EFFECT OF PRE-EMERGENCE HERBICIDES AND THEIR COMBINATIONS ON WEEDS INFESTATION YIELD COMPONENTS AND YELD OF CHICKPEA (*Cicer arietum* L.) AT EZHA WOREDA GURAGE ZONE, SOUTH ETHIOPIA.

MSc THESIS

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Effect of Pre-Emergence Herbicides and their Combinations on Weeds Infestation Yield Components and Yield of Chickpea (*Cicer arietum* L.) at Ezha Woreda Gurage Zone, South Ethiopia.

A Thesis Submitted to Department of Plant Science School of Graduate Studies

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In Partial Fulfillment of the Requirements for the Degree of Master of Science in Agriculture (Agronomy)

Tadele Bekele Taboge

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DEDICATION

I dedicate this thesis to my mother Lakech shiber , my wife Astewiy Almu , my brother Sahilu Bekele for their affection and consistent care in the success of my life

BIOGRAPHICAL SKETCH

The author, Tadele Bekele, was born on October 12, 1977 in wolkita town, SNNPR Region from his father Mr Bekele Taboge and his mother Mrs. Lakech Sebire . He attended his Elementary at Razeselasa School and Secondary School at Aberuse Senior Secondary School at wolkita town. After passing the Ethiopian School Leaving Certificate Examination (E.S.L.C.E., grade 10), the author joined in Hawassa University in 1996 and graduated with BSc degree in Applied biology June, 1998. After graduation, he worked Abeshega Woreda health office as a an expert and as vice head and also communicable disease prevention and control head. Then the author was assigned at Wolkita town municipality manager and also become wolkita town Mayer from 2003-2007 and then he also assigned in Gurage Zone youth office as a head from 2008 -2009. He also worked as an Environmental office Expert from 2010 onwards. He joined the School of Graduate Studies at wolkita university in July, 2012 to pursue a study leading to the Degree of Master of Science in Agronomy.

ABBREVIATIONS AND ACRONYMS

a.i.	Active ingredient
CABI	Centre for Agriculture and Bioscience International
CIMMYT	International Maize and Wheat Improvement Center
CSA	Central Statistical Agency
CV	Coefficient of variance
DAE	Days after emergency
DAS	Day after Sowing
GRDC	Grain research development cooperation
HW	Hand weeding
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IWM	Integrated weed management
LSD	Least significant difference
WAE	Weak after pre-emergency

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Effect of Pre-Emergence Herbicides and their Combinations on Weeds Infestation Yield Components and Yield of Chickpea (*Cicer arietum* L.)" at Ezha Woreda Gurage Zone, South Ethiopia.

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ABSTRACT

Chickpea (Cicer arietinum L.) is one of the most important pulses cultivated in Ethiopia. Chickpea is the third important food legume both in area and production after common beans and faba beans in Ethiopia. This is below the potential yield of chickpea at research center as well other major chickpea producing zones in Ethiopia. Among the factors responsible for low yields in chickpea; weeds is the major one. Hence, field experiment was conducted to investigate the effect of herbicides and their combination on yield component and yield of chickpea (Cicer arietum L.). The experiment was laid out in a Randomized Complete Block Design and replicated three times. Pre-emergence herbicides (Pendimethalin and S-metolachlor) were applied alone at different rate, their reduced dose combination with herbicides as well as supplemented with one hand weeding, only one hand weeding, and two hand weeding; completely weed free and weedy treatments. Applying the herbicides alone at different rate reduced density and dry matter of the weeds in chickpea as compared with control. The result indicated S-metolachlor was the most effective herbicide for controlling weed species presented in the experimental site as compared with Pendimethalin in relation with application at different rate alone. Among the herbicides applied S-metolachlor at 1.0kg ha^{-1} supplemented by one hand weeding at five weeks after emergence gave the highest yield components and yield as well as net benefit of chickpea (Cicer arietum L.). However; weed free, Hand weeding at 2 and 5 WAE treatments was the most effective treatment for controlling the weeds and increasing the chickpea yield compared with other treatments. But weed control through hand weeding is costly and non-available at critical time. Therefore; it is suggested when labours are not easily available, applying S-metolachlor at 1kg ha-1 supplemented by one hand weeding at five weeks after emergence is the best option of effective chickpea production. However, further study has to be done under different seasons and locations to exploit the recommendation of the present study.

Keywords: Chickpea**,** Herbicides, Weed, Yield, Yield Components,

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the third largest produced food legume globally, after common bean (*Phaseolus vulgaris* L.) and field pea (*Pisum sativum* L.) (Gaur *et al.*,2010).

The main chickpea-producing countries over the World are India, Australia, Burma, Turkey, Russia, Pakistan, United States, Iran, Mexico, Tanzania, Canada, Argentina, Spain, Yemen, Syria, and Ethiopia ranks fourth having greatly increased production in recent years and accounts for over 3.67% of world production during 2017 crop growing season (FAOSTAT, 2019).

Mean yields of chickpea have varied widely among producing countries and range from500–600 kg/ha. India, the largest producer has had stable mean yields of about 0.9 t/ha and has a global share of 64.7%. The high yields 30 t/ha in Mexico are largely due to the fact that most of the crop is irrigated and grown over the cool winter season (FAOSTAT, 2019). Chickpea is a valued crop and provides nutritious food for an expanding world population and will become increasingly important with climate change (Muehlbauer and Sarker, 2017).It is an annual legume which is the most important crop and the productivity is very low in Ethiopia (FAO, 2016).

The important of chickpea-based infant follow-on formula meets the WHO/FAO requirements on complementary foods and also the EU regulations on follow-on formula with minimal addition of oils, minerals, and vitamins. It uses chickpea as a common source of carbohydrate and protein hence making it more economical and affordable for the developing countries without compromising the nutrition quality (Mulungeta *et al*., 2014).

Chickpea (*Cicer arietinum* L.) accounts more than 17% of legumes in Ethiopia with a production of 0.47 million tons on an area of 258,486.29 ha (CSA 2012) with the engagement of over one million households. Chickpea is also an important export commodity where both export volume and export earnings of the country are increasing, especially in the last decade (FAOSTAT 2012). Ethiopia is the leading producer, consumer and exporter of chickpea in Africa, and is among the top ten most important producers in the world.

The major constraints accounting for chickpea low production and productivity are low input usage, limited availability of seed and limited familiarity with the variety of existing chickpea, and limited usage of modern agronomic practices, market problems and poor extension services (Asfaw *et al*., 2010).

The initial 60 days' period considered being the critical for weed crop competition in chickpea but continuously facing of the scarcity of labor and increase in labor cost, manual weed control has become a difficult task. Suitable herbicide for effective control of mixed weed flora is required for better adoption in this crop by farmers. Chickpea, being slow in its early growth and short stature plant, is highly susceptible to weed competition and often considerable losses may occur if weeds are not controlled at proper time and integrated weed management practices can be achieved by application of herbicides and hoeing twice at 20 and 40 days after the crop germination (Sunil *et al,* 2011).

Intensive agriculture, which largely depends on herbicides for weed control, indiscriminate use of herbicides could cause adverse changes on soil micro flora, poor quality crop production, human and animal health problems (Santosh, *et al*, 2018). Therefore, integrated weed management is an alternative for improving the chickpea production. Gurage Zone has been diverse crops were cultivating in two cropping season known as meher and belg. On the other hand; the arable field of the zone was infested by different weed species. However; chickpea is very sensitive to weed competition from early stages of growth. The zone is also under various labour intensive investment farms and other floriculture sites where producing in small and large scales. These lead the flow of labour towards those floriculture sites where producing resulting the farmers lack labor to properly manage crops at their critical time and consequently they either weeding once or left the crop un-weeded. While some model farmers undertake twice hand weeding and sometimes post emergence chemical were more frequently used than any other control methods in the district. Even though various effective weed control methods on the yield and yield components of chickpea are reported; there is shortage of information on the use of pre emergence herbicides and their combination as an alternative weed management practices in Southern Ethiopia in general and at Ezha Woreda in particular. For this reason, there is a need to evaluate various pre emergence herbicides and their reduced dose with hand weeding on chickpea field. Therefore; the study was aimed to:

- Evaluate the effect of herbicides and their combinations on yield components and yield of chickpea (*Cicer arietinum* L.) in Ezha district, Gurage zone, Southern Ethiopia
- To investigate the possibility of supplementing low dose of herbicides with hand weeding for effective weed control.
- Determine effective and economically feasible method of weed management in chickpea

2. LITERATURE REVIEW

2.1. Origin and Evolutionary Domestication of Chickpea

The center of origin of chickpea is in the Fertile Crescent around modern-day Turkey and Syria (Redden and Berger, 2007). This is inferred from archaeological records and the current distribution of wild ancestors of chickpea. The wild annual progenitor of chickpea, C. reticulatum, occurs only in a small region in eastern Turkey The proposed wild perennial progenitor, C. anatolicum, is found in Turkey, Armenia, northwest and western Iran, and northern Iraq (Berger *et al.,* 2003). Chickpea was part of an assemblage of crops (including wheat, barley, peas and lentils) that was domesticated in the Fertile Crescent around 10,000 years ago (Abbo *et al.,* 2003b).

The distribution of the wild progenitors of most West Asian crops, such as wheat (both diploid and tetraploid), barley, pea, lentil, bitter vetch and flax, is relatively wide, extending throughout the eastern Mediterranean basin into West Asia, and in some cases as far as Central Asia (Zohary and Hopf 2012). In contrast, the wild progenitor of cultivated chickpea, C. reticulate (Ladizinsky and Adler, 1976) is a rare species, currently reported from only 18 narrowly distributed locations (37.3–39.8° N, 38.3–43.6° E) in south-eastern Turkey (Berger *et al*. 2003).

Given the wide distribution of the genus as a whole, there is no a priori to reason to suggest that the current narrow distribution of C. reticulate is a subset of its original range in the Neolithic period. A narrowly distributed species, such as C. reticulate can harbor only limited adaptive variation compared with those spanning a much larger eco geographic range such as the wild progenitors of wheat, barley, pea or lentil. This is demonstrated within the annual wild Cicer species because the greatest diversity for important adaptive traits such as plant height, canopy width and flowering time is found in C. judaicum boiss. and C. pinnatifidumJaub. and Spach the most widely dispersed taxa of the genus (Berger *et al*. 2003).

Increasing human activity and minor climatic change during the last 10000 years in the Mediterranean basin and south-west Asia notwithstanding, it is likely that the current distribution of C. reticulate reflects the species' range during the early stages of Neolithic agriculture, when initial attempts at farming and domestication took place. Archaeological evidence demonstrates that Neolithic habitats often resemble present day environments in terms of species composition (Lev-Yadun and Weinstein-Evron 1994). Moreover, the Younger Dryas (13000–11500 years ago), a period of significant ecological change in mainland Europe, had very little impact on species composition in the eastern Mediterranean (Bottema 1995).

2.2. Ecological Requirement

Performance of chickpea is affected by a biotic factor such as soil salinity, extremes of temperatures and flooding (Potters *et al*., 2007). A biotic factor affects water relations of the plant, both at cellular level as well as the whole plant level, causing both specific and non-specific reactions, damage and adaptation reactions.Rasool *et al*. (2015) states that yield performance of chickpea is also influenced by deficiencies in some elements in agricultural soils such as nitrogen, phosphorus and the presence of heavy metals such as arsenic which is found in the oxidized state as arsenite (As (III)) and arsenate (As (V)). (Mckay *et al*., 2002) state that the crop can tolerate frost and high temperatures during flowering and behaves similar to spring cereal grains. Furthermore, it grows best when daytime temperatures are between 21 and 29°C, and nighttime temperatures are between 18 and 21°C. In some country the crop can be grown in winter to complement other winter crops such as winter wheat in dry land farming as well as in smallholder irrigation systems. In drought prone areas or water stress conditions, the maturity requirements for the chickpea are similar or longer than the majority of winter crops grown. The crop grows well in areas with annual rainfall of between 400 and 600 mm, its productivity under marginal rainfall conditions may be increased through genotype selection and manipulation of planting density.

2.3. Effects Weeds on Chickpea in Ethiopia

Chickpea is poor competitor to weeds because of slow growth rate and limited leaf development at early stage of crop growth and establishment). The bulk of the crop variety in the country is dominated by the sweet Desi type, and the Kabuli type is also grown in limited areas. In Ethiopia chickpeas are consumed widely fresh as green vegetables, sprouted, fried roasted and boiled. It is also ground into flour to make baby feed mixed with other cereals, soup bread and meat. It is also used to rehabilitate depleted fallow lands through utilizing crop rotation system (Ratnam, *et al* , 2011). The critical period for controlling weeds in chickpea is during the seedling stage and into flowering, as chickpea plants are slow to emerge and grow. Uncontrolled weed growth during this period leads to a greater than 10% reduction in yield. Overseas studies have shown that the critical weed-free period is around 17–60 days after emergence, depending on the environment (Mohammad *et al.,* 2005).

