicides is necessary. However, the uses of herbicides in conjunction with cultural and mechanical control methods usually result in the most effective management of weeds (Egan *et al.,* 1993).

Ahmad *et al.* (1993) reported that herbicides application decreased dry weight of weeds significantly compared to dry weight in non-treated plots. Chemical weed control in barley was best in producing higher grain yield than hand weeding. According to (Akhtar *et al.*1991) that application of grassy and broad leaf herbicides increased grain yield and yield components of barley.

3. MATERIALS AND METHODS

3.1. Description of the Study area

The field experiment was conducted during the 2022/23 main cropping season in Cheha district, Gurage Zone. Cheha district is situated approximately 185 km from Addis Ababa and 30 km from Welkite town. The elevation of the experimental area is 2722 meters above sea level, with geographic coordinates of 8° 02' 12.6"N latitude and 38° 01' 33.6"E longitude. The area receives an annual rainfall of 1268 mm. The mean minimum and maximum temperatures range from 10.69 to 24.97°C, with an average of 22°C (EIAR, 2011).

Cheha district consists of two agro-ecological zones, with 80% of the area classified as midland (WeinaDega) and 20% as highland (Dega). The specific kebele (administrative unit) where the study was conducted, Moche kebele, is located 16 km east of Emdibr, the capital town of Cheha district.

The dominant crops in the study area include tef, wheat, barley, maize, and faba bean. In the previous year, these crops covered an area of 4196 ha, 1068 ha, 807 ha, 1228 ha, and 154 ha, respectively (CWAO, 2022).

The soil in the experimental area is characterized as silt loam texture, which provides important information about the soil composition and its suitability for various crops.

These geographical and agricultural details provide context for understanding the specific conditions under which the field experiment was conducted in Cheha district, Gurage Zone.

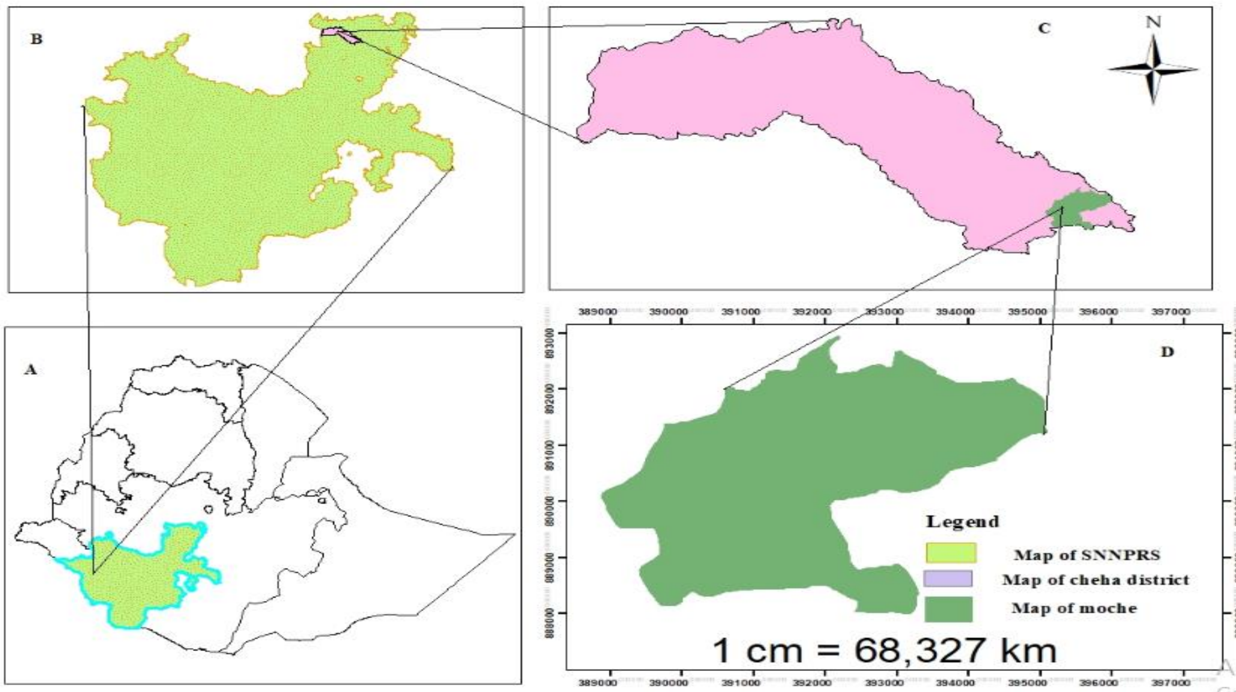

Figure 1Map of the study area.

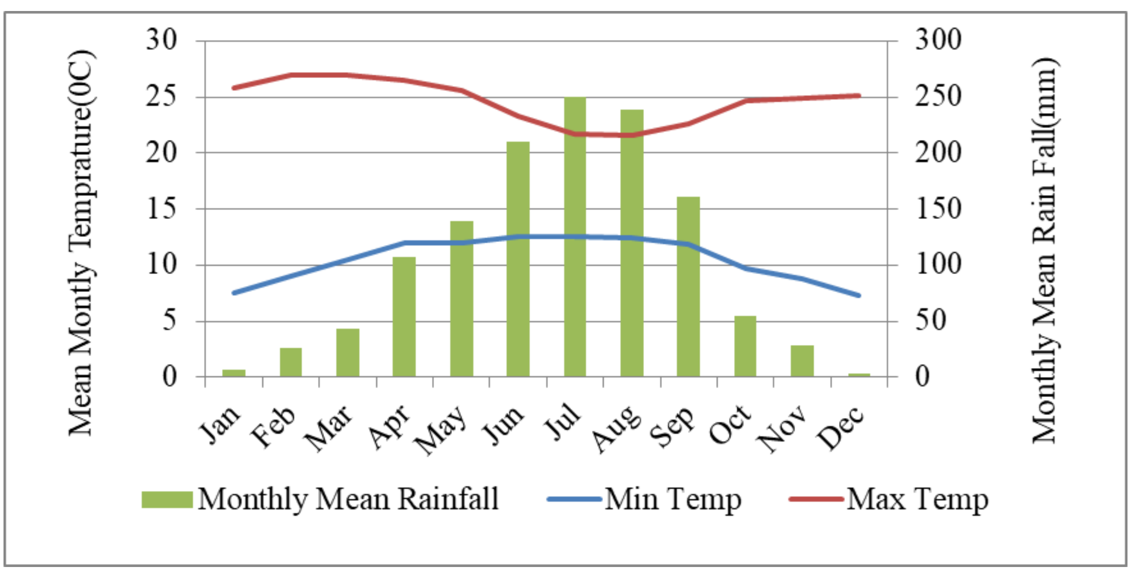

Figure 2.Weather condition of Cheha district, during the 2022/2023 cropping period

3.2. Experimental Materials

3.2.1. Plant material

Table 1.Description of Variety HB-1307

Year of released	2006
Altitude	2000 to 3000 m.a.s.l
Maturity date	135 to140 days
Yield on farmers field	2.16-3.5 ton ha^{-1}.
Yield in research site	3.5 to 5 ton ha^{-1}
Seed rate	100 kg ha^{-1}
Seed Germination	91 %

Source Holetta Agricultural Research Center (2006)

3.2.2. Fertilizer materials

The recommended fertilizer rate 100 kg of urea (46% N) and 100 kg of NPSB (18.9% N, 37.7% P_2O_5, 6.95% S, and 0.1% B) were applied during the study. These fertilizers were selected and applied based on the specific nutrient requirements of the barley crop in the study area.

3.2.3. Herbicide materials

Table 2 .Description of herbicide used in the experiment

Herbicide trade name	common name	Rate /ha	Mode of action(Spectrum of herbicides)
AXIS 50 EC	Pinoxaden 4.5%+ florasulam 0.5% EC	1L	Systemic herbicide for the control of grass weeds and broad leaved weeds in barley.

3.3. Treatments and Experimental Design

The experiment consisted of three levels of seeding rates (75, 100, and 125 kg/ha) and three rates of post-emergence herbicides (AXIS 50 EC) applied: 0.75L/ha, 1L/ha, and 1.25L/ha. In addition, there were three hand weeding treatments at 20 and 40 days after emergence (DAS), a complete weed-free treatment, and a control treatment (weedy check). The experiment was laid out in a Randomized Complete Block Design (RCBD) with a factorial arrangement with three replications, resulting in a total of 18 treatment combinations.

