

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

Tadele Bekele^{1,*}, Getachew Mekonnen², Ashenafi Mitiku^{3,*}

¹Tadele Bekele Gurage Zone Environmental and Forest Office, Wolkite, Ethiopia

²Department of Plant Science, Wolkite University College of Agriculture, Wolkite, Ethiopia

³Department of Horticulture, Wolkite University College of Agriculture, Wolkite, Ethiopia

Email address:

tadelebekele19@gmail.com (Tadele Bekele), sibuhmekdes@gmail.com (Getachew Mekonnen),

asnfmk.mitiku@gmail.com (Ashenafi Mitiku)

*Corresponding author

To cite this article:

Tadele Bekele, Getachew Mekonnen, Ashenafi Mitiku. Effect of Pre-Emergence Herbicides on Weeds Infestation and Yield of Chickpea (*Cicer arietum* L.) at Ezha Woreda Gurage Zone, Central Ethiopia. *International Journal of Nutrition and Food Sciences*.

Vol. 12, No. 4, 2023, pp. 90-100. doi: 10.11648/j.ijnfs.20231204.12

Received: February 16, 2023; Accepted: July 14, 2023; Published: July 26, 2023

Abstract: Chickpea (*Cicer arietinum* L.) is one of the most important pulses cultivated in Ethiopia. Hence, a field experiment was conducted in Central Ethiopia in Gurage zone at Ezha woreda to investigate the effect of herbicides and their combination on the yield and yield component of chickpea. at Ezha woreda. The experiment was laid out in a Randomized Complete Block Design and replicated three times. Pre-emergence (Pendimethalin and S-metolachlor) herbicides were applied alone at different rates, the reduced-dose combination with herbicides as well as supplemented with one time hand weeding, two-time hand weeding, completely weed-free and weedy treatments. Application of pre-emergence herbicide with their combinations are significantly ($P \leq 0.01$) affect the weed density and yield and yield component of chickpea. The lower weed density, high net benefit, higher yield component, and higher yield of chickpea was recorded from application S-metolachlor at 1.0 kg ha^{-1} supplemented by one time hand weeding at five weeks after emergence and Hand weeding at 2 and 5 WAE methods followed by integrated weed control methods. Whereas the lower yield and yield component of chickpea and higher weed density was recorded from at weedy check, one-time hand weeding and hoeing at 2 WAE. Therefore; for intensive farming methods Hand weeding at 2 and 5 WAE methods and for extensive farming methods applying S-metolachlor at 1 kg ha^{-1} supplemented by one time hand weeding at five weeks after emergence of chickpea is suggested to increase the chickpea yield.

Keywords: Chickpea, Herbicides, IPM, Weed Density, 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.) [1]. The main chickpea-producing countries in 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 [2].

Mean yields of chickpea have varied widely among producing countries and range from 500–600 kg/ha. India is the largest Chickpea producer which was 0.9 t/ha and has a global share is 64.7% from the World. The higher chickpea yields is 30 t/ha in Mexico [2].

Chickpea is a valued crop that provides nutritious food for an expanding world population and will become increasingly important with climate change [3]. It is an annual legume that is the most important crop and its productivity is very low in Ethiopia [4]. Chickpea (*Cicer arietinum* L.) accounts for more than 17% of legumes in Ethiopia with a production of 0.47 million tons on an area of 258,486.29 ha [5]. with the

engagement of over one million households. The importance 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 [6]. 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 [6]. Chickpea is also an important export commodity where both export volume and export earnings of the country are increasing, especially in the last decade [7]. 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's low production and productivity are low input usage, limited availability of seed and limited familiarity with the variety of existing chickpea, limited usage of modern agronomic practices, market problems, and poor extension services [8]. The initial 60 days period considered being critical for weed crop competition in chickpea but continuously facing the scarcity of labor and increase in labor cost, manual weed control has become a difficult task. A 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 the 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 [9]. Intensive agriculture, which largely depends on herbicides for weed control, indiscriminate use of herbicides could cause adverse changes in soil microflora, poor quality crop production, and human and animal health problems [10]. In Gurage Zone Maize, Wheat, Teffe, Barly, Fababean, pea, Hot pepper, and chickpea are cultivated as extensive and intensive farming methods. Chickpea is cultivated in an intensive farming system from October to December to improve soil texture and as a source of protein eaten as a green vegetable and powder form. At the time of cultivation, weed is one of the key factors affecting the production of chickpea within the zone. Most people in the zone are surviving by trade and the cultivation of chickpea is affected due to weed infestation. Therefore the objective of this research is to evaluate the effect of herbicides and their combinations on yield and yield components of chickpea

(*Cicer arietinum* L.) at Ezha district, Gurage zone, Central Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Tageme fruit and vegetable farming site, at Ezha district in Gurage Zone of Southern Nations, Nationalities and People's Regional state, geographically found in central Ethiopia in the 2020 main cropping season. The experimental site is located at 08°44'01.2"N latitude, 37°11'58.6"E longitude, and an 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 an annual average rainfall of 1500-2300 mm. The mean maximum temperature was 14°C to 30°C. the soil pH was ranging from 6.0 to 8.0.