One of the most important, yet often neglected weed management strategies is to reduce the number of weed seeds present in the field in which soil is used as a weed seed bank, and thereby limit potential weed populations during crop production can be accomplished by managing the weed seed bank found in soil (Hossain and Begum, 2015).The occurrence of invasive and noxious weed species is the main challenges of all parts of countries over the world aims for crop production in intensive agriculture, which largely depends on herbicides for weed control, indiscriminate use of herbicides could cause adverse changes on soil micro flora, poor quality crop production, human and animal health problems. However, scientists are doing their long strenuous efforts on this aspect (Mukherjee, 2007).

Chickpea, being slow in its early growth and short stature plant, is highly susceptible to weed competition and often considerable losses may occur if weeds are not controlled at proper time and integrated weed management practices can be achieved by application of herbicides and hoeing twice at 20 and 40 days after the crop germination (Sunil, *et al,* 2011).
(Santosh *et al,* 2018). State that germination phase of the crop is the appropriate time when the herbicide is to be applied for weed management and become effective in the pulse crops

especially in case of chickpea pendimethalin at 1000 g ha−1applied as pre-emergence is a very common herbicide which is used to control all type of weeds, but there is no herbicide available to be applied as post-emergence to control the emerging broad leaf weeds effectively Moreover, the management of weed in manual method has both advantage and disadvantages in which farmers not get always benefit, because weed is one the factors that cause of the significant loss on crop yield which is observed from the majority of people side like the Ethiopian country from the developing countries.

2.4. Management of Weeds.

2.4.1. Physical method of weed management

Since mulching and solar radiation were included in the preventive methods, because their herbicidal activity is related to the control of the soil seed bank, the direct physical methods discussed here refer to the thermal control. Based on their mode of action, thermal methods can be classified as direct heating methods (flaming, hot water, hot hair, and steaming, infrared weeds), indirect heating methods (electrocution, microwaves, and ultraviolet light, laser radiation) and freezing by liquid nitrogen or carbon dioxide snow (Jitsuyama, Y.; Ichikawa, 2011). Flame weeding is a direct thermal method commonly used in organic farming which relies on propane gas burners or, recently, renewable alternatives such as hydrogen (Ascard, J. 1995), to generate combustion temperatures up to 1900 °C. Once the foliar contact with the target plant occurs, the temperature of the exposed plant tissues raises rapidly up to ~50 °C inside plant cells, causing denaturation and aggregation (i.e., coagulation) of membrane proteins (Ascard, J. 1995).

The thermal control of these weeds can be done prior to sowing, in pre-emergence or in post emergence (Cisneros, Zandstra, 2008). In the first two cases, typical of fast-growing crops, flame weeding is commonly integrated with the stale seedbed, which allows a significant decrease of the first flush of weeds (Bond, Grundy, 2001). This is a sort of temporal selectivity. When applied after crop emergence, typical of slow-growing crops where later flushes of weeds can cause serious competition problems, flaming can be done directed or shielded. Flaming is commonly combined with the stale seedbed in pre-emergence or with mechanical methods such as hoeing or cultivators in post emergence. Several researches reported interesting results on the combination of preventive and direct methods (Melander, B.; Rasmussen,2005).

(Zimdahl 1999) state that dominance of the planted crop species characterizes agricultural plant communities that also have a few (rarely only one) weed species that occur in cropped fields. Their removal (control) creates open niches into which another weedy species will move, but perhaps not immediately weed management, especially successful weed management, is a never-ending process. The magnitude of yield loss is affected by many agronomic and environmental factors, but most importantly by the weed density, and time of emergence relative to the crop. Practices that (1) reduce the density of weeds or (2) maximize occupation of space or uptake of resources by the crop or (3) establish an early season size advantage of the crop over the weeds, will minimize the competitive effects of weeds on crops.

2.4.2. Herbicide use in chick pea

(GRDC, 2017) state that Chickpea crops are susceptible to damage from unintended exposure to herbicides, either present as residues in soil at planting and emergence, or via spray drift). Herbicide residues in soil become a problem during dry seasons, when inadequate moisture inhibits microbial breakdown of residual herbicides. Extreme temperatures and high pH can also reduce herbicide break down. Spray drift damage occurs when nearby paddocks are sprayed with herbicide when it is very windy or still, particularly when an inversion layer is present. This crop is a poor competitor with weeds particularly at earlier growth stages because of its slow growth and limited leaf area development (Abbas *et al.,* 2016).

Weeds compete with crops for available moisture, nutrients, space and solar radiation. The most common and problematic weeds for chickpea crops include *Chenopodium album*, *Asphodelustenuifolius*, *Argemone mexicana*, *Carthamusoxyacantha*, *Cenchrusciliaris*, *Cyperus rotundus, Fumaria*sp., *Polygonum*sp., *Lathyrus*sp., *Vicia sativa*, *Cynodondactylon* and *Cirsium arvense* (Latham .M.C,1997). Annual broad-leaved weeds are more competitive to chickpea because they have a similar growth pattern to that of chickpea and severity also increases with advance in growth (Latham and Kukula ,1987). For an effective control of weeds in field crops, various mechanical, chemical and biological methods are applied (Silva *et al*, 2004).

Likewise, in the chemical control method, herbicides are used to prevent yield losses caused by weeds. The use of herbicides can provide effective and economic weed control and, consequently, give similar yield values or only slightly smaller values than those of weed free treatments (Patel *et al*,.2006). However, in several cases of the chemical weed control method, herbicides residues have negatively affected the yield components and nodulation of susceptible varieties of chickpea (Waqas *et al*,.2016). As a consequence, there is an increasing interest in methods of weed control that allow a reduction in the use of herbicides. This is reflected in the increased interest in non-chemical methods of weed control (Weiner, 2001),

(Dewar., 2003) that the use of genetically modified herbicide-tolerant crops with glyphosate and glufosinate herbicides may allow a more flexible, knowledge-based management to weed control, permitting higher weed populations early in the season than is possible in conventional systems to promote biodiversity. If such systems are to be employed, however, it is essential that the impact of delayed control on the competitive balance between weeds and crop is fully understood, if yields are not to be reduced.

2.4.3. Effects of Low dose of Herbicides

Low dose of herbicides stimulates the growth and yield of target plant, this growth stimulating phenomenon of herbicides is known as herbicide homesick (Eqan , *et al* 2014). It is one of the emerging windows to improve crop production, which can change the focus of herbicide use towards crop production from crop protection. Different studies regarding herbicide's low dose effect against crops species have been conducted both under laboratory and field conditions, which revealed that some herbicides at low doses stimulate crop growth (Cedergreen *et al.*, 2007).

Hormetic effect of herbicides strongly depends upon the type of herbicide, herbicide dose, time of application, crop or weeds species and other management practices (Belz *et al 2018*).

Glyphoste which is one of the most widely used herbicide in the world showed biphasic dose response phenomenon (Cedergreen, 2008). Higher doses of glyphosate show its phytotoxic impact and kills plants but when glyphosate is applied to plants at 10 % of rate recommended in field conditions, it promotes crop growth (Asman *et al.*, 2003). By stimulating photosynthesis, glyphosate increases the growth of different crop species. Consistent hermetic effects of glyphoste have been reported against growth and yield of different crop species both under controlled and field conditions (Duke et al., 2006;).

2.4.4. Integrated Weed Management

Chickpea is poor competitor to weeds because of slow growth rate and limited leaf development at early stage of crop growth and establishment (Ratnam, *et al,* 2011). (Mukherjee, 2007) state that in intensive agriculture, which largely depends on herbicides for weed control, indiscriminate use of herbicides could cause adverse changes on soil micro flora, poor quality crop production, human and animal health problems. So, integrated weed management is an only alternative for improving the pulse production. Non-chemical weed management is quite difficult in this crop. However, scientists are doing their long strenuous efforts on this aspect. The elongation of rainfall for consecutive seven days or above and intermittent light rain are not a suitable time for herbicide applications. The effects of intermittent light rain and dew presence at application of an herbicide are variable according to research findings on this subject and are not specifically addressed on most product labels.

Chickpea, being slow in its early growth and short stature plant, is highly susceptible to weed competition and often considerable losses may occur if weeds are not controlled at proper time and integrated weed management practices can be achieved by application of herbicides and hoeing twice at 20 and 40 days after the crop germination (Sunil, *et al*, 2011).In the pulse crops especially in case of chickpea pendimethalin at 1000 g ha^{-1} applied as pre-emergence is a very common herbicide which is used to control all type of weeds, but there is no herbicide available to be applied as post-emergence to control the emerging broad leaf weeds effectively (Santosh *et al*, l218). Under rain fed ecosystem, efficient water use by weeds may increase severity of drought and results in a low crop yield. Most weed species can grow faster and taller than chickpea and inhibit its growth, absorbs sunlight, and affect photosynthesis and plant productivity adversely (Rasool, et *al* 2015).

Generally, for the control of weeds farmers do manual weeding. But with the increase in labor cost and scarcity of labor, manual weed control has become a difficult task in chickpea. Being slow in its early growth and short statured plant, chickpea is highly susceptible to weed competition and weeds causes up to 75% yield loss (Chaudhary *et al*., 2005). Solh and Pala (1990) reported 40-87 % yield loss in chickpea due to weeds. Weed management in chickpea is an important component of plant protection thus improving production potential of the crop. Therefore, the work was under taken to observe the effect of different weed management practices on productivity of chickpea under rain fed conditions. Weed management is an important key factor for enhancing the productivity of chickpea, as weeds compete severely with crop for nutrient, moisture, light and space and result in 17-75 per cent reduction in the yield (Chaudhary *et al.*, 2005).

Weeds emerge with crop and create severe competition unless controlled timely and effectively. The initial 60 days' period is considered to be the critical for weed-crop competition in chickpea (Singh and Singh, 1992). (Gunsolus, J.L.; Buhler, D.D. 1999). State that within this context grows and develops the concept of IWM (integrated weed management), a systematic weed management approach combining monitoring, prevention and control and not based on the complete eradication of weeds, but rather on their control below thresholds that are agronomically, environmentally and economically acceptable. The basic principle is that none of these individual methods on their own, except for chemical ones are able to provide an adequate control of weed flora. On the contrary, they should be implemented and integrated in a multi-dimensional regime.

The integration of indirect and direct control methods depends on the weed species, climatic conditions (e.g., solar radiation, temperature, rainfall regime and wind intensity), soil exposure and texture, irrigation method used, form of plant farming, socio-economic constraints and farmer's expectations Therefore, an IWM program is not absolute, but it needs to be adjusted according to the context-specific requirements and from year to year (Knezevic, S.Z.; Jhala

2017). many of these systems involve chemical–physical and chemical–cultural methods, while very few combine all weed management methods; indeed, the so-called integrated herbicide management, a “rationale” chemical weed control, is still the most adopted in advanced agro ecosystems, despite the fact that it is not an IWM program strict sense (Harker and O’Donovan, 2012).

3. MATERIALS AND METHODES

3.1. Description of the Study Area

The experiment was conducted at Tageme fruit and vegetable farming site, Ezha district in Gurage Zone of Southern Nations, Nationalities and People's Regional state, Southern Ethiopia in the 2020 main cropping season. The study of experimental site is located at 08°44'01.2" N latitude, 37°11'58.6"E longitude, and altitude of 1960 meters above sea level. The rainfall pattern of this area was characterized by bimodal distribution with small rainy season *belg* (March-June) and main rainy season *meher* (July- November) with annual average rainfall of 1500-2300 mm.