Each plot had a gross size of 2 m × 3 m (6 m2), consisting of ten rows. The distance between adjucent plots was 0.5 m, while the distance between blocks was 1 m. The net plot size, used for data collection, was 1.6 m × 2.8 m (4.48 m2), comprising eight rows of 2.8 m length. To avoid border effects, the outermost rows on both sides of each plot were considered as border rows and not used for data collection. The total area covered by the research was 63 m x 8 m (504 m2).

Barley seeds were sown manually on the respective plots, following the preplanned seeding rates, in rows with a spacing of 20 cm. The sowing took place in the first week of July, 2022.

3.4. Experimental Procedure and Crop Management

The experimental field was prepared appropriately for the study. The field was plowed three times using oxen to ensure proper soil preparation. Barley seeds were sown at the right time, on July 20/ 2022, with a row spacing of 20 cm.

The recommended fertilizer application was carried out at the appropriate time and rate. The whole NPSB fertilizer , with one-third of the urea were applied during sowing, while the remaining two-thirds of urea was applied at the tillering stage. This fertilizer management strategy ensured that the nutrients were supplied to the crop at the right stages of growth.

Post-emergence herbicide application was carried out at the appropriate stage, which was 30 days after emergence (DAE). The herbicide used was AXIS 50 EC, and the application was conducted using a knapsack sprayer with a capacity of 15 liters. The application rates varied based on the treatment combinations.

Hand weeding was performed at 20 and 40 days after sowing (DAS), and the treatments of complete weed-free and weedy check were also included in the study. These management practices aimed to control weed growth and assess their effect on the barley crop.

Harvesting was conducted properly when the crop reached 90% of physiological maturity. All the necessary agronomic practices are undertaken based on the recommendations given to the barley crop.

3.5. Data Collected

Weed parameters

Weed community: The weed community in the study was assessed at two different time points. The first counting was conducted 25 days after sowing, and the second counting took place 45 days after the herbicide application. To count the weed community, a 0.25 m x 0.25 m quadrat was randomly thrown at four different locations within the weedy check and other treatment sample plots. The weeds within the quadrat were identified, counted, and converted to the number of weeds per square meter (community per m2) using the methodology described by Stone and Pedigo (1972).

Dry biomass of weed: The dry biomass of the weeds was also recorded at the time of heading, the aboveground biomass of the weeds within each quadrat was harvested. The weeds were placed in separate paper bags and dried in an oven at a temperature of 65°C for 24 hours or until a constant weight was achieved. The dry weight of the weeds was measured and converted to the number of weeds per square meter (m^{-2}).

Weed population/ density: Weed population or density was assessed by measuring the number of weeds per unit area. This measurement was taken from the sample plots at two different times: 45 days after planting and at the time of heading stages. Quadratic sampling techniques, as described by Pragadal and Venkaiah (2012), were used to obtain representative samples for weed population measurement.

3.5.1. Parameters for weed control

Weed control efficiency (WCE): To assess the weed control efficiency (WCE), the following formula was used (Uygur and Mennan, 1995).

WCE = ((WDC - WDT) / WDC) x 100

Where:

WCE = Weed Control Efficiency

WDC = Weed dry matter in the weedy check (control treatment)

WDT = Weed dry matter in a particular treatment

This formula calculates the percentage of weed control achieved in a specific treatment by comparing the weed dry matter in that treatment with the weed dry matter in the weedy check (control treatment). A higher WCE indicates better weed control in the treatment.

Weed index (WI) The weed index (WI) was measured to compare the yield potential of a particular treatment with a weed-free treatment. It is expressed as a percentage and calculated using the following formula (Uygur and Mennan ,1995).

WI = (X-Y / X) x 100

Where:

WI = Weed Index

X = Yield in a complete weed-free treatment

Y = Yield in a particular treatment

This formula determines the percentage of yield potential achieved in a specific treatment compared to the yield potential in a weed-free treatment. A lower WI indicates better weed control and higher yield potential in the treatment.

The relative weed density can be calculated using the formula provided by Marwat et al. (2013).

RWD(%) = Number of weeds of a species / total number of weeds x 100

3.5.2. Crop Phenology and Growth Parameters

Days to 50% heading: This parameter represents the number of days from sowing to the time when 50% of the plants within a plot reached the heading stage. Heading is visually observed when the plants start to produce seed heads or spikes.

Days to 90% maturity: This parameter indicates the number of days from sowing to the time when 90% of the plants reached maturity. Maturity was determined based on visual observations, such as the senescence of leaves and the ability to easily thresh the grains from the glumes when pressed between the forefinger and thumb.

Plant height (cm): The plant height was measured at physiological maturity, which is the stage when the plant has fully developed and is ready for harvest. The measurement was taken from the soil surface to the top of the spike, excluding the awns. Ten randomly selected plants from the central unit area were used for measurement. The height values for each plant were summed together and divided by the number of plants to obtain the average height per plant.

3.5.3. Yield and Yield components

Kernels per spike (number/spike): The mean number of kernels per spike was determined by selecting 10 randomly chosen spikes from the net plot areas. The spikes were examined, and the number of kernels on each spike was counted. The average number of kernels per spike was then calculated.

Total number of tillers: At the physiological maturity stage, the mean number of tillers produced per plant was counted. This count was performed on ten randomly selected plants from each plot.

Number of effective tillers per plant: The mean number of effective tillers per plant was determined by counting the tillers on ten randomly selected plants from each net plot. Effective tillers are the ones that contribute to grain production.

Thousand grains weight: The weight of 1000 seeds was determined from a sample taken from the bulk grain yield of each treatment. The seeds were counted using an electronic seed counter, and their weight was measured using an electronic balance. The weight measurement was adjusted to account for a grain moisture content of 12.5%.

Grain yield: After threshing the sun-dried plants harvested from each net plot, the grain yield was measured. The yield was adjusted to a grain moisture content of 12.5%. This adjustment helps standardize the moisture content for accurate yield comparisons.

Straw yield: The straw yield was calculated by subtracting the grain yield from the above-ground biomass. The above-ground biomass includes the leaves, stems, and seeds of the harvested plants. The straw yield is expressed in tons per hectare.

Aboveground dry biomass: At maturity, the entire aboveground parts of the plants within the net plot area were harvested. The harvested plant material was sun-dried until a constant weight was achieved, and then the aboveground biomass was weighed. The biomass measurement is expressed in tons per hectare.

Harvest index: The harvest index was calculated by dividing the grain yield per plot by the total aboveground dry biomass yield per plot.

3.6. Partial Budget Analysis

The study conducted a partial budget analysis to assess the economic feasibility of different weed control methods. This analysis considered the additional input costs (variable costs) associated with implementing the weed control treatments, as well as the gross returns obtained from these treatments.

The variable costs included various factors such as labor costs for activities like harvesting, threshing, and winnowing. These labor costs varied depending on the yield obtained in each specific treatment. To represent the yield from the perspective of a farmer, the actual yield was adjusted downwards to 10% of the experimental yield. This adjustment aimed to reflect the typical yield that farmers may expect in practice.

To determine the gross returns, the prevailing local market price of barley in Birr per kilogram at the time of harvest was considered. The gross returns represent the revenue generated from selling the harvested barley.

The net returns were calculated by subtracting the variable costs (VC) from the gross returns (GR). The formula used to calculate the relative net returns (RNR) is RNR = GR - VC. This formula, as described by CIMMYT (International Maize and Wheat Improvement Center) in 1988, was applied to the yield results obtained from the different weed control treatments.

3.7. Data Analyses

The data collected and the measured parameters from the experiment at different growth stages were subjected to statistical analysis using SAS (Statistical Analysis Software) version 9.2. The statistical analysis followed the experimental design for each experiment.

To analyze the data, the ANOVA (Analysis of Variance) and GLM (General Linear Model) procedures in SAS were used. ANOVA helps determine the significance of differences among treatment groups, while GLM allows for the analysis of complex experimental designs by considering different factors and their interactions.

After conducting the ANOVA and GLM analyses, the mean separation of significant treatments was carried out using the least significant difference (LSD) test at a 5% level of probability.