2.2. The Experimental Materials and Treatment Composition

The experiment was conducted in a randomized complete block design with three replications with a total of 48 treatments. The treatments of each experimental plot were 3.6 m x 2.4 m (8.64m²) to reduce inter plot effect the gangway distance between block and plots were 1.5m and 1m respectively. The experiment was conducted with chickpea Kabuli type variety (Hora), which is larger sized and high market price, the crop was characterized by white-colored with ram's head shape, thin seed coat, smooth seed surface, white flowers, and lack of anthocyanin pigmentation on the stem and planted at 40 cm by 40cm inter and intra row spacing. The prepare-emergence herbicides; five stars (Dual Gold 960 EC) and Pendimethalin 450 EC were applied onto the soil as per emergence treatment immediately after sowing. The spraying was made using a Knapsack sprayer with a flat nozzle. Hand weeding (hand weeding and hoeing) were conducted in the assigned plots as per the treatment. To reduce exposure, the herbicide was applied with the safety role principle. After the application of each herbicide, the knapsack was washed with water after the next herbicide application. All agronomic practices were applied at the recommended methods and NPSB fertilizer was applied at the rate of 100kg ha⁻¹ for all plots at the time of sowing.

Table 1. Herbicides 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-xylydine]

Treatments distribution

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+ pendimethalin 1.0kg ha⁻¹, S-metholachlor 1.0kg 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 - time hand weeding and hoeing at 4-5 WAE, Two-time hands weeding at 2 and 5 WAE, One hand weeding and hoeing at 2 WAE, Weed-free check and Weedy check.

2.3. Soil Sampling and Analysis

Before sowing the seed, soil samples were taken from ten spots of a depth of 0 – 30 cm by zigzag method, and one composite sample was warmed. From the composite sample, soil's physical and chemical properties were analyzed at 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 a standard glass electrode PH meter [11]. The organic matter content of the soil. Total Nitrogen in the soil was determined by the Kjeldahal method [12]. Available soil Phosphorus was determined using the Olsen extraction method as described [13]. The Bouyoucas hydrometer method was used to determine soil texture. Electro-conductivity was determined by a standard glass electrode using an EC meter [14]. Soil Cation Exchange Capacity (CEC) was determined by the ammonium acetate method [15].

2.4. Data Collected

2.4.1. Weed Community

Weed populations: were collected as bimodal sampling techniques in diagonal sampling methods by quadrat. The size of the quadrat is ($0.25 \text{ m} \times 0.25 \text{ m}$) the quadrat was laid randomly two times in each plot.

Weed density: Weed density was recorded by throwing a quadrat ($0.25 \text{ m} \times 0.25 \text{ m}$) 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 sampling quadrat were identified, counted, categorized (broadleaved, grass, and sedges), and expressed in m^{-2} .

2.4.2. Crop Phenology and Growth Parameters

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

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.

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.

The 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.

1000 seeds weight: Out of seeds from the above, 100 seeds were counted and their weight was recorded at 10.5% moisture content for a 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 the 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.

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 was carried out using the least significant difference (LSD) test at a 5% level of probability [16].

2.5. Partial Budget Analysis

The partial budget analysis is described [17]. 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 labor cost involved and the gross benefits obtained from weed management practices. The 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 subject to partial budget and economic analysis was performed following the CIMMYT partial budget methodology [17]. The field price of rice was calculated as the sale price minus the costs of harvesting, threshing, winnowing, bagging, and transportation. The total cost that varied included the sum of the cost of seed and labor cost where hand weeding and hoeing are 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.

3. Results and Discussion

3.1. Physico-Chemical Properties of Soil

The soil analysis result shows that the soil texture was clay loam and the soil PH was 5.7 (Table 2). According to Tekalign T. [18] the pH of the experimental site was moderately acidic, and high in CEC contents (Table 2). According to Landon (1991) topsoil CEC greater than $40 \text{ Cmol (+) kg}^{-1}$ are rated as very high and $25\text{-}40 \text{ Cmol (+) kg}^{-1}$ as high, $15\text{-}25$ as mean dium, $5\text{-}15$ low, and $\leq 5 \text{ Cmol (+) kg}^{-1}$ of soil as very low in CEC. According to this classification,

the soils of the site had a 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. 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 soil in the site recorded EC 6.92 mS/cm, which was slightly saline (Table 2). according to Tekalign T. [18]. Tekalign T. [18] also classified soil total N availability of $\leq 0.05\%$ 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 the application of nitrogenous fertilizer. According to the research [19] soil classification soil organic carbon (%) >3.50 is very high, 2.51-3.5 high, 1.26-2.50 medium, 0.60-1.25 low, and ≤ 0.60 very low. Thus, the organic carbon content of the soil (2.26%) was in the medium range. The author [20] reported that available Sulphur (11.81 mg kg⁻¹) is classified as in the medium range.

Table 2. 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 ₂ O)	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

3.2. Weed Community

The result showed that experimental fields were infested with 17 weed species and eight families were found, and classified as broad-leaved, sedge, and grass weeds (Table 3 and Table 4). Sedge and Grassy weeds were more highly dominated and infested than grass weeds and broad-leaved weeds. From the data, *Cyperus rotundus* L accounted for the highest number, and thereafter was *Cyperus brevifolius* Rottb L. and *Cynodon dactylon*. This is maybe Sedge and Grassy weeds species are more tolerant to advert environmental factors than to broad leaves weeds. The result [21] reported that environmental and weeding frequency major factors that influenced weed species.

Table 3. Weed community in a chickpea field.