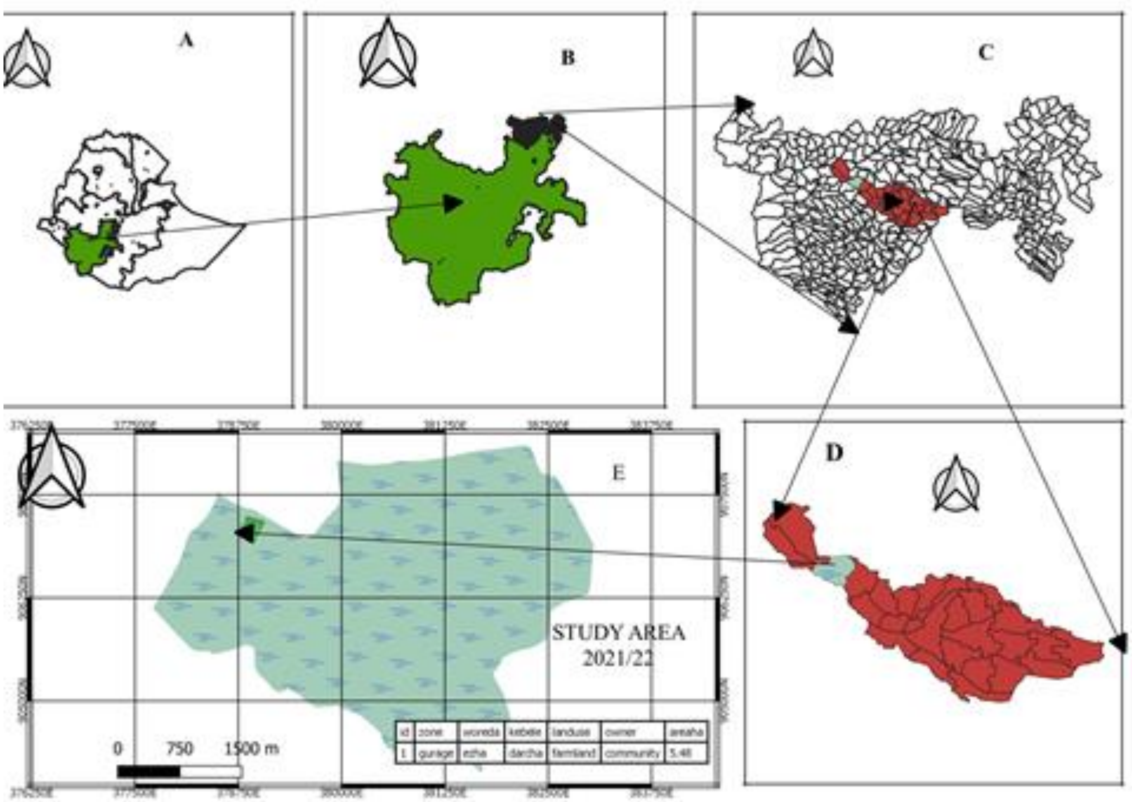

Figure 1. Map showing the experimental site of Ezha Woreda, Gurage, and Southern Ethiopia

3.2. The Experimental Materials

3.2.1. Chickpea

Kabuli type hora variety was used for the experiment. Which are characterized by white colored seed with ram's head shape, thin seed coat, smooth seed surface, white flowers, and lack of anthocyanin pigmentation on the stem. The Kabuli types generally have large sized seeds and receive higher market price than desi types. Chickpea can be successfully grown in a variety of soil types including coarse-textured sandy to fine-textured deep black cotton soils. However, the best suited soils are deep loams or silty clay loams with a pH ranging from 6.0 to 8.0 and 1960m.a.s.8.3237 latitude and 37.858 longitudes. The annual rainfall is about 1500-2600 mm with the mean maximum temperature 14 to 30 degree centigrade.

3.2.2. Herbicide

Table 1. Herbicide used and their common, trade and chemical

Common Name	Trade name	Chemical name
S-metholachlor	Five star (Dual Gold 960EC)	[2-chloro-6`-ethyl-N-(2-methoxy-1-methylethyl)acet-o-toluidide]
Pendimethalin	Pendamet 450 EC	[N-(1-ethylpropyl)-2, 6-dinitro-3, 4-xylidine]

3.3. Soil Sampling and Analysis

Before sowing of the seed, soil samples was taken from ten spots of a depth of 0 – 30 cm by zigzag method and one composite sample was formed. From the composite sample, soil physical and chemical properties were analyzed on Wolkite Regional Soil Laboratory.

The soil was analyzed for soil texture, pH, organic matter (OM), total nitrogen (TN), available phosphorus (AP), cation exchange capacity (CEC) and available sulfur (AS). Soil PH was measured with standard glass electrode PH meter (Van reeuuwijik, 1992). The Walkley and Black (1934) method was used to determine organic matter content of the soil. Total Nitrogen in the soil was determined by the Kjeldahal method (Dewis and Freitas, 1970). Available soil Phosphorus was determined using the Olsen extraction method as described by Olsen *et al.*, (1954). The Bouyoucas hydrometer method (Day, 1965) was used to determine soil texture. Electro-conductivity was determined by standard glass electrode using EC meter. Soil Cation Exchange Capacity (CEC) was determined by ammonium acetate method (Cottenie, 1980).

3.4. Treatments and Experimental Design

The experiment consisted of 16 treatments viz.

- S-metholachlor at 1.0 kg ha^{-1}
- S-metholachlor at 1.5 kg ha^{-1}
- S-metholachlor at 2.0 kg ha^{-1}
- Pendimethalin at 1.0 kg ha^{-1}
- Pendimethalin at 1.25 kg ha^{-1}
- Pendimethalin at 1.5 kg ha^{-1}
- S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1},
- S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,
- S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},
- S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},
- S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE

- Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE
- Two hand weeding at 2 and 5 WAE
- One hand weeding and hoeing at 2 WAE
- Weed free check
- Weedy check

The treatments were arranged in randomized complete block design with three replications.

3.5. Experimental Procedure and Management

Land preparation was made in middle of January 2021 by using manual labor to make it leveled, more appropriate and suitable for the crop. After the completion of specific design, field lay out were prepared. The sizes of each experimental plot were 3.6 m x 2.4 m (8.64m^2). The pathway between replications and plots were 1.5m and 1m respectively to facilitate movement to different plots for various operations and data recording. The Chickpea Kabuli type variety (Hora), which is larger sized and high market price, was be planted at 40 cm inter and10 cm intra row spacing mid of January, to February 2021 at Ezha Woreda. Uniform fertilizer was be applied at the time of sowing for each plot according to the recommended rate of (100kg NPSB ha^{-1}). The pre–emergence herbicides; five star (Dual Gold 960 EC), Pendimethalin 450 EC were applied onto the soil as per emergence treatment immediately after sowing. The low dose of herbicide combination would be applied one after the other onto the soil with specified treatment then wash the knap sack with water and the second treatment would be again applied on that specified treatment. The spray volume was 300 l ha^{-1}. The spraying was made using a Knapsack sprayer of flat nozzle. Hand weeding (hand weeding and hoeing) were conducted in the assigned plots as per the treatment. The outermost one row from one side and two rows from other side (40 cm) was serve as border rows whereas; three plants (10 cm) from each end of the rows were the border plants. These variations were necessitated to keep uniform net plot area. Thus, the net plot size was be 2.4 m x 1.8 m (4.32m^2).

3.6. Data collected

3.6.1. Weeds

Weed community: The weed flora present in the experimental field was recorded from weedy check plots by placing a quadrat (0.25 m × 0.25 m) randomly at two spots in each plot.

Weed density: Weed density was recorded by throwing a quadrat (0.25 m× 0.25 m) randomly at two places in each plot at the time of weed removal for early competition and about 15 days before the expected harvest time in the case of late competition to avoid possible foliage and seed shedding. The weed species found within the sample quadrat was identified, counted, categorized (broadleaved, grass, and sedges) and expressed in m^{-2}.

Weed dry biomass: While recording weed density the biomass was harvested from each quadrate and the harvested weeds were placed into paper bags separately. The samples were sun dried for 3-4 days and thereafter were placed to an oven at 65°C temperature till their constant weight and subsequently the dry weight was measured. The dry weight was expressed in g m^{-2}.

3.6.2. Parameters for weed control

Weed control efficiency (WCE): It was calculated from weed control treatments in controlling weeds and using the following formula:

$$WCE = \frac{(WDC - WDT)}{WDC} \times 100$$

Where; WCE= Weed Control Efficiency, WDC= weed dry matter in weedy check, WDT= weed dry matter in a particular treatment

Weed index (WI) – It was measured from a particular treatment when compared with a weed free treatment and expressed as percentage of yield potential under weed free and calculated with the help of the following formula:

$$WI = (\frac{X - Y}{X}) \times 100$$

Where; WI= Weed Index, X= Yield in complete weed-free, Y= Yield in a particular treatment

Herbicide Efficiency Index (HEI)-It is weed killing potential of herbicides treatments and their phytotoxicity on the crop and it was be calculated or obtained by:

$$HEI = \frac{YT-YC}{YC}100 / \frac{WDT}{WDC} X100$$

Where YT= yield from treatment; YC= yield from control; WDT= weed dry matter in treatment; WDC= weed dry matter in control

3.6.3. Crop

3.6.3.1. Phenology and growth parameters

Days of 50% seedling emergency: was be recorded as the number of days from time of sowing to the date when the seedling emerges to 50% in each plot. While Number of Days to 50% flowering was be recorded as the number of days from crop emergency to the time when 50% of the plants showed first flower. Whereas

Days to 90%Physiological maturity was recorded in each plot, as the number of days from emergence to when 90% of the plants senesced and the leaves and pods turned yellow in color.

Plant height (cm) was taken with the help of a ruler from 10 randomly selected and tagged plants in each net plot area from the base to the apex of the main stem at physiological maturity.

3.6.3.2. Parameters of yield components and yield of chickpea

Number of pods plant^{-1}: The total number of pods of 10 plants in each plot was counted at harvest and expressed as the average number of pods per plant.

Number of seeds pod $^{-1}$: The total number of seeds from the above pod was taken and counted to the average number of seeds per pod.

100 seeds weight: Out of seeds from the above, 100 seeds were counted and their weight was recorded at 10.5% moisture content for hundred seed weight (g).

Harvest index (%) was determined by harvesting ten plants in each plot at physiological maturity and their dried aboveground biomass (grain and straw) was recorded. This was made to avoid loss of leaves due to shedding like in other pulses. Then it was calculated as the ratio of grain yield to the total aboveground dry biomass yield.

Grain yield (kg ha $^{-1}$): was measured after threshing the sun-dried plants harvested from each net plot.

3.7. Data Analysis

The data collected and measured parameters from the experiment at different growth stages were subjected to statistical analysis as per the experimental designs for each experiment using SAS (Statistical Analysis Software) version 9.2 to analyze the data using ANOVA and GLM procedures. Mean separation of significant treatments were carried out using the least significant difference (LSD) test at 5 % level of probability (Gomez and Gomez, 1984).

3.8. Partial Budget Analysis

The partial budget analysis as described by CIMMYT (1988) was done to determine the economic feasibility of the weed management practices. Economic analysis was done using the prevailing market prices for inputs at planting and for output at the time the crop was harvested. It was calculated by taking into account the additional input and labour cost involved and the gross benefits obtained from weed management practices.he average yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same weed management practices and subjected to partial budget and economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). The field price of rice was calculated as sale price minus the costs of harvesting, threshing, winnowing, bagging and transportation. The total cost that varied included the sum of cost of seed and labour cost where hand weeding and hoeing is required. The net benefit was calculated as the difference between the gross field benefit (ETB ha^{-1}) and the total costs (ETB ha^{-1}) that varied.

4. RESULTS AND DISCUSSION

4.1. Selected Physico-chemical Properties of Soil of the Experimental Site

Selected physico-chemical properties of the soil for the experimental site was analyzed for composite soil (0-30 cm depth) samples collected from experimental site before planting. Based on the soil analysis made, the soil texture of the study area was clay loam and the soil PH was 5.7. Thus, according to Tekalign (1991) rating, the pH of the experimental site was moderately acidic (Table 2). Chickpea grows on a wide range of soils but prefers well-drained loams or sandy loams, with pH ranging from five to eight. The electrical conductivity (EC in mS/cm) of a soil in the site recorded EC 6.92 mS/cm, which was slightly saline according to Tekalign *et al*. (1991). Tekalign *et al.* (1991) also classified soil total N availability of ≤ 0.05 % as very low, 0.05-0.12% as poor, and 0.12 - 0.25 % as moderate and > 0.25 % as high. According to this classification, the total nitrogen of the study site (0.085%) was poor requiring application of nitrogenous fertilizer.

Table 2 Results of soil physical and chemical properties of the study area before sowing of chickpea bean

Soil properties	Results	Rating
Soil particle size		
Clay (%)	32	
Silt (%)	34	
Sand (%)	34	
Textural class	clay loam	
Soil pH (1:2 H_2O)	5.7	Moderately acidic
Electro-conductivity (dS/m)	6.92	Medium
Organic carbon (%)	2.26	Medium
Total nitrogen (%)	0.08	Very low
Available phosphorus (ppm)	10.83	Medium
Available sulfur S (mg kg^{-1})	11.81	Medium
Cation exchange capacity (CEC) (Cmol +kg^{-1})	24.42	High

In general, soils high in CEC contents are considered as agriculturally fertile. According to Landon (1991) top soils having CEC greater than 40 Cmol (+) kg^{-1} are rated as very high and 25-40 Cmol (+) kg^{-1} as high, 15-25 as medium, 5-15 low and ≤ 5 Cmol (+) kg^{-1} of soil as very low in CEC. According to this classification, the soils of the site had medium CEC of 24.42 $Cmolkg^{-1}$. The CEC value of the soil was medium in the study area, which indicates that the soil has the capacity to hold nutrient cations and supply to the crop. The Netherlands commissioned a study by Ministry of Agriculture and Fisheries (1995) classified soil organic carbon (%) >3.50,2.51-3.5, 1.26-2.50, 0.60-1.25 and ≤ 0.60 as very high, high, medium, low and very low, respectively. Thus, the organic carbon content of the soil (2.26%) was in the medium range. According to Lewis (1999), available sulphur (11.81 mg kg^{-1}) is in the medium range.