4. RESULTS AND DISCUSSION

4.1. Weed Parameters

4.1.1. Weed flora in the experimental site

According to the results of the study, the experimental field was found to be infested by both broad-leaved and grass weeds. The dominant weed families in the field were *Astraceae*, *Commelinaceae,* and *Polygonaceae,* with recorded densities of 36, 23.6, and 17.9% respectively. These families were found to have a greater number of species and better adaptability to the prevailing environmental conditions compared to other weed families.

In terms of life forms, the density of annual weeds was recorded as 12.06 plants per square meter, while perennial weeds had a density of 1.1 plants per square meter. This indicates that annual weeds were more prevalent in the experimental field compared to perennial weeds.

Among the weed species encountered, broad-leaved species were dominant, accounting for 82.6% of the total weed density, while grass species accounted for 17.4%. The most prevalent weed species were *Launaea corta* (29.8%), *Commelina benghalensis* (23.6%), *Polygonum neplense* (15.1%), and *Digitaria tarnata* (9% relative density).

The variation in weed species observed in the area could be attributed to weather conditions, as different weed species exhibit variations in their distribution patterns. Similar findings have been reported by Tamado and Milberg (2000), Getachew *et al.* (2018), and Assefa *et al.* (2019), who noted that factors such as altitude, rainfall, and soil type play significant roles in influencing the distribution of weed species in a given area.

Table 2. Weed density (m^{-2}) and relative density (%) of weed species of the experimental field during the 2022/2023 cropping season

Weed species	Family	Life form	Weed density (m-2)	Relative density (%)
Broad leaved				

Launaea cornuta	Astraceae	Annual	3.9	29.8
Galinsoga parviflora Cav	Astraceae	Annual	0.8	6.2
Commelina benghalensis L.	Commelinaceae	Annual	3.1	23.6
Rumex abyssinicus jacq.	Polygonaceae	Annual	0.4	2.8
Polygonum nepalense	Polygonaceae	Annual	2	15.1
Euphorbia indica	Euphorbiaceae	Annual	0.67	5.1
Total				82.6
Grass				
Bromus pectinatus	Poideae	Perennial	1.1	8.4
Digitaria tarnata	Poaceae	Annual	1.19	9
Total				17.4

4.1.2. Weed density

The weed density of the experimental plots was significantly($P<0.01$) influenced by the main effects of seeding rate and herbicide application, as well as the interaction between seeding rate and herbicide application (Appendix Table 2).

The highest weed density (39.00 plants per square meter) was observed in plots where the seeding rate was 75 kg and herbicide application was 0.75 liters per hectare of Axis 50 EC, which was next to the weedy check treatments. On the other hand, the lowest weed density was recorded in plots where the crop was hand weeded twice, at 20 and 40 days after crop emergence, regardless of the seeding rate. Additionally, the application of 1.25 liters per hectare of Axis 50 EC combined with a seeding rate of 125 kg per hectare resulted in significantly lower weed density, similar to hand weeding at 20&40 DAS plots (Table 4).

In general, the combination of two rounds of hand weeding at 20 and 40 days after crop emergence, along with a seeding rate of 125 kg per hectare and the application of 1.25 liters per hectare of Axis 50 EC, significantly reduced weed density (refer to Table 4). This reduction in weed density could be attributed to the reduction of the weed seed bank through early weeding, as well as the removal of later-emerging weeds through subsequent weeding, which enhanced crop competition. Moreover, the sowing of barley at a seeding rate of 125 kg per hectare, combined with the application of 1.25 liters per hectare of Axis 50 EC, contributed to lower inter and intra-specific competition. The herbicide was persistent enough to suppress weeds for up to 45 days after treatment and beyond. As a result, the reduced competition with weeds allowed barley to establish a dense canopy and out compete weeds throughout the growing season.

These findings are consistent with the results reported by Bibi *et al.* (2008), who concluded that herbicide application significantly influenced weed populations. Similar conclusions were reached by Nadeem *et al.* (2006) and Munsif *et al.* (2009), who found that unchecked weed growth in the weedy check plots resulted in higher weed density, while herbicide application caused weed mortality and reduced weed density at harvest.

Table 3.Interaction effect of seeding rate and herbicide application on weed density of barley during 2022/2023 cropping season

Herbicide application(L ha^{-1})	Seeding rate (kg ha^{-1})		
	75	100	125
AXIS 50EC at 0.75	39.00^{d}	35.33^{de}	32.00^{ef}
AXIS 50EC at 1	30.00^{ef}	27.33^{fg}	22.33^{gh}
AXIS 50EC at 1.25	20.00^{hi}	16.67^{hij}	13.67^{ij}
Hand weeding at 20&40 DAS	13.00^{j}	11.00^{j}	10.67^{j}
Weed free	0^{k}	0^{k}	0^{k}
Weedy check	115.67^{a}	81.00^{b}	61.67^{c}
LSD(0.05)		6.98	
CV (%)		14.3	

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.1.3. Weed dry weight of broad leaved and grass weeds

The dry weight of both broad-leaved and grass weeds was significantly influenced by the interaction effect of herbicide application and seeding rate, as well as their individual effects (Appendix Table 3).

The highest dry weight of broad-leaved and grass weeds (5.93 and 3.56 grams per square meter) were recorded in a plot with a seeding rate of 75 kg per hectare with an application rate of 0.75 liters per hectare of Axis 50 EC respectively, which was adjacent to the weedy check plots. On the other hand, the lowest dry weight of broad-leaved an grass weeds (1.53 and 0.92 grams per square meter) were observed in plots with a seeding rate of 125 kg per hectare, where the crop was hand weeded twice at 20 and 40 days after crop emergence, and an application rate of 1.25 liters per hectare of Axis 50 EC, respectively. These results indicate that higher seeding rates combined with herbicide application and subsequent hand weeding significantly reduced the dry weight of both broad-leaved and grass weeds compared to lower seeding rates.

Furthermore, the dry weight of broad-leaved weeds was significantly reduced at seeding rates of 100 kg and 125 kg compared to a seeding rate of 75 kg, regardless of the weeding and herbicide application rates (Table 5). Overall, higher seeding rates combined with two rounds of hand weeding and an application rate of 1.25 liters per hectare of Axis 50 EC resulted in a significant reduction in the dry weight of both broad-leaved and grass weeds compared to lower seeding rates. This could be attributed to lower weed density at higher seeding rates, providing a competitive advantage to the crops and forcing weeds to accumulate less dry matter.

The lower weed dry weight in plots where herbicides were applied can be attributed to the lower weed density resulting from weed mortality caused by the herbicide application. This finding is consistent with the conclusions of Nadeem *et al.* (2006) and Munsif *et al.* (2009), who reported that the application of herbicides caused weed mortality and subsequently reduced weed density at harvest. The absence of available nutrients in the control plots and the suppression by well-developed wheat plants might have contributed to similar weed density in those plots.

Table 4.Interaction effect of seeding rate and herbicide application on dry weight of broad and grass weeds during 2022/23 cropping season.

Herbicide application ($L\text{-}ha^{-1}$)	Seeding rate (kg)					
	75	100	125	75	100	125
	Dry weight of broad leaved ($g\ m^{-2}$)			Dry weight of grass ($g\ m^{-2}$)		
AXIS 50EC at 0.75	5.93^{d}	5.40^{de}	4.80^{def}	3.56^{d}	3.24^{de}	2.88^{def}
AXIS 50EC at 1	4.47^{efg}	4.13^{fg}	3.40^{gh}	2.68^{efg}	2.48^{fg}	2.04^{gh}
AXIS 50EC at 1.25	2.93^{hi}	2.40^{hij}	2.00^{ij}	1.76^{hi}	1.44^{hij}	1.20^{ij}

Hand weeding at 20&40 DAS	1.87^{ij}	1.67^{jk}	1.53^{jkl}	1.12^{ij}	1.00^{jk}	0.92^{jkl}
Weed free	0.53^{klm}	0.40^{lm}	0.20^{m}	0.36^{klm}	0.24^{lm}	0.12^{m}
Weedy check	17.93^{a}	11.87^{b}	9.33^{c}	10.76^{a}	7.12^{b}	5.60^{c}
LSD(0.05)	1.187			0.712		
CV (%)	15.94			15.93		

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.1.4. Weed control efficiency (WCE)

The weed control efficiency was significantly ($P<0.01$) influenced by the interaction effects of herbicide application and seeding rate, as well as their individual effects (Appendix Table 4).