Scientific Name	Family	Categories
<i>Ageratum conyzoides</i> L.	Asteraceae	Broadleaf
<i>Argemone ochroleuca</i> L.	Papaveraceae	Broadleaf
<i>Amaranthus spinosus</i> L.	Amaranthaceae	Broadleaf
<i>Bidens pilosa</i> L.	Asteraceae	Broadleaf
<i>Cassia pumila</i> Lam.	Fabaceae	Broadleaf
<i>Convolvulus arvensis</i> L.	Convolvulaceae	Broadleaf

Scientific Name	Family	Categories
<i>Chromolaena odorata</i> L. R. M. king & H. Rob	Asteraceae	Broadleaf
<i>Cyperus brevifolius</i> Rottb.	Cyperaceae	Sedge
<i>Commelina diffusa</i> L.	Asteraceae	Broadleaf
<i>Cyperus rotundus</i> L.	Cyperaceae	Sedge
<i>Datura stramonium</i> L.	Solanaceae	Broadleaf
<i>Dichanthium annulatum</i> (Forsk.) Stapf.	Poaceae	Grass
<i>Digitaria ternata</i> (A. Rich) Stapf	Poaceae	grass
<i>Eclipta alba</i> (L.) Hassk.	Asteraceae	Broadleaf
<i>Setaria glauca</i> (L.) P. Beauv.	Poaceae	Grass

3.3. Effect of Herbicide on Weed Density at 25 Days After Crop Emergence

Application of herbicide is significant ($P < 0.01$) effect on the weed density. The higher weed density was recorded from the weedy check which is 41.99m² followed by one-time hand weeding with hoeing at 2 WAE and Two-time hand weeding at 2 and 5 WAE which is 33.37m² and 33 m² respectively whereas the lower weed density was recorded at the rate of S-metholachlor at 1.5 kg ha⁻¹, and S-metholachlor at 2.0 kg ha⁻¹ which is 14.23m², and 11.067m² followed by Pendimethalin at 1.5 kg ha⁻¹, and Pendimethalin at 1.25 kg ha⁻¹ (Table 4). Medium weed density were recorded from S-metholachlor at 1.0 kg ha⁻¹, Pendimethalin at 1.0 kg ha⁻¹, Pendimethalin at 1.25 kg ha⁻¹, S-, metholachlor at 1.0kg ha⁻¹+ pendimethalin at 1.0kg ha⁻¹, S-metholachlor at 1.0kg 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 time hand weeding and hoeing at 5 WAE and Pendimethalin at 1.0 kg ha⁻¹ + one time hand weeding and hoeing at 5 WAE the weed population is ranging from 15.1m² - 22.27 m² (Table 4). Similar reports were reported [22] reported that the higher weed density was recorded m⁻² at 20 DAS in weedy check while the lowest weeds m⁻² was underhand hoeing. The author [23] reported that pre-emergence herbicide application of pendimethalin at 0.5 kg ha⁻¹ with atrazine at 0.5 kg ha⁻¹ recorded a lower density of monocot and dicot weeds. The author [24] stated that a higher weed density was recorded in the weedy check and the lowest weed density was recorded from 1.5 kg ha⁻¹ Pendimethalin. The author [25] reported that weed populations are dynamic in time, both within and between seasons, and in space, both within and between fields.

3.4. Effect of Herbicide on Weed Density at 55 Days After Emergence

Application of herbicide with its combination was significantly ($P < 0.01$) on weed population. The higher weed population was recorded from control plots which are 51m² followed by application of S-metholachlor at 1.0 kg ha⁻¹, S-metholachlor at 1.5 kg ha⁻¹, Pendimethalin at 1.0 kg ha⁻¹, Pendimethalin at 1.25 kg ha⁻¹, Pendimethalin at 1.5 kg ha⁻¹ and One hand weeding and hoeing at 2 WAE the population ranging from 33.9 m² to 46.5m² (Table 4). The lower weed population was recorded from two-time hand weeding at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one hand

weeding and hoeing at 5 WAE, and S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 5 WAE which is 21.87 m², 23.1 m² and 24.56 m² respectively (Table 4). The result was in line with the study [26] which reported that all weed control methods decreased the number and dry weight of weeds 60 and 90 days after sowing as compared to the weedy check. The author [27] reported 2, 4-DEE + one time hand weeding and hoeing at 5WAE is not effective in controlling the population of grass weed although controlled broad-leaved weed population in bread wheat. The author [28] stated that the application of pendimethalin failed to control *C. benghalensis*, but weeds other than *C. benghalensis* were controlled and reduced interspecific competition.

3.5. Effect of Herbicide on Weed Density at Harvest

Application of herbicide is a significant ($P < 0.01$) effect on weed density at harvesting time. The higher weed density was recorded at a weedy check and one-time hand weeding, hoeing at 2 WAE, Pendimethalin at 1.25 kg ha⁻¹, Pendimethalin at 1.0 kg ha⁻¹, and S-metholachlor at 1.0 kg ha⁻¹

¹ weed control methods which is 54.57, 47, 39.3, 39.63 and 41.1 weed density respectively followed by S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S- metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ Pendimethalin at 1.0kg ha⁻¹, Pendimethalin at 1.5 kg ha⁻¹ and S-metholachlor at 1.5 kg ha⁻¹ weed control methods whereas the lowest weed density was recorded from combined weed control methods such as two time hand weeding at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one-time hand weeding and hoeing at 5 WAE and S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 5 WAE which is 24.33, 27.56 and 26.13 weed density at harvesting (Table 4). The result was in line with the work [29] reported that a combination of herbicide and cultural weed control methods reduces offers a stronger weed-control system. The author [30] reported a maximum weed density recorded from a weedy check. The authors [31, 32] reported herbicides supplemented with hand weeding improved weed controlling ability.