4.2. Weed Parameters

4.2.1. Weed community

The result showed that experimental fields was infested with 17 weed species and eight families were found, including broad-leaved, sedge and grass weeds (Table 2). In the experimental field, observed that *Cyperus rotundus* L accounted the highest in number and thereafter were *Cyperus brevifolius* Rottb L. and *Cynodon dactylon*, Sedge and Grassy weeds was highly dominated and infests than grass weed and broad leaved weed. The possible reason for more species occurrence in the study area could be the previous crop grown in the sites and more rainfall at early stage of the crop growth. In line with this result, Tamado and Milberg (2000) reported that altitude, rainfall, month of planting, number of weeding and soil type were the major environmental or crop management factors that influenced weed species distribution.

Table 3. Weed community recorded in the experimental field of chickpea

Scientific Name	Family	Categories
Ageratum conyzoides L.	Asteraceae	Broad leaf
Argemone ochroleuca L.	Papaveraceae	Broadleaf
Amaranthus spinosus L.	Amaranthaceae	Broadleaf
Bidens pilosa L.	Asteraceae	Broad leaf
Cassia pumila Lam.	Fabaceae	Broad leaf
Convolvulus arvensis L.	Convolvulaceae	Broadleaf
Cuscuta spp.(dodder)	Convulvulaceae	Parasitic
Cynodon dactylon (L.) Pers.	Poaceae	Grass
*Chromolaena odorata*L. R.M. king & H. Rob	Asteraceae	Broadleaf
Cyperus brevifolius Rottb.	Cyperaceae	Sedge
Commelina diffusa L.	Asteraceae	Broadleaf
Cyperus rotundus L.	Cyperaceae	Sedge
Datura stramonium L.	Solanaceae	Broadleaf
Dichanthium annulatum (Forsk.) Stapf.	Poaceae	Grass
Digitaria ternata (A. Rich) Stapf	Poaceae	grass
Eclipta alba (L.) Hassk.	Asteraceae	Broad leaf
Setaria glauca (L.) P. Beauv.	Poaceae	Grass

4.2.2. Weed density

4.2.2. 1.Weed density at 25 days after emergence (DAE)

Analysis of variance showed significant ($P<0.01$) effect of treatments on grass, broadleaved and total weed density at 25 DAE It was recorded that the application pre emergence herbicides decrease broad leave weeds density m^{-2} at 25 DAE over non herbicidal treatments.. Analysis of the data indicated that broad leaved weeds density at 25 DAE was significantly affected by various treatments in chickpea crop (Table 4). The highest broad leaved weed was recorded from weedy check plots. The broadleaved weed density decreased with the increase in pendimethalin herbicide application rates between 1.25 and 1.5 kg ha−1 rates (Table 4). The result was similar with Amir *et al.* (2013) reported that the greatest density of weeds m^{-2} at 20 DAS was in weedy check while the lowest weeds m^{-2} was under hand hoeing. It was also comparable with Patel *et al. (*2006) who suggested that pre-emergence application of pendimethalin at 0.5 kg ha^{-1} with atrazine at 0.5 kg ha^{-1} recorded significantly lower density of monocot and dicot weeds.

Also at 25 DAE grass weed density was significantly affected with response to weed management practices. The highest grass density was observed in the plots treated with one hand weeding (12.73 m^{-2}). The lower grass weed density recorded from s- metolachlor at 2.0 $kgha^{-1}$ (4.9 m^{-2}) and s- metolachlor + hand weeding (8.77 at m^{-2}) and pendimethalin at 1.0 kg ha^{-1} + one hand weeding 35 DAE (9.37 m^{-2}) respectively. (Table 4). The current results were in line with Mishra and Singh, (2008) who stated that, higher weed density was recorded from weedy check and the lowest weed density recorded from 1.5 kg ha^{-1} pendimethalin .

Analysis of the data indicated that sedge weeds density at 25 DAE was significantly affected by various treatments in chickpea crop (Table 4). The highest sedge weed density was recorded from the plots treated with one hand weeding 2 WAE (11.33 m^{-2}) and two hand weeding (10.55 kg ha^{-1}) respectively. Application of both s-metolachlor and pendimethalin herbicides at lower dose were not significantly different. (Table 4). The data has not been presented as the variation in between might be due to the difference in number of weed seeds/propagules in soil seed bank because soil seed bank in agricultural soils is the primary source of weed abundant, means that it produce a lot of seed increasing numbers of seed in soil and subsequently, weeds in crops and the reverse is true. This is similar with the study of Holst *et al*. (2007) who reported that weed populations are dynamic in time, both within and between seasons, and in space, both within and between fields

Table 4. Weed density (m^{-2}) at 25 days after crop emergence at Ezha during 2020 main cropping season

Treatments	Broad leaved	Sedge	Grass
S-metholachlor at 1.0 kg ha^{-1}	6.667^{b}	7.233^{def}	8.5^{cde}
S-metholachlor at 1.5 kg ha^{-1}	3.1^{ef}	4.8^{fg}	6.33^{fgh}
S-metholachlor at 2.0 kg ha^{-1}	2.167^{f}	4^{g}	4.9^{h}
Pendimethalin at 1.0 kg ha^{-1}	5.233^{bcd}	7.46^{de}	8^{cde}
Pendimethalin at 1.25 kg ha^{-1}	3.9^{cdef}	7.167^{def}	7.2^{efg}
Pendimethalin at 1.5 kg ha^{-1}	2.2^{f}	5.1^{efg}	5.733^{fgh}
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin at 1.0kg ha^{-1},	4.167^{cdef}	5.4^{efg}	5.533^{hg}
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,	3.2^{def}	6.2^{defg}	5.7667^{fgh}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	4.667^{bcde}	5.833^{defg}	5.7667^{fgh}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	4.067^{cdef}	5.733^{defg}	6.9667^{efg}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	5.3^{bc}	8.2^{cd}	8.766^{c}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	4.633^{bcde}	8^{cd}	9.3667^{c}
Two hand weeding at 2 and 5 WAE	10^{a}	10.533^{bc}	13.233^{ab}
One hand weeding and hoeing at 2 WAE	9.667^{a}	11.33^{b}	12.733^{b}
Weed free check	0^{g}	0^{h}	0^{i}
Weedy check	11^{a}	16.33^{a}	14.667^{a}
LSD (5%)	2.0636	2.544	1.6185
CV	24.76	21.54	12.57

CV= coefficient of variation; LSD= least significant difference; WAE =weeks after crop emergence, Means in columns of same parameter followed by the same letter(s) are not significantly different at 5% level of significance

4.2.2. 2.Weed density at 55 days after emergence (DAE)

Different weed management practices significantly ($P<0.01$) affected broadleaved, grassy and total density of weed at 55 days after crop emergence. Statistical analysis of the data indicated that the lowest density of broadleaved weed (6.667 m^{-2}) was observed with Two hand weeding at 2 and 5 WAE, followed by the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE (Table 5). This study also addressed that there was significant reduction in broadleaved weed density as the rate of herbicides increase. This is because as the rate of herbicides increase, phytotoxisity of herbicides on physiology of plants (cell division, elongation and enlargement, tissue and organ differentiation and seedling growth) increase resulting higher mortality of weeds to bring lower weed density. Significantly lower broad- leaved weed density at 55 days after crop emergence was recorded in all plots treated with herbicides than weedy check plots. The result was in line with the study of Nassar (2008) who reported that all weed control treatments decreased significantly the number and dry weight of weeds 60 and 90 days after sowing as compared to the weedy check.

Furthermore, the statistical analysis of the data exhibited that the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE significantly affected the density of grass weeds after application. The minimum grass weed density **(**4.17 m^{-2}**)** was recorded in plots treated with Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE followed by the application of S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE . This result was in harmony with the study of Nano *et al.* (2012) who reported 2, 4-DEE + one hand weeding and hoeing at 5WAE to be ineffective in controlling the population of grass weed although controlled broad leaved weed population in bread wheat.

Over all, similar to that of density of grass and broadleaved weed, density of sedge had also showed variation due to the removal of sedge by hand weeding in weed free check and two hand weeding 55 days after crop emergence, but in most herbicide applied plots there was no significant variation observed as all of these three herbicides failed to control sedge. The minimum density of sedge (11.267 m^{-2}) was recorded in two hand weeding 55 days after crop emergence, while maximum density of sedge (23.6m^{-2}) was obtained from weedy plot. The reason is that due to the best control of both grass and broadleaved weed reduce weed-weed competition and availability of more space, nutrients, moisture and light and better use of available resources there by later germinating sedges were not affected under these less competition; resulting in higher density of sedge. This result is in line with the study of Getachew *et al.* (2015) who stated that the application of pendimethalin failed to control *C. benghalensis,* but weeds other than *C. benghalensis* were controlled which reduced inter specific competition in turn might have provided greater opportunity to *C. benghalensis* to germinate in larger amount in cowpea.

Table 5 Weed density (m^{-2}) at 55 days after crop emergence at Ezha during 2020 main cropping season

Treatments	Broad leaves	Sedge	Grassy
S-metholachlor at 1.0 kg ha^{-1}	12.667^{bcd}	18.667^{b}	7.667^{cb}
S-metholachlor at 1.5 kg ha^{-1}	11^{de}	16.567^{b}	6.33^{cd}
S-metholachlor at 2.0 kg ha^{-1}	11^{de}	9^{g}	4.73^{def}
Pendimethalin at 1.0 kg ha^{-1}	14.33^{abc}	18^{b}	7.63^{cb}
Pendimethalin at 1.25 kg ha^{-1}	11.833^{cd}	17.33^{bcd}	6.3^{cd}
Pendimethalin at 1.5 kg ha^{-1}	11.33^{cde}	17.667^{bc}	7.3^{c}
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1},	11.33^{cde}	14.667^{de}	6.23^{cd}
S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,	$9.9d^{def}$	15.233^{cde}	5.9^{cdef}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	10.33^{de}	13.667^{ef}	6.57^{cd}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	11.167^{de}	15.233^{cde}	6.1^{cde}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	8.333^{efg}	11.6^{gf}	4.63^{def}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	7.069^{fg}	11.867^{f}	4.17^{ef}
Two hand weeding at 2 and 5 WAE	6.667^{g}	11.267^{ef}	3.93^{f}
One hand weeding and hoeing at 2 WAE	15^{ab}	22^{a}	9.5^{ab}
Weed free check	0^{h}	0^{h}	0^{g}
Weedy check	17.167^{a}	23.6^{a}	10.33^{a}
LSD (5%)	3.047	2.679	1.97
CV	17.29	10.88	19.32

Means followed by the same letter are not significantly different at 5% level of significance
CV= Coefficient variation, LSD =Least significant difference

4.2.2. 3.Weed density at harvest

Different weed management practices significantly ($P<0.01$) affected broadleaved, grass and total density of weed at 15 days before crop harvest. Statistical analysis of the data indicated that the lowest density **(**6.37 m^{-2}**)** of broadleaved weeds at 15 days before crop harvest was existed with the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE which was statistically different from all weed management practices (Table 6). The analyzed data had also indicated that due to herbicide application there was highly reduction on broadleaved weed density over their lower dose. Moreover, in the integrated treatments lower weed density was recorded as compared to their sole application. This might be due to control of weeds during initial stage by herbicide and control of latter emerging weeds with hand weeding resulting in minimum weed density. The result was in line with the study of Egan *et al.* (2011) who noticed that a diversity of chemical and nonchemical weed management practices reduces herbicide use and offers a more robust weed-control system. In contrast to this, maximum broadleaved weed density (20.567m^{-2}) at 15 days before crop harvest was recorded in weedy check plots and it was significantly different from all weed management practices. The result was in consistence with the finding of Khan *et al.* (2004) who reported a maximum weed density in weedy check and weed control methods like application of herbicides and hand weeding and hoeing significantly deceased weed density over weedy check. The data pertaining to the density of grass weed was significantly ($P<0.01$) affected by the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE at 15 days before crop harvest. Statistical analysis of the data also exhibited that there was significant reduction on density of grass weed with the application of these herbicides over their lower dose other than S-metholachlor.

Over all, in the integrated treatments lower weeds density was recorded as compared to their sole application in all herbicide treated plots at 15 days before crop harvest. These might be due to control of weeds during initial stage by herbicide application and control of latter weeds through hand weeding resulting in minimum weed density at 15 days before crop harvest. The result was line with the study of Raize *et al.* (2006) and Bibi *et al.* (2008) who reported herbicides supplemented with hand weeding improved weed controlling ability.