The highest control efficiency (89.38) was observed in plots where the crop was hand weeded twice at 20 and 40 days after crop emergence, regardless of the seeding rate. Additionally, plots treated with an application rate of 1.25 liters per hectare of Axis-50EC, combined with all seeding rates, also showed high control efficiency. On the other hand, the lowest efficacy (47.93) was recorded in plots treated with an application rate of 0.75 liters per hectare of Axis-50EC, combined with all seeding rates. Moreover, the combination of twice hand weeding at 20 and 40 days after crop emergence, along with the application of 1.25 lha^{-1}Axis-50EC at all seeding rates, resulted in the highest control efficiency (Table 5).

Overall, sowing barley at higher seeding rates led to significantly higher weed control efficiency compared to lower seeding rate treatments, regardless of the weeding frequency and the application rate of Axis-50EC. These findings are consistent with the observations of Shah and Koul (1990) and Thakur (1994), who reported higher WCE when wheat crops were subjected to twice hand weeding at 20 and 40 days after sowing. Similarly, Ashiq *et al.* (2007) found that herbicides with a broad spectrum provided better weed control efficiency compared to control treatments. Tana *et al.* (2018) also reported that high control efficiency indicated effective control of weeds when they were in their early stages or before they accumulated significant dry matter through competition with crop plants.

Table 5.Interaction effect of seeding and herbicide application rates on Weed control efficiency of the study site during 2022/2023 cropping period.

Herbicide application(L ha^{-1})	WCE (%)		
	Seeding rate (kg ha^{-1})		
	75	100	125
AXIS 50EC at 0.75	47.93^{f}	53.86^{f}	66.48^{e}
AXIS 50EC at 1	61.93^{e}	61.27^{e}	75.27^{d}
AXIS 50EC at 1.25	76..18^{d}	79.15^{cd}	85.02^{bc}
Hand weeding at 20&40 DAS	83.51^{bc}	85.99^{b}	89.38^{b}
Weed free	100.00^{a}	100.00^{a}	100.00^{a}
Weedy check	0.00^{g}	0.00^{g}	0.00^{g}
LSD(0.05)	6.47		
CV(%)	6.02		

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.1.5. Weed index

The analysis of variance revealed that the Weed index was significantly ($p<0.05$) influenced by the main effects of herbicide application. However, the main effects of seed rate and the interaction effects of herbicide application and seeding rate were not found to be significant factors affecting this parameter (Appendix Table 4).

The highest weed index value (60.11%) was observed in plots treated with an application rate of 0.75 liters per hectare of Axis 50 EC, which were adjacent to the weedy check plots. This high weed index value can be attributed to severe competition among weeds and within weed species, leading to a higher overall weed index. On the other hand, the lowest weed index value (17.98%)

was recorded in plots hand weeded twice at 20 and 40 days after crop emergence, and these plots were adjacent to weed-free plots. This low weed index value can be attributed to lower dry weed biomass, better weed control efficiency, minimal competition among weed species, and higher grain yield, all of which contribute to a lower overall weed index (Table 6).

In general, the weed index value was lower in plots where the crop was subjected to twice hand weeding at 20 and 40 days after crop emergence, compared to plots treated with an application rate of 0.75 liters per hectare of Axis 50 EC. This suggests that hand weeding treatment resulted in better weed control and reduced competition, leading to a lower overall weed index in the field.

Table 6. Main effects of herbicide application on Weed index of the study site during 2022/2023 cropping period.

Seeding rate (kg ha^{-1})	Weed index
75	39.91
100	36.66
125	36.05
LSD(0.05)	Ns
Herbicide application(L ha-1)	
AXIS 50EC at 0.75	60.11^{b}
AXIS 50EC at 1	43.57^{c}
AXIS 50EC at 1.25	23.65^{d}
Hand weeding at 20&40 DAS	17.98^{e}
Weed free	0.00^{f}
Weedy check	79.93^{a}
LSD(0.05)	4.74
CV (%)	13.18

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.2. Crop Parameters

4.2.1. Days to heading

The analysis of variance showed that number of days to 50% heading was significantly ($p<0.05$) influenced by the main effects of herbicide application and seeding rate (Appendix Table 5.).

Early days to heading of barley (70.00 days) was recorded the seed rate 75kg ha^{-1} with the application of 0.75l ha^{-1} Axis 50EC while the longest days to heading (90.67 days) of the crop was recorded from the seed rate 100kg ha^{-1} with twice hand weeding at 20 and 40 days after crop emergence. On the other hand the seed rate at 100 kg ha^{-1} and 125 kg ha^{-1} with twice hand weeding at 20 and 40 days after crop emergence showed that statistically non- significant and also the seed rate at 100kg ha^{-1} and 125kg ha^{-1} with application of 1.25l ha^{-1} Axis 50EC showed that statistically non-significant. Therefore those twice hand weeding at 20 and 40 days after crop emergence and application of 1.25l ha^{-1} Axis 50EC with highest seed rate took longer period to heading (Table 8). In general, removing weeds from barley field elongates the days to heading as compared to leaving the crop with weeds entirely throughout the growing period. This might be due to the availability of resources (e.g. moisture, nutrient etc.) for a longer period of times without competition with weeds which will enable the plant to grow vegetative for a longer period without heading. Similarly, Sunday and Udensi (2013) reported that the plants in weed free plots took the highest time to reach 50% flowering and days to physiological maturity. Also this current result is in contrary to the observation of Blackshaw *et al.,* (2000) who stated that maturity was not affected by seed rate.

4.2.2. Days to physiological maturity

The analysis of variance showed that days to physiological maturity was significantly influenced by the interaction effects of herbicide application and seeding rate as well as by their interaction (Appendix Table 5.). The shortest days to physiological maturity of barley (80.97 days) was recorded from the seed rate 75kg ha^{-1} with application of 0.75l ha^{-1} Axis 50EC while the longest days to physiological maturity (130.67 days) of the crop was recorded from the seed rate 125kg ha^{-1} with twice hand weeding at 20 and 40 days after crop emergence and followed (118.67 days) of the crop was recorded from the seed rate 125kg ha^{-1} with 1.25l ha^{-1} Axis 50EC. However the seed rate at 75kg ha^{-1} and 100kg ha^{-1} with twice hand weeding at 20 and 40 days after crop emergence and also the seed rate at 125kg ha^{-1} with application of 1.25l ha^{-1} Axis 50EC showed that statistically non-significant (Table 7).

In general, removing weeds from barley field elongates the days to physiological maturity as compared to leaving the crop with weeds entirely throughout the growing period. This might be due to the availability of resources (e.g. moisture, nutrient etc.) for a longer period of times without competition with weeds which will enable the plant to grow vegetative for a longer period without heading and to increased days to maturity. The current finding is in agreement with the work of Tesfaye *et al.,* (2012) who concluded that increasing plants density shortened days to physiological maturity. Similarly, Sunday and Udensi (2013) reported that the plants in weed free plots took the highest time to reach 50% flowering and days to physiological maturity.

Table 7. Interaction effect of seeding and herbicide application rates on days to heading and days to physiological maturity during 2022/23 cropping season.