Table 4. Effect of herbicide with its combination on weed population.

Treatments	WDAE(1)25				WDAE(2)55				WDAH(3)			
	Broad leaved	Sedge	Grass	Total weed density	Broad leaves	Sedge	Grassy	Total weed density	Broad leaves	Sedge	Grass	Total weed density
S-metholachlor at 1.0 kg ha ⁻¹	6.667 ^b	7.233 ^{def}	8.5 ^{cde}	22.4c	12.667 ^{bcd}	18.667 ^b	7.667 ^{cb}	39 ^{bc}	16 ^{bc}	18.6 ^c	6.5 ^{ab}	41.1 ^c
S-metholachlor at 1.5 kg ha ⁻¹	3.1 ^{ef}	4.8 ^{fg}	6.33 ^{figh}	14.2fgh	11 ^{de}	16.567 ^b	6.33 ^{cd}	34.57 ^{cde}	12 ^{efg}	17.33 ^{cde}	6abc	35.33 ^{def}
S-metholachlor at 2.0 kg ha ⁻¹	2.167 ^f	4 ^g	4.9 ^h	11.1h	11 ^{de}	9 ^g	4.73 ^{def}	24.7 ^f	12.233 ^{def}	15.067 ^{ef}	5.3 ^{bc}	32.6 ^{fg}
Pendimethalin at 1.0 kg ha ⁻¹	5.233 ^{bcd}	7.46 ^{de}	8 ^{cde}	20.7cd	14.33 ^{abc}	18 ^b	7.63 ^{cb}	39.97 ^b	14.667 ^{bcd}	18.633 ^c	6.33 ^{abc}	39.633 ^{cd}
Pendimethalin at 1.25 kg ha ⁻¹	3.9 ^{cdef}	7.167 ^{def}	7.2 ^{cfig}	18.27de	11.833 ^{cd}	17.33 ^{bcd}	6.3 ^{cd}	35.5 ^{bcd}	14.5 ^{bcd}	18.233 ^{cd}	6.167 ^{abc}	38.9 ^{cde}
Pendimethalin at 1.5 kg ha ⁻¹	2.2 ^f	5.1 ^{efg}	5.733 ^{figh}	13gh	11.33 ^{cde}	17.667 ^{bc}	7.3 ^c	36.3 ^{bcd}	14.33 ^{bcd}	16.761 ^{cde}	5.767 ^{bc}	36.867 ^{cde}
S-metholachlor at 1.0kg ha ⁻¹ + pendimethalin at 1.0kg ha ⁻¹	4.167 ^{cdef}	5.4 ^{efg}	5.533 ^{hg}	15.1efg	11.33 ^{cde}	14.667 ^{de}	6.23 ^{cd}	32.2 ^{de}	13.667 ^{cde}	15.6 ^{ef}	6.167 ^{abc}	35.43 ^{def}
S-metholachlor at 1.0kg ha ⁻¹ + pendimethalin at 0.75 kg ha ⁻¹	3.2 ^{def}	6.2 ^{defg}	5.7667 ^{figh}	14.8efg	9.9d ^{def}	15.233 ^{cde}	5.9 ^{cdef}	31.03 ^f	12.967 ^{cde}	15.733 ^{ef}	8.33 ^{bc}	34.03 ^{ef}
S- metholachlor at 0.75kg ha ⁻¹ + pendimethalin at 1.0 kg ha ⁻¹	4.667 ^{bcd}	5.833 ^{defg}	5.7667 ^{figh}	16.6efg	10.33 ^{de}	13.667 ^{ef}	6.57 ^{cd}	30.57 ^e	14.167 ^{bcd}	16.067 ^{de}	8.667 ^{bc}	35.9 ^{def}
S-metholachlor at 0.75kg ha ⁻¹ + pendimethalin at 1.25kg ha ⁻¹	4.067 ^{cdef}	5.733 ^{defg}	6.9667 ^{efg}	16.8ef	11.167 ^{de}	15.233 ^{cde}	6.1 ^{cde}	32.5 ^{de}	14.03 ^{bcd}	15.767 ^{def}	5.667 ^{bc}	35.47 ^{def}
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	22.3c	8.333 ^{efg}	11.6 ^{ef}	4.63 ^{def}	24.57 ^f	10.33 ^{efg}	11.467 ^g	4.33 ^c	26.13 ^h
Pendimethalin at 1.0 kg ha ⁻¹ + one hand weeding and hoeing at 5 WAE	4.633 ^{bcd}	8 ^{cd}	9.3667 ^c	22c	7.069 ^{fg}	11.867 ^f	4.17 ^{ef}	23.1 ^f	9.33 ^{fg}	13.567 ^{fg}	4.667 ^{bc}	27.57 ^{gh}
Two hand weeding at 2 and 5 WAE	10 ^a	10.533 ^{bc}	13.233 ^{ab}	33.8b	6.667 ^g	11.267 ^{ef}	3.93 ^f	21.87 ^f	8.667 ^g	11.33 ^g	4.33 ^c	24 ^h
One hand weeding and hoeing at 2 WAE	9.667 ^a	11.33 ^b	12.733 ^b	33.7b	15 ^{ab}	22 ^a	9.5 ^{ab}	46.5 ^a	17.33 ^{ab}	21.667 ^b	8 ^a	47 ^b
Weed free check	0 ^g	0 ^h	0 ⁱ	0i	0 ^h	0 ^h	0 ^g	0 ^g	0 ^h	0 ^h	0 ^d	0 ⁱ
Weedy check	11 ^a	16.33 ^a	14.667 ^a	42a	17.167 ^a	23.6 ^a	10.33 ^a	51.1 ^a	20.567 ^a	26 ^a	8 ^a	55.17 ^a
LSD (5%)	2.06	2.54	1.61	3.68	3.047	2.679	1.97	9.7	3.438	2.4856	2.0957	5.18
CV	24.76	21.54	12.57	11.14	17.29	10.88	19.32	5.09	16.1	9.44	22.789	9.11