The maximum density of grass weed ($26m^{-2}$) was recorded from plots treated with weedy check plots. Similar to that of density of grass and broadleaved weed, density of sedge has also shown variation due to the removal of sedge by hand weeding in comparison with un-weeded plots. The minimum density of sedge ($8.667m^{-2}$) was recorded with the application of -metholachlor at 1.0 kg ha^{-1} supplemented with one hand weeding at 35 days after chemical application, while the maximum density of sedge weed ($8.667m^{-2}$) was obtained with the application of S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},. The reason might be that due to the best control of both grassy and broadleaved weed reduce weed-weed competition and availability of more space, nutrients, moisture, light and better use of available resources by sedge weeds there by later germinating weeds were not suppressed under these less competition, ultimately resulting in higher density of sedge.

Table 6. Weed density (m^{-2}) at harvest at Ezha during 2020 main cropping season

Treatments	Broad	Sedge	Grass
S-metholachlor at 1.0 kg ha^{-1}	16^{bc}	18.6^{c}	6.5^{ab}
S-metholachlor at 1.5 kg ha^{-1}	12^{efg}	17.33^{cde}	6abc
S-metholachlor at 2.0 kg ha^{-1}	12.233^{def}	15.067^{ef}	5.3^{bc}
Pendimethalin at 1.0 kg ha^{-1}	14.667^{bcd}	18.633^{c}	6.33^{abc}
Pendimethalin at 1.25 kg ha^{-1}	14.5^{bcd}	18.233^{cd}	6.167^{abc}
Pendimethalin at 1.5 kg ha^{-1}	14.33^{bcd}	16.761^{cde}	5.767bc
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1},	13.667^{cde}	15.6^{ef}	6.167^{abc}
S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha-1,	12.967^{cde}	15.733^{ef}	8.33^{bc}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	14.167^{bcd}	16.067^{de}	8.667^{bc}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	14.03^{bcd}	15.767^{def}	5.667^{bc}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	10.33^{efg}	11.467^{g}	4.33^{c}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	9.33^{fg}	13.567^{fg}	4.667^{bc}
Two hand weeding at 2 and 5 WAE	8.667^{g}	11.33^{g}	4.33^{c}
One hand weeding and hoeing at 2 WAE	17.33^{ab}	21.667^{b}	8^{a}
Weed free check	0^{h}	0^{h}	0^{d}
Weedy check	20.567^{a}	26^{a}	8^{a}
LSD (5%)	3.438	2.4856	2.0957
CV	16.10	9.44	22.789

Means followed by the same letter are not significantly different at 5% level of significance CV= Coefficient variation, LSD =Least significant difference

4.2.3. Weeds Dry Biomass

4.2.3. 1.Weed dry bio mass at 55 Days after emergence

Similar to weed density different weed management practices have significantly ($P<0.01$) affect broadleaved, grass and total dry weight of weed at 55 days after crop emergence. Statistical analysis of data showed that the dry weight of broadleaved weed was affected by various weed management practices (Table 7). The data exhibited that the mean minimum dry weight of broadleaved weed (5.3gm^{-2}) was recorded with the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE which was statistically different from all of the other treatments. This might be due to consequence of activeness of the herbicide to its effective weed controlling ability to have a minimum weed density which ultimately resulting in lower dry weight of broadleaved weeds to be recorded. In addition, lower dry weight of broadleaved weed at 55 days after crop emergence was recorded with the application of S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE with no statistical variation observed among them. Perusal of the ANOVA also exhibited that in all herbicide applied treatments there was significant reduction in dry weight over their lower doses. Generally, as the rate of herbicides increased, the density of broadleaved weeds decreased in all herbicides treatments resulting in significant reduction in dry weight. On the other hand, maximum dry weight of broadleaved weed was recorded in weedy check plots. The reason is that in un-weeded plots, weeds existed in higher density and provided an opportunity to compete more with crop plants for available resources and accumulated the maximum nutrients, resulting in higher biomass production. The result was in accordance with the study of Kumar (2009) who reported that maximum weed dry weight in weedy check in groundnut production.

The result revealed that at 55 days after crop emergence, there was significant reduction in grass weed dry weight with the application of Pendimethalin and smetholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE among their rates as well as hand weeding. This might be due to that as the rate of herbicide increases density of weed decreases, ultimately resulting in significant reduction in above ground dry matter of weeds. Similar to that of the density, minimum dry weight of sedge (7.93 gm^{-2}) was recorded in two hand weeding 55 days after crop emergence. The reason is that due to the better control of both grassy and broadleaved weed that reduce weed-weed competition and availability of more space, nutrients, moisture and light and better use of available resources by weeds there by later germinating weeds were not suppress under these less competition, resulting in higher dry weight of sedge. Over all comparison of herbicide treatments indicated that there was higher reduction of total dry weight of weed with the application of pendimethalin and s-metholachlor at 55 days after their application. This significant reduction of total dry weight of weed might be due to effectiveness of these herbicides to control both grassy and broadleaved weed lower total dry weight than s-methlorachlor. The higher weed dry weight in weedy check might be due to higher weed density as well as more competition of weeds with crop for nutrients, space, light and water resulting in higher biomass production. The result was in line with the study of Sareta *et al*. (2016) who reported that the highest dry weed mass was recorded in weedy check treatment.

Table 7. Weed dry biomass (gm^{-2}) at 55 DAE at Ezha during 2020 main cropping season

Treatments	Broadleaved	Sedge	Grass
S-metholachlor at 1.0 kg ha^{-1}	10.667^{cb}	15.83^{bc}	6.53^{c}
S-metholachlor at 1.5 kg ha^{-1}	10^{bcd}	10.7^{efg}	4.66^{ef}
S-metholachlor at 2.0 kg ha^{-1}	8^{cde}	14.57^{bcde}	5.67^{cde}
Pendimethalin at 1.0 kg ha^{-1}	10.067^{bcd}	14.33^{bcde}	6.06^{cd}
Pendimethalin at 1.25 kg ha^{-1}	7^{def}	14.77^{bcde}	5.67^{cde}
Pendimethalin at 1.5 kg ha^{-1}	9^{bcd}	11.67^{defg}	4.67^{ef}
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1},	8^{cde}	12.33^{cdef}	5.83^{cde}
S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,	8^{cde}	14.40^{bcd}	5.67^{cde}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	9^{bcd}	12.90^{bcde}	5.67^{cde}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	10.033^{bcd}	14.9^{bcd}	4.93^{def}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	5.5^{ef}	9.67^{gf}	3.83^{f}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	5.3^{ef}	9^{gf}	4.5^{ef}
Two hand weeding at 2 and 5 WAE	4.33^{f}	7.93^{g}	3.7^{f}
One hand weeding and hoeing at 2 WAE	11.67^{ab}	17^{b}	8.67^{b}
Weed free check	0^{g}	0	0
Weedy check	14.667^{a}	24.87	10.67^{a}
LSD (5%)	3.99	4.11	1.36
CV	24.85	19.23	14.95

CV= coefficient of variation; LSD= least significant difference; WAE =weeks after crop emergence, Means in columns of same parameter followed by the same letter(s) are not significantly different at 5% level of significance

4.2.3. 2.Weed dry biomass at harvest

The statistical analysis of data showed that different weed management practices significantly affected dry weight of broadleaved weed. At 15 days before crop harvest, minimum dry weight of broadleaved weed (9.03gm^{-2}) was recorded in plots treated with S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE followed by pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE (Table8). The application of s methlorachlor and pendimethalin, in combination with one hand weeding and two hand weeding 2 and 5 days after crop emergence were statistically in parity regarding broadleaved weed dry weight at 15 days before crop harvest. The analyzed data exhibited that there were significant reduction in broadleaved weed dry matter weight in all herbicide treated plots with one hand weeding supplementation, but no statistical difference was observed with application of pendimethalin combined with one hand weeding. Moreover, in the integrated treatments lower broadleaved weed dry weight was recorded as compared to their sole application in all herbicide treated plots. These might be due to control of weeds by herbicide application and removing latter emerged and tolerant weeds through hand weeding resulting in minimum weed density and later growing weeds (after hand weeding) accumulated less biomass production, ultimately resulting minimum dry weight. The result was in accordance with the finding of Raize *et al.* (2006) and Tesfay *et al*. (2014) who reported post- emergence herbicides and /or hand weeding and hoeing at tillering stage reduced the dry weight of weeds as compared to herbicides alone or weedy check.

On the other hand, maximum broadleaved weed dry weight (19.33gm^{-2}) was recorded in weedy check plots and it was significantly higher than other weed management practices. This higher weed dry weight might be due to higher weed density, high growth as well as maximum dry matter accumulation resulting maximum weed dry weight at harvest. The result was in accordance with the study of Das and Yaduraju (1999) who reported that the weeds that germinated earlier or at the same time as the crop offered a serious competition as they got an opportunity to establish and accumulate higher dry matter weight.

Similar to dry weight of broadleaved weed, lower grass weed dry weight was recorded in the integrated weed management practices as compared to their sole application. These might be due to control of weeds during initial stage by herbicide application and latter weeds through hand weeding resulting in minimum weed density and later growing weeds accumulated less dry weight, ultimately resulting minimum dry weight. The result was in line with the finding of Getachew *et al*. (2015) who identified that at 55 days after emergence weeds accumulated significantly the lowest dry weight in plots treated with 1.0 kg ha^{-1} of s-metolachlor and pendimethalin with one hand weeding supplementation which might be due to the cumulative effect of herbicide and hand weeding in Cowpea. This higher weed dry weight might be due to higher weed density and more competition for nutrients, space, light and water resulting in higher weed biomass production. This result is in line with the study of Mandal *et al.* (2014) who reported that maximum weed biomass was found from control (no weeding) in wheat.

Table 8. Weed dry biomass (gm^{-2}) at harvest in Ezha during 2020 main cropping season

Treatment	Broadleaved	Grass	Sedge
S-metholachlor at 1.0 kg ha^{-1}	15.33^{bc}	8^{b}	16.33^{b}
S-metholachlor at 1.5 kg ha^{-1}	10.9^{ghi}	6.467^{bc}	14^{bc}
S-metholachlor at 2.0 kg ha^{-1}	9.667^{ghi}	5.2^{de}	9.33^{df}
Pendimethalin at 1.0 kg ha^{-1}	14.5^{bcd}	7^{bcd}	17.3^{b}
Pendimethalin at 1.25 kg ha^{-1}	13^{def}	6.167^{bcd}	14.866^{b}
Pendimethalin at 1.5 kg ha^{-1}	13.63^{cde}	6.8^{bcd}	14.233^{b}
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1},	11.9667^{efg}	4.967^{de}	15^{b}
S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,	11.4^{fgh}	5.3^{cd}	14.44^{b}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	11^{gh}	5.63^{cd}	14.33^{b}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	12.13^{efg}	5.367^{cde}	15.567^{b}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	8.167^{jk}	2.933^{e}	10.33^{cd}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	9.03^{ij}	4.9^{de}	8^{df}
Two hand weeding at 2 and 5 WAE	6.833^{k}	2.733^{e}	5.67^{e}
One hand weeding and hoeing at 2 WAE	16.33^{b}	8^{bc}	23^{a}
Weed free check	0^{l}	0^{f}	0^{f}
Weedy check	19.33^{a}	13.33^{a}	26^{a}
LSD (5%)	1.92	3.81	2.64
CV	10.06	27.2	16.74

CV= coefficient of variation; LSD= least significant difference; WAE =weeks after crop emergence, Means in columns of same parameter followed by the same letter(s) are not significantly different at 5% level of significance

4.2.4. Parameters for weed control

4.2.4. 1. Weed control efficiency

Weed control efficiency indicates the efficiency of applied herbicide or other weed control practices which expressed as the percentage reduction in weed dry matter by any weed control treatment in comparison to weedy check plots thus the higher weed control efficiency of a treatment is the better the treatment. Statistical analysis of the data indicated that the highest weed control efficiency (73.8 %), next to weed free check was recorded with the application of Two hand weeding at 2 and 5 WAE followed by the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE (Table 9).

Higher weed control efficiency also recorded with the application of herbicides supplemented with one hand weeding as compared to their sole application. This might be due to effective weed control with the application of herbicides at early growth stage and removing both tolerant and late emerging weeds by hand weeding which resulted in to the low weed counts and finally reduced the total dry weight of weeds at harvest. Similar result was obtained by Patro and Ray (2016) who concluded that the application of pendimethalin at 1.0 kg ha^{-1} + one hand weeding remarkably reduced the weed dry matter resulted in increase in weed control efficiency in wheat. This is because both grass and broadleaf weeds were controlled effectively by the application of these herbicides. This result is in line with the study of Tesfay *et al.* (2014) who stated that higher weed control efficiency was obtained with the application of isoproturon (broad spectrum herbicide) at 1.50 kg ha^{-1} in wheat.