Herbicide application(L ha^{-1})	Seeding rate (kg ha^{-1})					
	75	100	125	75	100	125
	Days to heading			Days to physiological maturity		
AXIS 50EC at 0.75	70.00^{ij}	72.67^{hi}	72.67^{hi}	80.67^{jkl}	82.33^{ijk}	83.33^{hij}
AXIS 50EC at 1	72.67^{hi}	80.00^{fg}	76.67^{gh}	88.00^{ghi}	89.00^{gh}	90.00^{g}
AXIS 50EC at 1.25	79.33^{g}	85.33^{de}	84.67^{def}	101.00^{f}	108.67^{e}	118.67^{d}
Hand weeding at 20&40 DAS	81.33^{efg}	90.67^{bc}	89.33^{cd}	119.00^{d}	123.33^{d}	130.67^{c}
Weed free	97.33^{a}	94.33^{ab}	96.67^{a}	138.00^{b}	146.00^{a}	150.33^{a}
Weedy check	63.67^{k}	64.33^{k}	66.33^{jk}	76.00^{l}	77.00^{kl}	78.00^{jkl}
LSD(0.05)	4.669			6.725		
CV (%)	3.52			3.53		

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.2.3. Plant height

The analysis of variance showed that plant height was significantly affected by the main effects of herbicide application and seeding rate. However, the interaction of herbicide application and seeding rate were not significant on this parameter (Appendix Table.5). As to the herbicide application effect, taller plants (101.86 cm) were recorded when the barley crop was kept twice hand weeding at 20 and 40 days after crop emergence and followed (94.78cm) recorded the application of 1.25l ha^{-1} Axis 50EC. The shortest plants (68.14 cm) were recorded from plots in 0.75l ha^{-1} Axis 50EC that was next to weedy check plots (Table 8). According to the result of this study, plant height of barley increase with increasing herbicide application rate and weeding frequency. This could be due to the fact that plant height significantly increased with increasing length of weed free period and decreased with increasing length of weed infested period that resulted in significantly lower weed dry matter and minimum competition between the weeds and the crop for growth resources particularly for light, moisture, soil nutrients and assimilate. This allows the crop to fully utilize these resources which promoted better crop growth performance and resulted in increase in plant height of the crop. On the other hand, increasing duration of weedy period resulted in sever competition for the environmental resources. Such limited light, water, nutrients might have been taken by the weeds for longer period of time that reduced the plant height of barley crop. This was in agreement with Martinkova and Honken (2001) who reported a decrease in plant height of maize with increase in competition duration. Furthermore, Hussain *et al*. (2009) reported lower plant height in black seed with increased competition periods.

The tallest plants height (93.61 cm) was recorded when the barley crop was kept that the seed rate of (125kg ha^{-1}) and the shortest plants (76.49 cm) were recorded from plots in the seed rate of (75kg ha^{-1}).

The current result is in line with the study by Lake (2018) reported that the highest barley plant height (104.6) was obtained when the seed was applied at 100kgha^{-1}.Suleiman (2014) who reported that increase in the seeding rate resulted in a slight increase in the heights of the plant.

Table 8. Effect of seeding rate and herbicide application on plant height during 2022/23 cropping season.

Seeding rate (kg ha^{-1})	Plant height (cm)
75	76.49^{c}
100	87.99^{b}
125	93.61^{a}
LSD(0.05)	2.54
Herbicide application(L ha-1)	
AXIS 50EC at 0.75	68.14^{e}

AXIS 50EC at 1	80.29[d]
AXIS 50EC at 1.25	94.78[c]
Hand weeding at 20&40 DAS	101.86[b]
Weed free	110.46[a]
Weedy check	60.66[f]
LSD(0.05)	3.60
CV (%)	4.36

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.3. Yield Component and Yield

4.3.1. Total number of tillers

The analysis of variance showed that total number of tillers was significantly ($p<0.01$) influenced by the main effects of herbicide application and seeding rate as well as by their interaction (Appendix Table 6.).

The maximum number total number of tillers (13.03) was recorded from the lowest seed rate (75 kg ha^{-1}) with twice hand weeding at 20 and 40 days after crop emergence followed by 10.47 was recorded from the seed rate (125 kg ha^{-1}) with application of 1.25l ha^{-1} Axis 50 EC. However the minimum number of total number of tillers (6.90) of the crop was recorded from the seed rate of 75 kg ha^{-1} with 0.75l ha^{-1} Axis 50 EC that was next to weedy check plots (Table 10).The reduced number of tillers per plant at low seed rate might be due to the increasing weed competition.

In general the increase in number of tillers per plant from two times hand weeding and the application of optimum rate of Axis 50 EC might be due to the availability of enough resources as there is no competition and enable to increase number of tillers. Whereas lower seed rate with the lower application rate of Axis 50 EC treatment there is a fierce competition between the crop and the weed making resources availability limited for tiller numbers. Similarly, Ahmadi *et al.*, (2007) reported that number of tillers per plants significantly increased with increasing length of weed-free period and decreased with increasing length of weed infested period. Furthermore, Naveed *et al*., (2008) who stated that weeds are naturally strong competitor and compete with crops for space, nutrient, moisture, light and carbon dioxides that they could reduce the yield components of the crop.

4.3.2. Number of effective tillers per plant

The analysis of variance showed that number of effective tillers was significantly influenced by the interaction effects of herbicide application and seeding rate. (Appendix Table 6.).

The maximum number of effective tillers (10.90) was recorded from twice hand weeding at 20 and 40 days after crop emergence with 75 kg ha^{-1} seed rate and followed by 8.47 effective tillers which was recorded from the application of 1.25l ha^{-1} Axis 50 EC with 125 kg ha^{-1} seed rate. However the minimum number of effective tillers of barley (4.90) was recorded from the application of 0.75l ha^{-1} Axis 50 EC with 75 kg ha^{-1} seed rate (Table 9).

The increase in effective tillers per plant from the twice hand weeding at 20 and 40 days after crop emergence might be due to the availability of enough resources as there is no competition and enable to increase number of productive tillers. Whereas under the lower rate of Axis 50 EC treatment there was a fierce competition between the crop and the weed making resources availability limited for productive tiller numbers. Similarly, Ahmadi *et al., (*2007) reported that number of tillers per plants significantly increased with increasing length of weed-free period and decreased with increasing length of weed infested period. Furthermore, Naveed *et al*., (2008) who stated that weeds are naturally strong competitor and compete with crops for space, nutrient, moisture, light and carbon dioxides that they could reduce the yield components of the crop.

Dalga (2016) reported similar results that under low competition between weeds and crop for resources that enhanced productive tillers. Asad *et al*. (2017) also stated that increase in number of fertile productive tillers relatively better weed control which ultimately facilitated by more translocation of photosynthate towards reproductive growth due to lower weed wheat competition. Hussein *et al*. (2013) also reported that effective weed control methods could reduce dry matter of weed and increased number of wheat productive tillers.

Table 9. Interaction effect of seeding rate and herbicide application on total number of tillers and number of effective tillers per plant during 2022/23 cropping season.

Herbicide application(L ha^{-1})	Seeding rate (kg ha^{-1})					
	75	100	125	75	100	125
	Total number of tillers			Number of effective tillers per plant		

AXIS 50EC at 0.75	6.90^{k}	7.13^{jk}	7.53^{ij}	4.90^{j}	5.13^{hi}	5.53^{gh}
AXIS 50EC at 1	8.07^{hi}	8.57^{gh}	8.93^{g}	6.07^{fg}	6.57^{ef}	6.93^{e}
AXIS 50EC at 1.25	9.1^{fg}	9.57^{ef}	10.47^{d}	7.10^{de}	7.57^{d}	8.47^{c}
Hand weeding at 20&40 DAS	13.03^{ab}	10.13^{de}	11.53^{c}	10.90^{a}	8.13^{c}	9.53^{b}
Weed free	13.30^{a}	11.77^{c}	12.67^{b}	11.20^{a}	9.77^{b}	10.67^{a}
Weedy check	3.20^{m}	3.63^{lm}	3.90^{l}	2.20^{k}	2.63^{jk}	2.90^{j}
LSD(0.05)		0.58			0.57	
CV (%)		3.94			4.86	

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.3.3. Kernels per spike

Number of kernels per spike was significantly ($p<0.01$) affected by the main effect of herbicide application and seeding rate as well as by their interaction (Appendix Table 6.).

The highest number of seeds per spike (63.92) was recorded from plots where twice hand weeding at 20 and 40 days after crop emergence with 75 kg ha^{-1} seed rate; followed by the application 1.25l ha^{-1} Axis 50 EC with 125kg ha^{-1} seed rate (53.63) was recorded. Whereas, the application 0.75l ha^{-1} Axis 50 EC with seed rate of 75 kg ha^{-1}, had the lowest number (16.77) of seeds per spike that was next to weedy check plots (Table 10). Similar results have also been reported by Pandey *et al*. (2007) increase in number of grains per spike can be attributed to availability of nutrients and greater spike length of wheat. According to Ali *et al*. (2014) the number of seeds per spike increased with decreased weed competition. The poor grain filling due to presence of weeds was reported to be due to reduced number of tillers, ear formation, and stem weight and height reduction in wheat (Fazal *et al*., 2012).

4.3.4. Thousand grains weight (g)

The analysis of variance showed that thousand grains weight was significantly influenced by the main effects of herbicide application and seeding rate as well as by their interaction (Appendix Table 6.)