Means in columns of same parameter followed by the same letter(s) are not significantly different

Key;- WDAE1;- Weed density at 25 days after the crop emergence, WDAE2;- Weed density at 55 days after crop emergence, WDAE3;- Weed density at harvesting time

3.6. Effect of Weed Controls on Grain Yield and Yield Component of Chick Pea

3.6.1. Days to 50% Flowering

Application of herbicide with their combination is a

significant ($P \leq 0.01$) effect on herbicide days of 50% flowering of chickpea. The longest das of 50% flowering was recorded from complete weed-free, two-time hand weeding at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one-time hand weeding, and hoeing at 4-5 WAE, S-metholachlor at 1.0 kg ha⁻¹

+ one time hand weeding and hoeing at 4-5 WAE, S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹, Pendimethalin at 1.5 kg ha⁻¹, S-metholachlor at 2.0 kg ha⁻¹ and S-metholachlor at 1.5 kg ha⁻¹ flowering is ranging from 60.8-51.33 days of 50% flowering. This is maybe no competition with a crop. Followed by S-metholachlor at 1.0 kg ha⁻¹, Pendimethalin at 1.0 kg ha⁻¹, Pendimethalin at 1.25 kg ha⁻¹, and One-time hand weeding and hoeing at 2 WAE. The shortest days of 50% flowering were recorded at the weedy check which is 46.6 days of 50% flowering. This may be due to competition Intra and inter-competition effects (Table 5). The result was in line with [33] reported that the longest was recorded from weed-free. While, the minimum days to the bulb, the formation was recorded from a weedy check. [34] reported that the plants' weed free plots took the highest time to reach 50% flowering. The result disagrees with the report of [35] reported that treating plots with chemicals and supplementing with hand weeding at intervals helped to reduce the number of days to flowering and maturity in cowpea.

3.6.2. Days to 90% Physiological Maturity

Weed control practices were a significant ($P < 0.01$) effect on the 90% physiological maturity of the chickpea. The longest physiological maturity was recorded in complete weed-free, two-time hand weeding at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 WAE, S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 WAE, S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹, S-metholachlor at 2.0 kg ha⁻¹ and S-metholachlor at 1.5 kg ha⁻¹ the maturity was ranging

from 90% to 76.33% days for philological maturity whereas the shortest philological maturity was recorded from Weedy check, One hand weeding and hoeing at 2 WAE, Pendimethalin at 1.5 kg ha⁻¹, Pendimethalin at 1.25 kg ha⁻¹, Pendimethalin at 1.0 kg ha⁻¹ and S-metholachlor at 1.0 kg ha⁻¹ the maturity days are ranging from 73% to 68.67% days of 90% for philological maturity (Table 5). The results [33] reported that 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 the weedy check. The author [36] reported that weed control with intervals helped to increase the number of days to maturity in cowpea.

3.6.3. Plant Height

Weed control practices were a significant ($P < 0.01$) effect on the plant height of chickpeas. The highest plant height was recorded from complete weed-free plots, two-time hand weeding at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one-time hand weeding and hoeing at 4-5 WAE, S-metholachlor at 1.0 kg ha⁻¹ + one time hand weeding and hoeing at 4-5 WAE, S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹ and S-metholachlor at 2.0 kg ha⁻¹ treated plots which is ranging from 47.67cm to 37.8cm followed by Weedy check, Pendimethalin at 1.5 kg ha⁻¹ Pendimethalin at 1.25 kg ha⁻¹ and Pendimethalin at 1.25 kg ha⁻¹ Whereas the shortest plant height was recorded from S-metholachlor at 1.0 kg ha⁻¹ and Pendimethalin at 1.0 kg ha⁻¹ which is 31.67cm and 30.67cm respectively (Table 5). The results were in line with [37] reported that the highest plant height was recorded from butachlor+ one time hand weeding, while the lowest plant height was recorded in the weedy check. The authors [38-39] also reported the same results.

Table 5. Effect of pre and post emergence herbicide on yield and yield component of chickpea.