4.2.4. 2. Weed index: (WI)

Weed index refers to the reduction in crop yield due to the presence of weeds in comparison to weed free check, and measures the efficacy of a particular treatment compared with a weed free check which expressed as percentage of yield potential under weed free check, and lower weed index indicates less loss of yield due to infestation of weeds, and vice versa. The result revealed that weed index was statistically the highest (67.1%) in weedy check than the rest of all treatments. This might be due to the maximum weed density was recorded in weedy check plots so that highest competition for sunlight, moisture and nutrients, less free space available for growth and bringing reduction in yield attributes which resulted in the highest reduction in yield due to presence of weeds in comparison with weed free situation. The result was nearly the same with the finding of Tesfay *et al.* (2016) who reported that uncontrolled weed growth throughout the crop growth period caused a yield reduction of 72% in wheat. On the other hand, Significantly the lowest weed index (9.3%) was recorded with the application two hand weeding among the weed management practices. Moreover, statistical analysis of the variance exhibited that in the integrated application of chemical with one hand weeding, lower weed index was recorded as compared to their sole application and un-weeded plots. This might be due to that of control of weeds by herbicide application and control of latter weeds through hand weeding reduce weed competition among crops bringing higher grain yield, ultimately resulting low weed index. The result was in line with the finding of Kumar *et al.* (2012) who stated that to get effective control of composite weed flora, a logical combination of several weed control methods is likely to prove the most effective approach.

4.2.4. 3. Herbicide Efficiency Index (HEI)

Herbicide efficiency index is the weed killing potential of herbicide treatments and their phytotoxicity on the crop, and higher herbicide efficiency index indicates better weed control efficiency achieved under a particular treatment with the reduction of weed index due to better weed control. Statistical analysis of the data exhibited that the highest herbicide efficiency index (2.8%) was recorded in plots Two hand weeding at 2 and 5 WAE (Table 9). The analyzed data indicated that, as the rate increases herbicide efficiency index became increased. This might be as herbicide rate increases, weed control efficiency increase so that reduction in weed density and dry matter accumulation at harvest to obtain much yield, ultimately resulting higher herbicide efficiency index. The result was in accordance with the finding of Mirza *et al.* (2013) who revealed that the herbicide efficiency index was increased when the rates of herbicides increased due to better weed control efficiency and lower weed index.

Table 9. Parameters for weed control at Ezha during 2020 main cropping season

Treatments	**Weed index** (%)	**WCE**	**HEI**
S-metholachlor at 1.0 kg ha^{-1}	50.1^{bcd}	34.8^{ge}	1.72^{bcd}
S-metholachlor at 1.5 kg ha^{-1}	36.6^{de}	43.4^{de}	2.21^{abc}
S-metholachlor at 2.0 kg ha^{-1}	19.6^{f}	61.4^{c}	2.4^{ab}
Pendimethalin at 1.0 kg ha^{-1}	52^{cb}	29.9^{f}	1.37^{cd}
Pendimethalin at 1.25 kg ha^{-1}	42.16^{cde}	41.8^{de}	1.8^{bcd}
Pendimethalin at 1.5 kg ha^{-1}	35.4^{e}	40.5^{efg}	2.09^{abc}
S-metholachlor at 1.0kgha^{-1}+ pendimethalin1.0kg ha^{-1},	20.9^{cde}	45.3^{de}	2.27^{abc}
S-metholachlor1.0kgha^{-1}+ pendimethalin at 0.75 kg ha¯1,	40^{cde}	46.6^{d}	1.68^{bcd}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	38.4^{cde}	46.7^{d}	1.8^{bcd}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	42.5^{cde}	43.4^{de}	1.8^{bcd}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	13.4^{fg}	65.3^{bc}	2.4^{ab}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	18.6^{f}	65.7^{bc}	2.4^{ab}
Two hand weeding at 2 and 5 WAE	9.3^{ef}	73.8^{b}	2.8^{a}
One hand weeding and hoeing at 2 WAE	62^{ab}	15.03^{g}	1^{d}
Weed free check	0^{g}	100^{a}	0^{e}
Weedy check	67.1^{a}	0^{h}	0^{e}
LSD(5%)	14	0.9	10.9
CV	24.6	13.9	34

CV= coefficient of variation; LSD= least significant difference; WAE =weeks after crop emergence, Means in columns of same parameter followed by the same letter(s) are not significantly different at 5% level of significance

4.3. Crop parameters

4.3.1. Phenology and growth parameters

4.3.1. Days to 50% flowering

The days to 50% flowering of the chickpea crop was significantly affected by weed management practices. The longest days of heading (60.08) was recorded from the weed free plots, which was at par with the plots that received pendimethalin at 1 0 kg ha^{-1} supplemented with one hand weeding and hoeing, at 5 WAE, Two hand weeding at 2 and 5 weeks WAE. While, the shortest (46.6) days to 50% flowering was recorded from weedy check plots (Table 10). It might be the removal of weeds from inter and intra row spaces besides better aeration due to manipulation of surface soil and thus more spaces, water, light and nutrients were available, which resulted in to delay day to 50% heading.

The current result was in line with Prasad *et al*. (2017) who reported that the maximum (68.49) day to bulb formation was recorded from weed free. While, the minimum (54.86) days to bulb, formation was recorded from weedy check. Similarly, Sunday and Udensi (2013) w ho reported that the plants in weed free plots took the highest time to reach 50% flowering. On the contrary, the finding of Chattha *et al*. (2007) who reported that treating plots with chemical and supplementing with hand weeding at intervals helped to reduce the number of days to flowering and maturity in cowpea

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4.3.2. Days to 90% physiological maturity

The effect of weed management practices was highly significant (P< 0.01) on 90% physiological maturity of the crop (Table 10). The maximum (90) days to maturity was recorded in weed free plots. Which was at par with pendimethalin at 1.0 kg ha^{-1} superimposed with one hand weeding and hoeing at 5 WAE, smetholachlor at 1.0 kg ha^{-1} combined with one hand weeding and hoeing at 5 WAE and two hand weeding at 2 and 5 WAE . While the minimum (68. 67) days to 90 % physiological maturity was recorded from weedy check plots. The current results were in line with Prasad *et al*.(2017) who reported that the application of pendimethalin at 0.75 kg ha^{-1} recorded maximum(134) days to maturity, while the minimum (123) days to maturity was recorded from weedy check. The result was also in line with the findings of Getachew *et al*. (2016) who stated that treating plots with chemical and supplementing with hand weeding at intervals helped to increase number of days to maturity in cowpea.

Table 10. Effect of weed management practices on days to 50 % flowering and 90 % physiological at harvest of chickpea at during 2020 main cropping season

Treatments	Daysto50% flowering	Days to 90% physiological maturity
S-metholachlor at 1.0 kg ha^{-1}	47^{cd}	73^{cd}
S-metholachlor at 1.5 kg ha^{-1}	53.63^{a-d}	76.33^{a-d}
S-metholachlor at 2.0 kg ha^{-1}	54.66^{a-d}	83.67^{a-c}
Pendimethalin at 1.0 kg ha^{-1}	48^{cd}	71.67^{cd}
Pendimethalin at 1.25 kg ha^{-1}	50^{b-d}	73.67^{cd}
Pendimethalin at 1.5 kg ha^{-1}	53^{a-d}	74.67^{b-d}
S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1}	54.33^{a-d}	81^{a-d}
S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,	52.33^{a-d}	83^{a-d}
S-metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	52^{a-d}	80.33^{a-d}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	51.33^{a-d}	81^{a-d}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	56.33^{a-c}	89^{ab}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	58.66^{ab}	88.33^{ab}
Two hand weeding at 2 and 5 WAE	59.6^{a}	89.67^{a}
One hand weeding and hoeing at 2 WAE	48.83^{cd}	71^{cd}
Weed free check	60.8^{a}	90^{a}
Weedy check	46.6^{d}	68.67^{d}
LSD(5%)	9.61	14.43
CV	10.95	11

CV= coefficient of variation; LSD= least significant difference; WAE =weeks after crop emergence, Means in columns of same parameter followed by the same letter(s) are not significantly different at 5% level of significance

4.3.3. Plant height (cm)

Analysis of variance showed that the plant height was highly significantly ($P<0.01$) affected by the weed management practices. The tallest (47.67) plant height was recorded from weed free plots, while the shortest (29.67cm) plant height was recorded from weedy check (Table 11). Application of herbicides alone or in combination with hand weeding resulted in significantly higher plant height than in weedy check. The taller plant height of the treatments mi ght be due to better nutrient utilization, accelerated cell enlargement and meristematic tissue development under least weed growth environment. The current results were in line with Taslima *et al*. (2018) who reported that the highest plant height was recorded from butachlor+ one hand weeding, while the lowest plant height was recorded in weedy check. The variation in plant height of chickpea in weed free control that could be attributed to varying effect of weed competition duration for available resources offered by different weed densitie in different weed control practices and highest from weed free. This finding is in conformity with the finding s of Singh *et al.*, 2005; Mahajan and Chauhan, 2015. Subramanyam *et al*. (2007) also reported co mparable results.

Table 11. Effect of weed management practices on plant height (cm) at harvest of chickpea at during 2020 main cropping season.

Treatments	Plant height
S-metholachlor at 1.0 kg ha^{-1}	31.667^{efg}
S-metholachlor at 1.5 kg ha^{-1}	35^{defg}
S-metholachlor at 2.0 kg ha^{-1}	37.8^{a-f}
Pendimethalin at 1.0 kg ha^{-1}	30.667^{fg}
Pendimethalin at 1.25 kg ha^{-1}	36.33^{cdefg}
Pendimethalin at 1.5 kg ha^{-1}	35^{defg}
S-metholachlor at 1.0 kgha^{-1}+ pendimethalin1.0 kg ha^{-1},	42^{abc}
S-metholachlor1.0 kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-1},	40.667^{a-e}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	40.33^{a-f}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	39.3^{a-f}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	44.33^{a-d}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	45.33^{a-c}
Two hand weeding at 2 and 5 WAE	46.2^{ab}
One hand weeding and hoeing at 2 WAE	30^{d}
Weed free check	47.67^{a}
Weedy check	29.67^{d}
LSD (5%)	9.8
CV	15.2

CV= coefficient of variation; LSD= least significant difference; WAE =weeks after crop emergence, Means in columns of same parameter followed by the same letter(s) are not significantly different at 5% level of significance

4.3.5. Yield components and yield of chickpea

4.3.5.1. Number of pods plant^{-1}

Analysis of variance showed that number of pod per plants was highly significant (P<0.01) affected by the weed management treatments on chickpea (Table 12). The highest number of pods per plant (52.6) was obtained from the interaction of pre emergence application of s-metolachlor 1.0 kg ha^{-1} supplemented hand weeding and hoeing at 35 DAE (Table 12). This might be due to decreased weed competition as these treatments had relatively lower weed dry weight than the rest of the weeding method treatments. Consequently, it might result in higher net assimilation rate thus retaining more flowers and development of more and vigorous leaves under low weed infestation might helped to improve the photosynthetic efficiency of the crop and supported large number of pods. In line with this result, Abdellatif (2008) reported that the integrated use of herbicides with hand weeding might have helped in producing more vigorous leaves under low weed infestation that improved the photosynthetic efficiency of the faba bean (*Vicia faba* L.) and supported a large number of pods. These results in line with Getachew *et al*., (2016) who observed the application of 1.0 kg ha^{-1} of pendimethalin and 1.0 kg ha^{-1} of s-metolachlor, each accompanied with one hand weeding resulted in significant increase in number of pods per plant on cowpea. This result line with, Tamado Tana *et al.,* (2015) reported that unweeded check plots gave the lowest number of pods per plant in common bean. A similar result was reported that, season long weed competition significantly reduced the number of pods per plant for white bean (Ghadiri and Bayat, 2004).