The highest thousand grains weight (63.90g) was recorded from plots where twice hand weeding at 20 and 40 days after crop emergence with 75 kg ha^{-1} seed rate, and followed by 56.03g) from the application of 1.25l ha^{-1} Axis 50 EC with 125 kg ha^{-1} seed rate. These could be related to lower dry weed biomass, better weed control efficiency, minimum intra and inter-specific competition that enable the crop to utilize resources efficiently to produce well vigor seeds. Whereas the application of 0.75l ha^{-1} Axis 50 EC with 75 kg ha^{1} seed rate, treatments had the lowest thousand grains weight (32.97) that was next to weedy check plots (Table 10). The lowest number of thousand grain weight was due to higher competition of plant growth resources that resulted in less vigor grains.

Similar results from Pandey *et al*. (2007) reported that lower thousand grain weight in weedy check. Bogale *et al*. (2020) also reported that the highest thousand grain weight at high seed rate with application of optimum rate of herbicide but at weedy check treatments lowest number of thousand grain weight due to higher competition of plant for growth resources that resulted in less vigor seeds.

Table 10. Interaction effect of seeding rate and herbicide application on kernels per spike and thousand grains weight during 2022/23 cropping season.

Herbicide application(L ha^{-1})	Seeding rate (kg ha^{-1})					
	75	100	125	75	100	125
	Kernels per spike			Thousand grains weight		
AXIS 50EC at 0.75	16.77^{j}	22.00^{i}	27.83^{h}	32.97^{i}	36.37^{hi}	42.33^{fg}
AXIS 50EC at 1	21.33^{i}	27.47^{h}	34.27^{g}	39.63^{gh}	45.87^{ef}	47.80^{e}

AXIS 50EC at 1.25	43.40^{f}	47.57^{e}	53.63^{d}	42.67^{fg}	54.67^{d}	56.03^{cd}
Hand weeding at 20&40 DAS	63.92^{a}	54.90^{cd}	58.63^{bc}	63.90^{a}	57.97^{bcd}	59.50^{bc}
Weed free	64.17^{a}	61.96^{ab}	63.90^{a}	64.08^{a}	60.90^{ab}	63.97^{a}
Weedy check	7.00^{k}	8.67^{k}	9.67^{k}	24.07^{j}	24.30^{j}	25.03^{j}
LSD(0.05)		3.75			4.18	
CV (%)		5.92			5.38	

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.3.5. Grain yield (tha^{-1})

The analysis of variance indicated that grain yield was significantly ($p<0.01$) influenced by the interaction effects of herbicide application and seeding rate, as well as their individual effects (Appendix Table 7).

The highest grain yield (5.03tha^{-1}) was recorded in plots treated with twice hand weeding at 20 and 40 days after crop emergence, with a seeding rate of 125 kg per hectare. This was followed by plots treated with an application rate of 1.25 liters per hectare of Axis 50 EC, also with a seeding rate of 125 kg per hectare, which had a grain yield of 4.81tha^{-1}. These higher grain yields can be attributed to lower dry weed biomass, better weed control efficiency, minimal competition among weed species, and optimal resource utilization by the crop. These factors contribute to the crop's ability to flourish, produce fertile tillers, increase the number of seeds per spike, enhance thousand grain weight, and achieve higher overall biomass production.

On the other hand, plots treated with an application rate of 0.75 liters per hectare of Axis 50 EC, combined with a seeding rate of 75 kg per hectare, had lower grain yield (1.60tha^{-1}). This can be attributed to severe competition among weeds and within weed species, resulting in reduced yield and compromised yield components.

The results of this study align with the findings of Begum *et al.* (2008), who reported that grain yield significantly decreased with increasing weed competition duration. Nadeem *et al.* (2006)

also found that different herbicidal treatments had a significant effect on the grain yield of wheat, with the greatest reduction in yield occurring when no herbicide was applied. Increased grain yield in herbicide-treated plots can be attributed to efficient weed control, allowing the crop to utilize all available resources. These findings are consistent with the work of Tunio *et al.* (2004), who reported that herbicidal treatments significantly increased grain yield in wheat. Ali *et al.* (2014) also noted that maximum grain yield was achieved in weed-free conditions due to a lower weed population and improved nutrient and water use efficiency, while the yield was minimum in weedy check plots.

4.3.6. Straw yield (tha^{-1})

The analysis of variance showed that straw yield was significantly ($p<0.01$) influenced by the main effects of herbicide application and seeding rate as well as by their interaction (Appendix Table 7.).

The highest straw yield (7.12 tha^{-1}) was recorded from plots where twice hand weeding with (125 kg ha^{-1}) seed rate followed by (6.82 tha^{-1}) which was recorded from plots with the application of 1.25l ha^{-1}Axis 50 EC with (125 kg ha^{-1}) seed rate. This could be related to lower dry weed biomass, better weed control efficiency, minimum intra and inter-specific competition that enable the crop to utilize resources efficiently to flourish and produce high total biomass. The optimum rate of herbicide application and frequent weeding also had the ability of controlling various weed species and persistent. Whereas, application of 0.75l ha^{-1}Axis 50 EC with 75 kg ha^{-1} seed rate, gave low straw yield (2.46tha^{-1}) due to the severe inter and intra specific competition (Table 11).

Teferi *et al*., (2019) report that the highest straw yield of food barley was 10.5 ton ha^{-1} observed from seeding rate of 150 kg ha^{-1}, while the lowest (5.38 ton ha^{-1}) straw yield was found from seeding rate of 75 kg ha^{-1} Ali and Awan (2004) also stated that decreasing the biological yield in wheat might be due to weed competition as a consequence of depletion of nutrient supply and water by weeds, which resulted in reduced growth, grain and straw yields of crop plants.

Table 11. Interaction effect of seeding and herbicide application rates on grain yield and straw yield during 2022/23 cropping season.

Herbicide application(L ha^{-1})	Seeding rate (kg ha^{-1})					
	75	100	125	75	100	125
	Grain yield(t/ha)			Straw yield(t/ha)		
AXIS 50EC at 0.75	1.60^{h}	2.07^{gh}	2.47^{fg}	2.46^{hi}	3.08^{gh}	3.70^{fg}
AXIS 50EC at 1	2.15^{g}	3.19^{de}	3.29^{d}	3.23^{g}	4.67^{de}	4.89^{cd}
AXIS 50EC at 1.25	2.74^{ef}	3.91^{c}	4.81^{b}	4.01^{ef}	5.55^{bc}	6.82^{b}
Hand weeding at 20&40 DAS	3.33^{d}	4.18^{c}	5.03^{ab}	4.80^{d}	5.78^{b}	7.12^{a}
Weed free	4.21^{c}	5.13^{ab}	5.35^{a}	5.82^{b}	6.79^{a}	7.30^{a}
Weedy check	0.98^{i}	1.03^{i}	1.01^{i}	2.08^{i}	1.93^{i}	2.09^{i}
LSD(0.05)	0.495			0.703		
CV (%)	9.52			9.29		

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.3.7. Aboveground dry biomass (t ha^{-1})

The analysis of variance revealed that aboveground dry biomass was significantly ($p<0.01$) influenced by the main effects of herbicide application and seeding rate, as well as their interaction (Appendix Table 7).

The highest aboveground dry biomass (12.15tha^{-1}) was recorded in plots where the crop was subjected to twice hand weeding at 20 and 40 days after crop emergence, with a seeding rate of 125 kg per hectare. This was followed by plots treated with an application rate of 1.25 liters per hectare of Axis 50 EC, with a seeding rate of 125 kg per hectare, which had an aboveground dry biomass of 11.63tha^{-1}. These higher biomass values can be attributed to lower dry weed biomass, better weed control efficiency, minimal competition among weed species, and optimal resource utilization by the crop. These factors enable the crop to utilize resources efficiently, leading to increased total biomass production.

On the other hand, plots treated with an application rate of 0.75 liters per hectare of Axis 50 EC, combined with a seeding rate of 75 kg per hectare, had lower aboveground dry biomass (4.06tha^{-1}). This can be attributed to severe competition among weeds and within weed species, resulting in reduced crop growth, yield, and overall biomass production.