Treatment	Days to 50% Flowering	Days to 90% physiological Maturity	Plant Height	Number of Pod-1	Number of Grain pod-1	Thousand grain Weight (g)	ABG (kg ha ⁻¹)	GY (kg ha ⁻¹)	HI
S-metholachlor at 1.0 kg ha ⁻¹	47cd	73cd	31.67efg	37.3de	13def	20.667ef	3612ef	1091efd	30.3def
S-metholachlor at 1.5 kg ha ⁻¹	53.63a-d	76.33a-d	35defg	40bcde	14.9bcde	22def	4836.3cd	1635.3cd	34.4cd
S-metholachlor at 2.0 kg ha ⁻¹	54.66a-d	83.67a-c	37.8a-f	41.1bcde	15.9bcd	23.667bcde	5879a	2265.7ab	38.6abc
Pendimethalin at 1.0 kg ha ⁻¹	48cd	71.67cd	30.67fg	36.8de	12.2ef	20.167ef	3635.3ef	1230.7ed	33.8cd
Pendimethalin at 1.25 kg ha ⁻¹	50b-d	73.67cd	36.33cdefg	38.4cde	14.2def	24def	4298de	1491cd	34.9bcd
Pendimethalin at 1.5 kg ha ⁻¹	53a-d	74.67b-d	35defg	38.6cde	14.2cdef	22.767cde	5003.3cd	1666.3c	33.8cd
S-metholachlor at 1.0kg ha ⁻¹ + pendimethalin 1.0kg ha ⁻¹	54.33a-d	81a-d	42abc	42.5bcd	16.7bc	23.833bcde	5712ab	2038.7b	35.7bcd
S-metholachlor 1.0kg 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	52.33a-d	83a-d	40.667a-e	41.5bcde	15.2bcde	25.33abcd	4266.7de	1539cd	36bcd
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	52a-d	80.33a-d	40.33a-f	38.3de	14.2cdef	22def	4322de	1593c	36.6bc
S-metholachlor at 1.0 kg ha ⁻¹ + one hand weeding and hoeing at 4-5 WAE	51.33a-d	81a-d	39.3a-f	40.7bcde	15.2bcde	24.33bcde	3876.3ef	1481.3cd	38abc
Pendimethalin at 1.0 kg ha ⁻¹ + one hand weeding and hoeing at 4-5 WAE	56.33a-c	89ab	44.33a-d	44.8b	17.3b	26.667abc	5448.3abc	2227ab	40.9ab
Two timehand weeding at 2 and 5 WAE	58.66ab	88.33ab	45.33a-c	44.2bc	16.7bc	24.267bcde	5602.3abc	2098.3b	37.6abc
	59.6a	89.67a	46.2ab	45b	17.8b	27.567ab	5991a	2338ab	39abc

Treatment	Days to 50% Flowering	Days to 90% physiological Maturity	Plant Height	Number of Pod-1	Number of Grain pod-1	Thousand grain Weight (g)	ABG (kg ha ⁻¹)	GY (kg ha ⁻¹)	HI
One time hand weeding and hoeing at 2 WAE	48.83cd	71cd	30d	36.3ef	12fg	20ef	3208.3fg	887ef	27.6ef
Weed free check	60.8a	90a	47.67a	52.6a	21.6a	29.33a	6025a	2582.3a	42.9a
Weedy check	46.6d	68.67d	29.67d	31f	11f	18f	2698f	690.3f	25.4f
LSD (5%)	9.61	14.43	9.8	5.7	3	4.42	812.6	355.3	6
CV	10.95	11	15.2	8.5	12	11.4	10.5	12.7	10.3

means in the same column the same letter not significant

Key; ABG, above ground biomass, HI, Harvesting index, and GY, Grain yield

3.6.4. Number of Pods Plant⁻¹

Weed control practices were a significant ($P < 0.01$) effect on the number of pods per plant chickpea. The higher pod numbers were recorded from complete weed-free which is 52.6 pods per plant followed by combined weed control methods of Two-time hand weeding at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one time hand weeding, and hoeing at 4-5 WAE, S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 WAE, S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹, S-metholachlor at 2.0 kg ha⁻¹ and S-metholachlor at 2.0 kg ha⁻¹ treated plots. The lower number of pods were counted by S-metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹, S-metholachlor at 1.0 kg ha⁻¹, and Weedy check which is 38.3, 37.3 and 31 respectively (Table 5). The result is in line with [40] reported that the integrated use of herbicides with hand weeding has a large number of pods of fababean (*Vicia faba* L.). The author [36] reported that application of 1.0 kg ha⁻¹ of pendimethalin and 1.0 kg ha⁻¹ of s-metolachlor, each accompanied by one hand weeding increased the number of pods per plant on cowpea, The author [41] 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 beans [42].

3.6.5. Number of Seed Per Pod

The analysis of variance showed that the number of seeds per pod was significant ($P \leq 0.01$) (Table 5). The highest number of seeds per pod (21.6) was recorded from weed-free check, followed by two-time hand weeding and hoeing at 2 and 5 WAE, Pendimethalin at 1.0 kg ha⁻¹ + one time- hand weeding and hoeing at 4-5 WAE, S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 5 WAE, S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 2.0 kg ha⁻¹ and S-metholachlor at 1.5 kg ha⁻¹. 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 the large number of seeds per pod. Whereas the lower seed per pod was recorded from Weedy check and S-metholachlor at 1.0 kg ha⁻¹ which is 11 and 13 seeds per pod respectively (Table 5). This may be due to the interference of weed. The results

agree with [43] reported that integration of herbicides and hand weeding and hoeing 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 and also produced the highest number seed per pods. The author [41] reported that the highest number of seeds per pod was recorded from the treatment s-metolachlor 1.0 kg ha⁻¹ supplemented with one hand hoeing and weeding 4 WAE on common bean. The author [44] reported that the highest number of seeds 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 were 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 resulting in reduced seed filling of the pods. The author [43] reported that unchecked growth of weeds resulted in the lowest number of seeds per pod as compared to weed-free check soybean.