4.3.5.2 Number of seeds per pod

The analysis of variance showed that number of seed per pods was significantly (P<0.01) affected by treatments (Table 12). The highest number of seeds per pod (21.6) was obtained from weed free check, followed by two hand weeding and hoeing at 2 and 5 WAE (17.8) and S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE (17.3) (Table 12). This might be due to reduced interference of weeds and the growth of vigorous leaves might have helped to improve the photosynthetic efficiency of the crop that supported large number of seeds per pod. Moreover, integration of herbicides and hand weeding and hoeing at 35 days after crop emergence provided good weed control efficiency and reduction of weed competition which resulted in more translocation and assimilation of photosynthesis towards grain formation also produced the highest number seed per pods (Borras *et al.,* 2004). In agreement with this result, Tamado Tana *et al.,* (2015) reported that the highest number of seeds per pod (7.1) was recorded from the treatment s-metolachlor 1.0 kg ha^{-1} supplemented with one hand hoeing and weeding 4 WAE on common bean. Similarly Amare Fufa *et al.,* (2013) reported that, the highest number of seed per pod was obtained from the integration weeding practices of s-metolachlor and hand weeding at 45 days after sowing on haricot bean. While, plants that not weeded throughout the season, had the lowest number of seeds per pod (7.244); it was followed by pre emergence application of s-metolachlor 1.0 kg ha^{-1} (8.638) treated plots. This might be due to, higher competition for available limited resources ultimately resulted in reduced seed filling of the pods. Similarly, unchecked growth of weeds resulted in the lowest number of seeds per pod as compared to weed free check in soybean (Peer *et al*., 2013).

4.3.5.3. Hundred -Seed Weight

The analysis data depicted that, 100 grain weight were significantly influenced by weed control treatments. The highest (29.33) thousand grain weight was recorded from weed free plots, which was at par with pendimethalin at 1.0 kg ha^{-1}supplemented with one hand weeding and hoeing at 35 DAE, Smetholachlor 1.0 k gha^{-1} superimposed with one hand weeding and hoeing at 35 DAE and two hand weeding at 2 and 5 WAE. While the lowest (18.00) thousand grain weights were recorded from weedy check (Table 12). The highest thousand-grain weight recorded from weed free check might be due to availability of more space for better light interception, more nutrients available and moisture for grain development as compared to other treatments. In conformity with this result, Khalid *et al*. (2010) who reported that the more and vigorous leaves under weed free environment had improved the supply of assimilates to be stored in the grain. Moreover, in complete weed free treatment, the spikes were healthy and completely filled as against shriveled and few grain in weedy check. This was because of the effect of the competition for limited nutrients available, ultimately resulting in reduced grain filling of the pods. The current results were in line with Sarkar *et al*. (2017) who reported that the application of pre-emergence herbicide at 2.5 L ha^{-1}follwed by hand weeding once at 20 DAS produced the highest 100-grain weight. While the lowest recorded from weedy check plots. This might be weeding at proper time employing herbicide and supplementing with hand weeding and hoeing could provide favorable environment for the crop, which ultimately lead to better grain filling, which leads max imizing grain weight. This is quite possible that weed free crop stand produced robust grains and ultimately resulted in more 100-grain weight on chick.

Table 12. Effect of weed management practices on number of pod per plant , Number of seed per pod and hundred seed weight at harvest of chickpea at during 2020 main cropping season.

Treatments	Number of pod $^{-1}$	Number of seed pod $^{-1}$	Hundred seed weight
S-metholachlor at 1.0 kg ha^{-1}	37.3^{de}	13^{def}	20.667^{ef}
S-metholachlor at 1.5 kg ha^{-1}	40.^{bcde}	14.9^{bcde}	22^{def}
S-metholachlor at 2.0 kg ha^{-1}	41.1^{bcde}	15.9^{bcd}	23.667^{bcde}
Pendimethalin at 1.0 kg ha^{-1}	36.8^{de}	12.2^{ef}	20.167^{ef}
Pendimethalin at 1.25 kg ha^{-1}	38.4^{cde}	14.2^{def}	4^{def}
Pendimethalin at 1.5 kg ha^{-1}	38.6^{cde}	14.2^{cdef}	22.767^{cde}
S-metholachlor at 1.0 kgha^{-1}+ pendimethalin1.0 kg ha^{-1},	42.5^{bcd}	16.7^{bc}	23.833^{bcde}
S-metholachlor1.0 kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1,	41.5^{bcde}	15.2^{bcde}	25.33^{abcd}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	38.3^{de}	14.2^{cdef}	22^{def}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	40.7^{bcde}	15.2^{bcde}	24.33^{bcde}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	44.8^{b}	17.3^{b}	26.667^{abc}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE	44.2^{bc}	16.7^{bc}	24.267^{bcde}
Two hand weeding at 2 and 5 WAE	45^{b}	17.8^{b}	27.567^{ab}
One hand weeding and hoeing at 2 WAE	36.3^{ef}	12^{fg}	20^{ef}
Weed free check	52.6^{a}	21.6^{a}	29.33^{a}
Weedy check	31^{f}	11^{f}	18^{f}
LSD (5%)	5.7	3	4.42
CV	8.5	12	11.4

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) = Least significant difference at 5%, and CV (%) = coefficient of variation.

4.3.5.4. Aboveground Biomass

The analysis of variance showed that the weed management treatment highly significant ($P<0.01$) effects on aboveground dry biomass of chickpea (Table13). The highest aboveground dry biomass was recorded from weed free check (6025.00 kg ha^{-1}) followed by Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE and Smetholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE . The increments of crop aboveground dry biomass in these treatments might be due to the crop utilized the growth resources more efficiently that resulted in higher final crop stand. In addition to the above, using integrated pre emergence application of s-metolachlor 1.0 kg ha^{-1} with hand weeding and hoeing at 35 DAE control measures suppress of weed growth that lead to low competition by weeds for light, space and nutrients by which the crop could utilize growth resources efficiently, leading to higher dry biomass production. These results line with Getachew *et al.*, (2016) who observed that the highest aboveground dry biomass yield (10797 kg ha^{-1}) was obtained in 1.0 kg ha^{-1} of s-metolachlor + one hand weeding at 5 WAE treated plots in cowpea. Similar with present results, Alfonso *et al.*, 2013 reported good suppression of weed growth by cultural and herbicidal control measures that lead to low competition by weeds for light, space and nutrients by which the crop could utilize growth resources efficiently, leading to higher dry biomass production. On the other hand, significantly lower aboveground dry biomass yield (1799.6 kg ha^{-1}) was recorded from the interaction of unweeded plots.This might be due to severe competition for growth resources resulting in lower availability of nutrients for the crop thus causing lower aboveground dry biomass yield.

4.3.5.5. Grain yield (Kg ha^{-1})

The data analysis showed that grain yield was significantly affected by different weed management treatments (Table 13). The highest grain yield (2582.3 kg ha^{-1}) was recorded from weed free plots followed by the pre emergence application of s-metolachlor 1.0 kg ha^{-1} with hand weeding and hoeing at 35 DAE and pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE (Table 13). However, the grain yield in all weeding methods was statistically different from each other and although herbicides alone was not effective without supplementary hand weeding. This might be due to s-metolachlor herbicide reduced competition from weeds by inhibiting weed emergence when applied at pre emergence of the weeds and later on weeds, was control with hand weeding and hoeing at 35 DAE, which could have resulted in initial advantage in favor of the crop. Therefore, increased grain yield in these treatments might be due to the proper utilization of moisture, nutrients, light and space by the Chickpea bean in the lesser of weed competition. The findings of this study were in coherence with Waktole *et al*. (2013) who reported that application of s-metolachlor superimposed with one hand weeding resulted in the highest grain yield on haricot bean. Similarly, Singh and Sekhon (2013) also reported that integration of herbicides and hand weeding provided high weed control efficiency and produced the highest grain yield. Whereas, the lower grain yields (690.3 kg ha^{-1}) was obtained from the weedy check plots . Pre emergence application of s-metolachlor 2.0 kg ha^{-1} produced higher grain yield than pre-emergence application of s metholachlor 1.0 kg ha^{-1} treatment. This might be due to the interference of weed with the crop for high competition of sunlight, moisture and nutrients hence leads to reduction of grain yield. This result agrees with, Prakash *et al*. (2000), reported that season-long crop weeds competition reduced the grain yield of peas.

4.3.5.6. Harvest index

Statistical analysis of the data revealed (Table 13) that harvest index was significantly affected by different treatments (Table 13). Harvest index was useful in measuring nutrient partitioning in crop plants, which provides an indication of how efficiently the plant utilized acquired nutrients for grain production. On the other hand, the higher harvest index value, the greater the physiological potential of the crop for converting dry matter to grain yield. Therefore, the highest harvest index also implies higher partitioning of dry matter into grain.

The highest harvest index (42.9 %) was obtained from weed free check followed by s-metolachlor 1.0 kg ha^{-1} supplemented with one hand weeding, hoeing at 35 DAE, followed by pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE and two hand weeding and hoeing at 2 and 5 WAE (Table.13). Whereas, the lowest harvest index (25.4%) was obtained from unweeded plot. The highest harvest indexes from these treatments might be due to higher ability of a crop plant to convert the dry matter into economic yield. Further, severe weed interference might have decreased root to shoot ratio increased vegetative growth duration and allocation of more assimilates for shoot rather than root growth. Likewise, the photosynthetic activity might be more during the vegetative phase of crop growth that contributed towards more total dry matter production, but the pace of this photosynthetic rate might have registered much higher decline due to disintegration of nodules with the initiation of pod development resulting in lower harvest index (Getachew Mekonnen *et. al.,* 2016). This result in line with, Getachew *et al*. (2016), who reported that lowest harvest index of cowpea obtained in weedy check unweeded plots. Similarly, Zhu *et al*. (2010) reported that partitioning efficiency (harvest index) was determined by the amount of biomass energy allocated to vegetative vs. reproductive structures.

Table 13. Effect of weed management practices on aboveground biomass yield, Grain yield and Harvest index at harvest of chickpea at during 2020 main cropping season

Treatments	ABG(kg ha^{-1})	GY(kg ha^{-1})	HI
S-metholachlor at 1.0 kg ha^{-1}	3612^{ef}	1091^{efd}	30.3^{def}
S-metholachlor at 1.5 kg ha^{-1}	4836.3^{cd}	1635.3^{cd}	34.4^{cd}
S-metholachlor at 2.0 kg ha^{-1}	5879^{a}	2265.7^{ab}	38.6^{abc}
Pendimethalin at 1.0 kg ha^{-1}	3635.3^{ef}	1230.7^{ed}	33.8^{cd}
Pendimethalin at 1.25 kg ha^{-1}	4298^{de}	1491^{cd}	34.9^{bcd}
Pendimethalin at 1.5 kg ha^{-1}	5003.3^{cd}	1666.3^{c}	33.8^{cd}
S-metholachlor at 1.0 kgha^{-1}+ pendimethalin1.0 kg ha^{-1},	5712^{ab}	2038.7^{b}	35.7^{bcd}
S-metholachlor1.0 kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-1},	4266.7^{de}	1539^{cd}	36^{bcd}
S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1},	4322^{de}	1593^{c}	36.6^{bc}
S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1},	3876.3^{ef}	1481.3^{cd}	38^{abc}
S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	5448.3^{abc}	2227^{ab}	40.9^{ab}
Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 4-5 WAE	5602.3^{abc}	2098.3^{b}	37.6^{abc}
Two hand weeding at 2 and 5 WAE	5991^{a}	2338^{ab}	39^{abc}
One hand weeding and hoeing at 2 WAE	3208.3^{fg}	887^{ef}	27.6^{ef}
Weed free check	6025^{a}	2582.3^{a}	42.9^{a}
Weedy check	2698	690.3^{f}	25.4^{f}
LSD (5%)	812.6	355.3	6
CV	10.5	12.7	10.3

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) = Least significant difference at 5%, and CV (%) = coefficient of variation.

4.4. Partial budget analysis

The, partial budget analysis result was performed using the partial budget technique (CIMMYT, 1988) and the partial budget analysis of the 16 treatments was shown in (Table14). Based on this result, the highest net benefit of (92300 Birr ha^{-1}) was obtained from pre emergence application of s-metolachlor at 1.0 kg ha^{-1} supplemented with one hand weeding at 5WAE (Table 14).

While, the lowest net returns (33,618 ETB ha^{-1}) was recorded from unweeded plot (weedy check) plots. This might be due to in the case of interaction effects of s-metolachlor 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE. This might be due to weeds were suppressed by pre emergence application of herbicide at early stage and the later emerged weeds were controlled by hand weeding and hoeing at 35 DAE then after weeds were suppressed by the crop canopy, hence, (Table 14) as the result of grain yield was increased (Table 14). Moreover, the highest net benefit from this herbicide treated plot could be attributed to high yield and low cost of weeding method with fertilizer application compared to the labour cost. This result in line with, Dawit *et al.* (2011) reported that the application of s-metolachlor 1.0 kg ha^{-1} + one hand weeding and hoeing at 35 days after sowing gave the highest net benefit (ETB 12296 ha^{-1}) in common bean. Thus, from the economic point of view, it was noticeable that lower rate of s-metolachlor 1.0 kg ha^{-1} supplemented with one hand weeding and hoeing at 35 days.