Therefore, it can be concluded that higher seeding rates should be used in combination with a broad-spectrum herbicide or effective weed control methods to decrease weed growth in the field and increase biological yield. Similar results were reported by Ali and Awan (2004), also found that decreasing the biological yield in wheat was due to weed competition, leading to nutrient and water depletion by weeds and reduced growth, grain yield, and straw yield of the crop. It is also worth noting that high seed rates were found to increase yield under well-watered conditions, while the opposite effect was observed under low soil moisture conditions (Marwat *et al.*, 2011). Studies by Zahoor *et al.* (2012) that weed control methods increased the biological yield of wheat by reducing weed infestation. Adverse effects of increasing the duration of weed infestation on biomass production were reported by Anwar (2014), with the negative impact gradually increasing with the advancement of growth stages. Naveed *et al.* (2008) also noted that weeds are strong natural competitors that compete with crops for space, nutrients, moisture, light, and carbon dioxide, leading to reduced straw and grain accumulation.

Table 12. Interaction effect of seeding rate and herbicide application on aboveground dry biomass during 2022/23 cropping season.

Herbicide application(L ha^{-1})	Aboveground dry biomass (t ha^{-1})		
	Seeding rate (kg ha^{-1})		
	75	100	125
AXIS 50EC at 0.75	4.06^{gh}	5.15^{fg}	6.17^{df}
AXIS 50EC at 1	5.38^{f}	7.86^{cd}	8.18^{c}

AXIS 50EC at 1.25	6.75^{de}	9.46^{b}	11.63^{a}
Hand weeding at 20&40 DAS	8.13^{c}	9.96^{b}	12.15^{a}
Weed free	10.03^{b}	11.91^{a}	12.65^{a}
Weedy check	3.07^{h}	2.95^{h}	3.10^{h}
LSD(0.05)		1.177	
CV (%)		9.21	

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.3.8. Harvest index

The analysis of variance revealed that herbicide application had a significant ($p<0.05$) effect on harvest index, while seeding rate and their interaction did not show a significant effect on this parameter (Appendix Table 7).

The highest harvest index value (41.38%) was recorded in plots where the crop was subjected to twice hand weeding at 20 and 40 days after crop emergence. This was followed by plots treated with an application rate of 1.25 liters per hectare of Axis 50 EC, which had a harvest index value of 41.04%. These results indicate that the application of herbicides, particularly Axis 50 EC and hand weeding, significantly increased the harvest index compared to the weedy check treatment. On the other hand, the lowest value (30.67%) was recorded in the weedy check treatment, indicating that weed competition had a negative impact on the harvest index.

Similar findings were reported by Nano (2012), who found that twice hand weeding resulted in the highest harvest index (46%) compared to other treatments on the same variety. Ali *et al.* (2014) and Amare *et al.* (2014) also reported that harvest index increased with a decrease in weed competition. Sujoy *et al.* (2006) observed significant variations in the harvest index of wheat due to weed control treatments.

In summary, the results indicate that herbicide application, particularly Axis 50 EC, and hand weeding at specific time points significantly improved the harvest index of the crop by reducing weed competition. These findings are consistent with previous studies that highlight the importance of weed control in enhancing harvest index in wheat cultivation.

Table 13 Main effects of herbicide application rate on harvest index during 2022/23 cropping season.

Herbicide application(L ha-1)	Harvest index (%)
AXIS 50EC at 0.75	34.70^{d}
AXIS 50EC at 1	37.26^{c}
AXIS 50EC at 1.25	41.04^{b}
Hand weeding at 20&40 DAS	41.38^{b}
Weed free	45.71^{a}
Weedy check	30.67^{e}
LSD(0.05)	2.26
CV (%)	10.46

Means in a column followed by the same letters are not significantly different at P= 0.05 CV= Coefficient of variation

4.4. Partial Budget Analysis

Partial budget analysis of the net benefits, total costs that vary and marginal rate of returns are presented in (Table 15). Information on costs and benefits of treatments is a prerequisite for adoption of technical modernization for farmers. The results in this study indicated that the combined use of 125kg ha^{-1} seed rate with application of 1.25L ha^{-1} AXIS 50EC resulted in higher net benefits and followed 125kg ha^{-1} seed rate with twice hand weeding at 20 and 40 days after crop emergence and also 100kg ha^{-1} seed rate with application of 1.25L ha^{-1} AXIS 50EC respectively (Table 15).The partial budget analysis showed that the highest net benefit (Birr154326 ha^{-1}) was recorded at 125kg ha^{-1} seed rate with application of 1.25L ha^{-1} AXIS 50EC followed 125kg ha^{-1} seed rate with twice hand weeding at 20 and 40 days after crop emergence (154254 ha^{-1}), whereas the lowest net benefit (Birr 16276 ha^{-1}) was recorded from weedy check with seed rate of 75 kg ha^{-1}.

According to CIMMYT (1988) suggestion, the minimum acceptable marginal rate of return should be more than 100%. In this study, even 125kg ha^{-1} seed rate with application of 1.25L ha^{-1} AXIS 50EC ha-1 gave the maximum net benefit (Birr 154326 ha^{-1}), the marginal rate of return was in acceptable range with marginal rate of return (604.01%). Thus, 125kg ha^{-1} seed rate with application of 1.25L ha^{-1} AXIS 50EC ha^{-1} gave the maximum economic benefit (Birr 154326ha^{-1}) with marginal rate of return (604.01%) (Table 15).Therefore, on economic grounds, 125kg ha^{-1} seed rate with application of 1.25L ha^{-1} AXIS 50EC ha^{-1} would be best and economical for production of food barley in the study area and other areas with similar agro-ecological conditions. The interaction of higher seed rates with herbicides showed that better relative returns over lower seed rate with herbicides application as the result of better weed management. The similar result was reported from Babu *et al.* (2017) and Khalid *et al.*, (2014) suggested that herbicides combinations with higher seed rates effectively controlled weed infestation in bread wheat and gave higher yield that related directly with high relative net return. All interaction of seed rates and herbicides application gave higher net benefit over weedy checks.

Table 14. Partial budget analysis of herbicide application and seeding rates on barley during the 2022/2023 cropping period.

Herbicide application ($L\ ha^{-1}$)	Seed rate ($kg\ ha^{-1}$)	Average yield($kg\ ha^{-1}$)	Adjusted yield (10 %)	SY	GY $Etbha^{-1}$	SY $Etbha^{-1}$	Gross benefit (Birr)	Total cost (Birr)	Net benefit (Birr)	MRR (%)
Control	75	980	882	2080	36162	728	36890	20615	16275	78.95
AXIS 0.75	75	1600	1440	2460	59040	861	59901	22400	37501	167.41
AXIS 1	75	2150	1935	3230	79335	1130	80465	22925	57540	251
AXIS 1.25	75	2740	2466	4010	101106	1403	102509	23450	79059	337.13
Two hand weeding	75	3330	2997	4800	122877	1680	124557	31745	92812	292.37
Weed free	75	4210	3789	5820	155349	2037	157386	62195	95191	153.05
Control	100	1030	927	1930	38007	675	38682	21615	17067	78.96
AXIS 0.75	100	2070	1863	3080	76383	1078	77461	23400	54061	231.03
AXIS 1	100	3190	2871	4670	117711	1634	119345	23925	95420	398.83
AXIS 1.25	100	3910	3519	5550	144279	1942	146221	24450	121771	498.04
Two hand weeding	100	4180	3762	5780	154242	2023	156265	32745	132520	404.70
Weed free	100	5130	4617	6790	189297	2376	191673	63195	128478	203.30
Control	125	1010	909	2090	37269	731	39000	21715	17285	79.60
AXIS 0.75	125	2470	2223	3700	91143	1295	92438	24500	67938	277.30
AXIS 1	125	3290	2961	4890	121401	1711	123112	25025	98087	391.96
AXIS 1.25	125	4810	4329	6820	177489	2387	179876	25550	154326	604.01
Two hand weeding	125	5030	4527	7120	185607	2492	188099	33845	154254	455.77
Weed free	125	5350	4818	7300	197538	2555	200093	64295	135798	211.21

Where; AXIS= AXIS50 EC, Two hand weeding = two hand weeding at 20 and 40 days after crop emergence, GY= Grain yield, SY= Straw yield, MRR= Marginal Rate of Return

5. SUMMARY AND CONCLUSIONS

Ethiopia is the second largest producer of barley in Africa accounting 26% of the total barley production in the continent. Barley is a crop that is very sensitive to weed competition and suffers the greatest yield reduction through competition to its third to sixth leaf stage. This is between two and four weeks after emergence. Growth and development of weeds can be suppressed by seed rate, plant pattern of crop plants and weed controlling methods. Herbicide application is the major weed control method in crop production in Ethiopia. Therefore, the objective of this study was to determine the effect of seed rate and AXIS 50 EC on grass and annual broad leave weeds, growth and yield of barley, and to determine the best combinations of seed rate and AXIS 50 EC rate on grass and annual broad leave weeds, growth and yield of barley.