3.6.6. Thousand-Grain Seed Weight

The data shows that thousand-grain weight significantly ($P \leq 0.01$) effect chickpeas. The highest thousand-grain weight was recorded from complete weed-free, and integrated weed control methods such as two-time hand weeding at 2 and 5 WAE, S-metholachlor at 1.0 kg ha⁻¹+ one-time hand weeding, and hoeing at 4-5 WAE, and S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹ which is 29.33g, 27.57g, 26.67g, and 25.33g respectively (Table 5). Followed by combined weed control methods of Pendimethalin at 1.0 kg ha⁻¹ + one-time hand weeding and hoeing at 4-5 WAE, S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹ and S-metholachlor at 2.0 kg ha⁻¹. Whereas the lower thousand-grain weight was recorded from Weedy check and S-metholachlor at 1.0 kg ha⁻¹ which is 18g and 20.67g respectively (Table 5). The highest thousand-grain weight recorded from weed-free check might be due to the availability of more space for the better light interception, more nutrients available and moisture for grain development as compared to other treatments. In conformity with this result, The author [45] reported that the more vigorous leaves in a weed-free environment had improved the supply of assimilates to be stored in the grain. Moreover, with

incomplete weed-free treatment, the spikes were healthy and completely filled as against shriveled and few grains 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 [46] who reported that the application of pre-emergence herbicide at 2.5 L ha⁻¹ followed by hand weeding once at 20 DAS produced the highest 100-grain weight. While the lowest was recorded from weedy check plots. This might be weeding at the proper time employing herbicide and supplementing with hand weeding and hoeing could provide a favorable environment for the crop, which ultimately leads to better grain filling, which leads to maximizing grain weight. This is quite possible that weed-free crop stand produced robust grains and ultimately resulted in more 100-grain weight on the chick.

3.6.7. Aboveground Biomass

The analysis of variance showed that weed control methods are highly significant ($P < 0.01$) effects on the aboveground dry biomass of chickpea (Table 6). The highest aboveground dry biomass was recorded from competing for weed-free, Two-time hand weeding at 2 and 5 WAE Pendimethalin at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 WAE and S-metholachlor at 1.0 kg ha⁻¹ + one time hand weeding and hoeing at 4-5 WAE which is 6025.00 kg ha⁻¹, 5991 kg ha⁻¹, 5602.3kg ha⁻¹ and 5448.3 kg ha⁻¹ respectively (Table 6) followed by S-metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, Pendimethalin at 1.5 kg ha⁻¹, Pendimethalin at 1.25 kg ha⁻¹ and S-metholachlor at 1.5 kg ha⁻¹. The lower aboveground biomass was recorded from Weedy check and S-metholachlor at 1.0 kg ha⁻¹ which is 2698 kg ha⁻¹ and 3612 kg ha⁻¹ respectively (Table 5). This is maybe due to weed interference. These results are in line with [36] reported 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 to the present results, [47] 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 was recorded from the interaction of unweeded plots.

3.6.8. Grain Yield (Kg ha⁻¹)

The data showed that grain yield was significantly ($P < 0.01$) affected by weed control methods (Table 5). The highest grain yield (2582.3 kg ha⁻¹) was recorded from complete weed-free plots, Two-time hand weeding at 2 and 5 WAE (2338 kg ha⁻¹), and S-metholachlor at 2.0 kg ha⁻¹.

(2265.7 kg ha⁻¹) followed by integrated weed control methods of Pendimethalin at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 WAE and S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹. Medium yield was recorded from S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹, S-metholachlor at 0.75kg ha⁻¹+ pendimethalin at 1.0 kg ha⁻¹,

S-metholachlor 1.0kg ha⁻¹+ pendimethalin at 0.75 kg ha⁻¹, Pendimethalin at 1.5 kg ha⁻¹, Pendimethalin at 1.25 kg ha⁻¹, S-metholachlor at 1.5 kg ha⁻¹ of weed control methods (Table 5). The lower grain yield was recorded from Weedy check (690.3 kg ha⁻¹), One time hand weeding and hoeing at 2 WAE (887 kg ha⁻¹), and S-metholachlor at 1.0 kg ha⁻¹ (1091kg ha⁻¹). The findings in line with [48] reported that application of S-metolachlor superimposed with one hand weeding resulted in the highest grain yield on haricot bean. Similarly, [49] reported that the integration of herbicides and hand weeding provided high weed control efficiency and produced the highest grain yield. The author [50] reported that season-long crop weeds competition reduced the grain yield of peas.

3.6.9. Harvest Index

Statistical analysis of the data revealed that weed control methods significantly ($P < 0.01$) affect the harvest index of chickpea. The highest harvest index was recorded from complete weed-free (42.9%), Two-time hand weeding at 2 and 5 WAE (39%), Pendimethalin at 1.0 kg ha⁻¹ + one hand weeding, and hoeing at 4-5 WAE (37.6%), S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 WAE (40.9%), S-metholachlor at 0.75kg ha⁻¹+pendimethalin at 1.25kg ha⁻¹ (38%) and S-metholachlor at 2.0 kg ha⁻¹ (38.6%) followed by S-metholachlor at 0.75kg ha⁻¹+ Pendimethalin at 1.0 kg ha⁻¹, S-metholachlor 1.0kg ha⁻¹+ Pendimethalin at 0.75 kg ha⁻¹, S-metholachlor at 1.0kg ha⁻¹+ pendimethalin 1.0kg ha⁻¹ and Pendimethalin at 1.25 kg ha⁻¹ weed control methods. The lower harvesting index was recorded from Weedy check (25.4%), One-time hand weeding and hoeing at 2 WAE (27.6%), and S-metholachlor at 1.0 kg ha⁻¹ (30.3%) (Table 5). The highest harvest indexes from these treatments might be due to the 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 contributed towards more total dry matter production, but the pace of this photosynthetic rate might have registered a much higher decline due to the disintegration of nodules with the initiation of pod development resulting in lower harvest index and also the lowest harvest index of cowpea obtained in weedy check [36]; Similarly, the author [51] reported that partitioning efficiency (harvest index) was determined by the amount of biomass energy allocated to vegetative vs. reproductive structures.