Table 14 Results of partial budget analysis of weed management Practices in Chick in 2020 main cropping season

Weed Management Practices	**Average Yield (kg ha^{-1})**	**Adjusted Yield (kg ha^{-1})**	**Gross benefit (ETB ha^{-1})**	**Total variable Cost (ETB ha^{-1})**	**Net benefit (ETB ha^{-1})**
S-metolachlor 1.0 kg ha^{-1}	1284.7	1156.2	57,780	6150	51630
S-metolachlor 1.5 kg ha^{-1}	1635.3	1471.8	73,588.5	6750	66838
S-metolachlor 2.0 kg ha^{-1}	2074.3	1866.9	93,343.5	7350	85,993.5
Pendimethalin 1.0 kg ha^{-1}	1230.7	1107.7	55,381.5	5100	50281.5
Pendimethalin 1.25 kg ha^{-1}	1491	1341.9	67,095	5300	61795
Pendimethalin 1.5 kg ha^{-1}	1666.3	1499.7	74,983.5	5825	69158.5
S-metolachlor 1.0 kg ha^{-1} +HW 5 WAE	2227	2004.3	100,215	7915	92300
Pendimethalin 1.0 kg ha^{-1} +HW 5 WAE	2098	1888.2	94,410	7665	86745
One hand weeding at 2 WAE	982.3	884	44,203.5	5515	38688.5
Two hand weeding at 2 and 5 WAE	2338	2104.2	105,210	8915	97295
Weed free	2582.3	2324.07	116203.5	15234	100,969.5
Weedy check	816.3	734.7	36,733	3115	33,618

WAE = Weeks after crop emergence; Cost of pendimethalin and s-metolachlor 950 and 1200 ETB 1kg ha^{-1} , respectively; Spraying 1200 ETB ha^{-1}; Cost of hand weeding and hoeing 2 WAE 12 persons, 2400, two hand weeding 24 persons at ETB 200 /person=4800 Sale price of Chickpea 1kg *45 ETB kg^{-1}; Cost of harvesting, Threshing and winnowing 850 ETB100 kg^{-1}; Packing and material cost 20 ETB 100 kg^{-1} and Transportation 45 ETB,NPSB fertilizer 2200/100kg ha^{-1}

5. SUMMERY AND CONCLUSION

Chickpea (*Cicer arietinum* L.) is one of the most important pulses cultivated in Ethiopia. Chickpea is the third important food legume both in area and production after common beans and faba beans in Ethiopia. Even though various effective weed control methods on the yield and yield components of chickpea are reported; there is shortage of information on the use of pre emergence herbicides and their combination as an alternative weed management practices in Southern Ethiopia in general and at Ezha Woreda in particular. For this reason, there is a need to evaluate various pre emergence herbicides and their reduced dose with hand weeding on chickpea field. Therefore; the study was aimed to: Evaluate the effect of herbicides and their combinations on yield components and yield of chickpea (Cicer arietinum L.) in Ezha district, Gurage zone, Southern Ethiopia; To investigate the possibility of supplementing low dose of herbicides with hand weeding for effective weed control. Determine effective and economically feasible method of weed management in Chickpea

The experiment was conducted at Tageme fruit and vegetable farming site, Ezha district in Gurage Zone of Southern Nations, Nationalities and People's Regional state, Southern Ethiopia in the 2020 main cropping season. Kabuli type hora variety was used for the experiment. Before sowing of the seed, soil samples was taken from ten spots of a depth of 0 – 30 cm by zigzag method and one composite sample was formed. From the composite sample, soil physical and chemical properties were analyzed on Wolkite Regional Soil Laboratory. The experiment consisted of 16 treatments viz. S-metholachlor at 1.0 kg ha^{-1} ; S-metholachlor at 1.5 kg ha^{-1} ; S-metholachlor at 2.0 kg ha^{-1} ; Pendimethalin at 1.0 kg ha^{-1} ; Pendimethalin at 1.25 kg ha^{-1} ; Pendimethalin at 1.5 kg ha^{-1} ; S-metholachlor at 1.0kg ha^{-1}+ pendimethalin1.0kg ha^{-1} ; S-metholachlor1.0kg ha^{-1}+ pendimethalin at 0.75 kg ha^{-}1; S- metholachlor at 0.75kg ha^{-1}+ pendimethalin at 1.0 kg ha^{-1}; S-metholachlor at 0.75kg ha^{-1}+pendimethalin at 1.25kg ha^{-1}; S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE; Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE; Two hand weeding at 2 and 5 WAE; One hand weeding and hoeing at 2 WAE; Weed free check and Weedy check plots. The treatments were arranged in randomized complete block design with three replications. Land preparation was made in middle of January 2021 by using manual labor to make it leveled, more appropriate and suitable for the crop. The data collected and measured parameters from the experiment at different growth stages were subjected to statistical analysis as per the experimental designs for each experiment using SAS. Economic analysis was done using the prevailing market prices for inputs at planting and for output at the time the crop was harvested.

The result showed that experimental fields were infested with 17 weed species and eight families were found, including broad-leaved, sedge and grass weeds. The highest broad leaved weed was recorded from weedy check plots. The broadleaved weed density decreased with the increase in pendimethalin herbicide application rates. Also at 25 DAE grass weed density was significantly affected with response to weed management practices. The highest sedge weed density was recorded from the plots treated with one hand weeding 2 WAE and two hand weeding respectively. Statistical analysis of the data indicated that the lowest density of broadleaved weed (6.667 m^{-2}) was observed with Two hand weeding at 2 and 5 WAE, followed by the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE. Over all, similar to that of density of grass and broadleaved weed, density of sedge had also showed variation due to the removal of sedge by hand weeding in weed free check and two hand weeding 55 days after crop emergence, but in most herbicide applied plots there was no significant variation observed as all of these three herbicides failed to control sedge.

The data exhibited that the mean minimum dry weight of broadleaved weed was recorded with the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE which was statistically different from all of the other treatments. This might be due to consequence of activeness of the herbicide to its effective weed controlling ability to have a minimum weed density which ultimately resulting in lower dry weight of broadleaved weeds to be recorded. The result revealed that at 55 days after crop emergence, there was significant reduction in grass weed dry weight with the application of Pendimethalin and smetholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE among their rates as well as hand weeding. At 15 days before crop harvest, minimum dry weight of broadleaved weed was recorded in plots treated with S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE followed by pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE .

Similar to dry weight of broadleaved weed, lower grass weed dry weight was recorded in the integrated weed management practices as compared to their sole application. Statistical analysis of the data indicated that the highest weed control efficiency, next to weed free check was recorded with the application of two hand weeding at 2 and 5 WAE followed by the application of Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE. The result revealed that weed index was statistically the highest (67.1%) in weedy check than the rest of all treatments. Statistical analysis of the data exhibited that the highest herbicide efficiency index (2.8%) was recorded in plots Two hand weeding at 2 and 5 WAE.

The longest days of heading (60.08) was recorded from the weed free plots, which was at par with the plots that received pendimethalin at 1 0 kg ha^{-1} supplemented with one hand weeding and hoeing, at 5 WAE, Two hand weeding at 2 and 5 weeks WAE. The maximum (90) days to maturity was recorded in weed free plots. The tallest (47.67) plant height was recorded from weed free plots, while the shortest (29.67cm) plant height was recorded from weedy check. The highest number of pods per plant (52.6) was obtained from the interaction of pre emergence application of s-metolachlor 1.0 kg ha^{-1} supplemented hand weeding and hoeing at 35 DAE. The highest number of seeds per pod (21.6) was obtained from weed free check, followed by two hand weeding and hoeing at 2 and 5 WAE (17.8) and S-metholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE (17.3). The highest (29.33) thousand grain weight was recorded from weed free plots, which was at par with pendimethalin at 1.0 kg ha^{-1}supplemented with one hand weeding and hoeing at 35 DAE, Smetholachlor 1.0 k gha^{-1} superimposed with one hand weeding and hoeing at 35 DAE and two hand weeding at 2 and 5 WAE. The highest aboveground dry biomass was recorded from weed free check (6025.00 kg ha^{-1}) followed by Pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE and Smetholachlor at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE . The highest grain yield (2582.3 kg ha^{-1}) was recorded from weed free plots followed by the pre emergence application of s-metolachlor 1.0 kg ha^{-1} with hand weeding and hoeing at 35 DAE and pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE . The highest harvest index (42.9 %) was obtained from weed free check followed by s-metolachlor 1.0 kg ha^{-1} supplemented with one hand weeding, hoeing at 35 DAE, followed by pendimethalin at 1.0 kg ha^{-1} + one hand weeding and hoeing at 5 WAE and two hand weeding and hoeing at 2 and 5 WAE . Based on this result, the highest net benefit of (92300 Birr ha^{-1}) was obtained from pre emergence application of s-metolachlor at 1.0 kg ha^{-1} supplemented with one hand weeding at 5WAE.

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7. APPENDIX

Appendix 1 Analysis of variance showing mean squares for Broad leaved, Grassy and sedge weed density at 25 days after crop emergence

		Mean squares		
Source	**DF**	**Broad leaved**	**Grass**	**Sedge**
Rep	2	8.66	1.38	5.3
Trt	15	27**	38.9**	38.7*
Error	30	1.5	0.9	2.3
CV%		24.8	12.6	21.5

**=highly significant, *=significant,

Appendix 2 Analysis of variance showing mean squares for Broad leaved, Grassy and sedge weed density at 55 days after crop emergence

		Mean squares		
Source	**DF**	**Broad leaved**	**Grass**	**Sedge**
Rep	2	1.7	1.3	0.2
Trt	15	45.9**	17.3**	91.5**
Error	30	3.34	1.4	2.5
Cv%		17.3	19.3	10.8

**=highly significant, *=significant,

Appendix 3 Analysis of variance showing mean squares for Broad leaved, Grassy and sedge weed density at harvest

		Mean squares		
Source	**DF**	**Broad leaved**	**Grass**	**Sedge**
Rep	2	5.	39	2.5
Trt	15	58.2**	116**	24.9*
Error	30	1.3	5.2	2.5
Cv%		10	16.7	27.2

**=highly significant, *=significant,

Appendix 4 Analysis of variance showing mean squares for Broad leaved, Grassy and sedge weed dry biomass at 25 days after crop emergence

		Mean squares		
Source	**DF**	**Broad leaved**	**Grass**	**Sedge**
Rep	2	6.5	1.4	0.3
Trt	15	17**	34*	61**
Error	30	2	0.9	1.1
Cv%		34	13.7	10

**=highly significant, *=significant,

Appendix 5 Analysis of variance showing mean squares for Broad leaved, Grassy and sedge weed dry biomass at 55 days after crop emergence

		Mean squares		
Source	**DF**	**Broad leaved**	**Grass**	**Sedge**
REP	2	14.5	2.6	9
TRT	15	34*	15.4*	81*
ERROR	30	4.1	5.4	6
CV%		24.8	14.9	19.2

**=highly significant, *=significant

Appendix 6 Analysis of variance showing mean squares for Broad leaved, Grassy and sedge weed dry biomass at harvest

		Mean squares		
Source	**DF**	**Broad leaved**	**Grass**	**Sedge**
rep	2	5.2	4.9	4.5
trt	15	60.7**	9.8*	94*
Error	30	4.2	1.6	2.2
CV%		16.1	22.8	9.4

**=highly significant, *=significant

Appendix 7 Analysis of variance showing mean squares for 50% flowering and 90% maturity

		Mean squares	
Source	**DF**	**DF 50%**	**DPM 90%**
Rep	2	121.9	370
Trt	15	59.7**	155**
Error	30	33.5	76.8
CV%		10.57	11

DF= degree of freedom DF=dates of 50% flowering, DPM =days of 90% maturity **=highly significant, *=significant

Appendix 8 Analysis of variance showing mean squares for plant height, number of plant per pod, number of seed per plant, hundred seed weight

		Mean squares			
Source	**DF**	**PH**	**NPP**	**NSPP**	**100SW**
rep	2	31.8	6.2	0.07	141.2
trt	15	104.8**	45**	4.7**	27.4**
Error	30	34.5	6	2.9	7
CV%		15.3	11.9	17	11.4

DF=degree of freedom, PH=plant height NPP =number of plant per pod NSPP =number of seed per pod (no plant-1), HSW=hundred seed weight, significant, *=significant

Appendix 9. Analysis of variance showing mean squares for aboveground biomass, grain yield harvest index ,weed index herbicide efficiency Index.

		Mean squares				
Source	**DF**	**AGBM**	**GY**	**HI**	**WI**	**HEI**
rep	2	1075511	23533	18.5	38.5	0.3
trt	15	3371685**	729291.9**	31**	1093**	2*
Error	30	239480	50875.3	20.3	71.4	0.3
CV%		10.5	13.3	12.5	24.6	34

DF=degree of freedom AGBM=aboveground biomass, GY=grain yield HI=harvest index, WI=weed index HEI=herbicide efficiency Index.