According to the result of the present study, the major weed species recorded in the experimental fields were broad-leaved and followed grassy. There was a highly significant differences among the herbicide application and seed rate treatments on dry weight of grasses and Broad-leaved weed species where their dry weight increased with the weedy check treatments. Treatments which are left weedy combined with a seed rate 75kg ha^{-1} produced higher dry biomass weight while significantly lower dry weight was produced from treatments which are weeded.

Moreover the study revealed that barley crops when sown at a seed rate of 125kg ha^{-1} and kept free from weed delay maturity and heading significantly as compared to lower seed rate and weedy check. The results also showed that treatments left weed free for the whole season resulted in increased in plant height of barely. On the other hand, treatments left weedy for the whole season resulted in decreased in plant height of barley. Based on the result, the maximum grain yield (5.35t ha^{-1}), above ground dry matter, thousand grain weight and kernels per spike were recorded from the weed free check combined with 125kg ha^{-1} seed rate.

However, based on the partial budget analysis the most economically feasible treatments were keeping the crop 1.25l ha^{-1} AXIS 50EC combined with 125kg seed rate followed by weeding the crop twice at 20 and 40 days after emergence combined with 125kg seed rate. Generally, this study was conducted only in one location and one year it is difficult to give a conclusive recommendation. Therefore this study should be replicated over locations and year to improve productivity of barley on areas with similar agro ecology with the study area.

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7. APPENDICES

Appendix Table 1 Mean monthly annual total rainfall and minimum and maximum temperatures of ten years (2013-2022); mean monthly minimum and maximum temperatures and total rainfall recorded in the experimental area during the experimental year of test crop (January 2022 – November 2022)

Months	2013-2022 meteorological data			2022 meteorological data			
	Total rainfall (mm)	Min. temp. (ºC)	Max. temp. (ºC)	Total rain fall (mm)	Maximum temp. (ºC)	Minimum temp.(ºC)	Average temp. (ºC)
January	4.0	7.5	25.9	23.1	26.0	8.5	17.3
February	25.7	9.1	26.9	16.1	27.0	10.4	18.7
March	43.3	10.5	26.9	119.4	26.2	12.6	19.4
April	109.6	12.0	26.5	200.2	26.0	12.3	19.2
May	138.9	11.9	25.5	134.2	24.7	12.7	18.7
June	209.6	14.0	23.3	191.0	23.0	12.9	18.0
July	250.0	12.5	21.7	372.4	21.0	13.1	17.1
August	138.2	12.5	21.6	260.9	21.3	13.2	17.3
September	160.5	11.9	22.6	163.2	22.3	12.0	17.2
October	54.3	9.6	24.6	64.9	24.4	9.0	16.7
November	28.7	8.8	24.9	24.9	25.3	7.7	16.5
December	3.5	7.4	25.2	NA	25.5	6.2	15.9
Total	1166.3			1570.3	292.7	130.6	212
Average	97.2			130.8	24.4	10.9	17.7

Source: National Meteorological Agency, Hawassa Branch (2022)

Appendix Table 2 Means square analysis of variance for weed density due to seed rate and herbicide application of barley at Cheha Woreda during 2022/2023 cropping season

Source	DF	Mean Square
Rep	2	46.80
Her	5	8285.18***
Sr	2	757.35***
Her* Sr	10	321.11**
Error	34	17.70
Cv	14.30	

Her = herbicide application; Sr = Seed rate; DF = degrees of freedom; rep=replication; CV = coefficient of variation

Appendix Table 3 Means square analysis of variance for yield and yield components of barley as affected by seed rate and herbicide application of barley at Cheha Woreda during 2022/2023 cropping season

Source	DF	Mean Square	
		weed dry weight for broad leaved	weed dry weight for grass
Rep	2	1.33^{ns}	0.45^{ns}
Her	5	185.66***	66.72***
Sr	2	19.65***	7.15***
Her* Sr	10	8.32***	2.98***
Error	34	0.51	0.18
CV		15.94	15.93

Her = herbicide application; Sr = Seed rate; DF = degrees of freedom; rep=replication; CV = coefficient of variation

Appendix Table 4 Means square analysis of variance for yield and yield components of barley as affected by seed rate and herbicide application of barley at Cheha Woreda during 2022/2023 cropping season

Source	DF	Mean Square	
		Weed Control Efficiency	Weed Index
Rep	2	20.52^{ns}	149.63*
Her	5	11183.11***	7788.62***
Sr	2	303.60***	77.30^{ns}
Her* Sr	10	50.24**	41.08^{ns}
Error	34	15.20	24.49
CV		6.02	13.18

Her = herbicide application; Sr = Seed rate; DF = degrees of freedom; rep=replication; CV = coefficient of variation

Appendix Table 5 Means square analysis of variance for yield and yield components of barley as affected by Days to heading, Days to physiological maturity and Plant Height at Cheha Woreda during 2022/2023 cropping season

Source	DF	Mean Square		
		FH	NM	PH
Rep	2	257.72***	471.05***	1104.27***
Her	5	1137.07***	6368.13***	3456.02***
Sr	2	84.50**	292.05***	1371.47***
Her * Sr	10	17.03*	35.32*	23.38^{ns}
Error	34	7.92	12.15	14.09
CV		3.52	3.34	4.36

Where, Her = herbicide application; Sr = Seed rate; DF = degrees of freedom; rep=replication; CV = coefficient of variation; FH=50% Heading; NM= 90% Maturity; PH= Plant Height

Appendix Table 6 Means square analysis of variance for yield and yield components of barley as affected by Total Number of Tillers, Number of Effective Tillers, Kernel Per Spike and Thousand Grain weight at Cheha Woreda during 2022/2023 cropping season

Source	DF	Mean Square			
		TNT	NET	KPS	TGW
Rep	2	26.31***	26.86***	1245.79***	410.49***
Her	5	94.97***	76.49***	4360.42***	1913.63***
Sr	2	2.32***	2.27***	138.61***	93.67***
Her*Sr	10	1.71***	1.55***	45.96***	45.93***
Error	34	0.12	3.95	5.11	6.33
CV		3.94	4.86	5.92	5.38

Where, Her = herbicide application; Sr = Seed rate; DF = degrees of freedom; rep=replication; CV = coefficient of variation; TNT=Total number of Tillers; NET= Number of Effective Tillers; KPS= Kernel per Spike; TGW= Thousand Grain Weight at Cheha Wereda during 2022/2023 cropping season

Appendix Table 7 Means square analysis of variance for yield and yield components of barley as affected by Grain Yield, Straw Yield, Aboveground Dry Biomass and Harvest Index at Cheha Woreda during 2022/2023 cropping season

Source	DF	Mean Square			
		GY	SY	AGM	HI
Rep	2	3.47***	5.77***	18.20***	23.76^{ns}
Her	5	18.76***	28.06***	92.65***	153.04***
Sr	2	6.19***	11.41***	34.36***	21.32^{ns}
Her*Sr	10	0.41**	0.79**	2.32**	16.61^{ns}
Error	34	0.09	0.18	0.50	17.67
CV		9.52	9.29	9.21	10.46

Where, Her = herbicide application; Sr = Seed rate; DF = degrees of freedom; rep=replication; CV = coefficient of variation; GY=Grain Yield; SY= Straw Yield; AGM= Above ground Dry Biomass; HI= Harvest Index at Cheha Wereda during 2022/2023 cropping season

Appendix figure.1 Seedling stage of experimental field

Figure.2 Tillering stage of experimental field

Figure.3 Heading stage of experimental field

Figure.4 Time of maturity of experimental field

Figure.5 Measuring plant height of experimental field

Figure.6. Dry biomass of weed of experimental field

Figure.7. Harvesting time of experimental field

Figure 8. Thousand seed sampling of experimental field

Fig 9.Thousand seed counting

Fig .10. Weighting of thousand seed