3.7. Partial Budget Analysis

The partial budget analysis result was performed using the partial budget technique [17] and the partial budget analysis of the 16 treatments was shown in (Table 6). The highest net benefit was obtained from Two-time hand weeding at 2 and 5 WAE (97,295 Birr ha⁻¹) and application of s-metolachlor at 1.0 kg ha⁻¹ supplemented with one hand weeding at 5WAE (92,300 Birr ha⁻¹) and S-metolachlor 1.0 kg ha⁻¹ +HW 5

WAE (92,300 Birr ha⁻¹) (Table 6). Followed by Pendimethalin 1.0 kg ha⁻¹ +HW 5 WAE (86,745 Birr ha⁻¹) and S-metolachlor 2.0 kg ha⁻¹ (85,993.5 Birr ha⁻¹). Medium net benefit was recorded from S-metolachlor 1.0 kg ha⁻¹, S-metolachlor 1.5 kg ha⁻¹, Pendimethalin 1.0 kg ha⁻¹, Pendimethalin 1.25 kg ha⁻¹, and Pendimethalin 1.5 kg ha⁻¹ which is 69158.5 Birr ha⁻¹ to 51630 Birr ha⁻¹ income range.

While the lowest net returns (33,618 ETB ha⁻¹) were recorded from unweeded plot (weedy check) plots and One-time hand weeding at 2 WAE (38,688.5 ETB ha⁻¹) (Table 6). This result is in line with, [52] 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.

Table 6. Effect of weed control methods on partial budget analysis in Chickpea crop.

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

Key;- 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

4. Conclusion and Recommendation

The experiment was conducted in Gurage zone at Ezha Woreda to evaluate the effect of herbicides and their combinations on yield components and yield of chickpea (*Cicer arietinum* L.). From the result different 17 weed species was identified with different eight families and classified as broad-leaved, sedge and grass weeds in weed community. The highest Weed density at 25 days after the crop emergence, weed density at 55 days after crop emergence, weed density at harvesting time, was recorded from Weedy check and One-time hand weeding and hoeing at 2 weeks after crop emergence (WAE) followed by integrated weed control methods. The lowest weed density at 25, and 55 days after crop emergence, at harvesting time was recorded from Two-time hand weeding at 2 and 5 weeks after crop emergence (WAE) and application of S-metholachlor and Pendimethalin at different rates.

The higher yield defining traits and yield of chickpea was recorded from two-time hand weeding at 2 and 5 weeks after crop emergence, complete weed-free, S-metholachlor at 1.0 kg ha⁻¹ + one-time hand weeding, and hoeing at 4-5 weeks after crop emergence (WAE) followed by integrated weed control methods. Medium yield and yield components were recorded from the application of S-metholachlor and Pendimethalin at different rates. Whereas the lower yield defining traits and yield of chickpeas was recorded from weed check and one-time hand weeding integrated with hoeing two weeks after crop emergence. From the result, chickpea is susceptible to weeds interference until 55 days after crop emergence. Therefore, intensive farming methods

two-time hand weeding at 2 and 5 weeks after crop emergence and S-metholachlor at 1.0 kg ha⁻¹ + one hand weeding and hoeing at 4-5 weeks after crop emergence are recommended to increase the yield of chickpea whereas for extensive farming methods integrated weed control methods was recommended to increase the yield of chickpea.

Data Availability

The data used to support the findings of this study are available and can be requested from the corresponding author.

Conflict of Interests

The authors have not declared any conflict of interest.

Funding Statement

This research was fully funded by the Gurage Zone administration office to acquire my M.Sc. Degree in Wolkite University.

Authors' Contributions

This work was carried out in collaboration with all authors. Author Tadele Bekele is an M. Sc student who designed the study, performed the statistical analysis, wrote the protocol, and write the first draft of the manuscript. Co-authors Dr. Getachew Mekonen and Ashenafi Mitiku are an advisor. For publication, the final manuscript was written by Ashenafi Mitiku. All authors read and approved the final manuscript.

Acknowledgements

The author would like to acknowledge the Gurage Zone administration office for giving me to acquire my M.Sc. in Wolkite University and funding for all activity in my study time and my special thanks goes to Asebe Teka and Mihirte Webarega head of Gurage Zone environmental and forest office for their support and Tenaw Horticultural Business PLC for giving research site.

References

- [1] Gaur P M., Tripathi S., Gowda CL., Ranga RG V., Sharma HC., Pande S., and Sharma M. 2010. Chickpea seed production manual. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics pp 28.
- [2] Food and Agriculture Organization (FAO). 2019. FAOSTAT Statistical Database of the United Nations Food and Agriculture Organization (FAO) statistical division. Rome.
- [3] Muehlbauer FJ., and Sarker A. 2017. Economic importance of chickpea: Production, value, and world trade. In Varshney R., Thudi M., Muehlbauer F. (eds) The chickpea genome (pp. 5–12). Cham: Springer. doi: 10.1007/978-3-319-66117-9.
- [4] FAO (Food and Agricultural Organization). 2016. Fact sheet: livestock Ethiopia. Livestock in Ethiopia and opportunity analyses for Dutch investment NABC.
- [5] CSA. 2012. The Federal Democratic Republic of Ethiopia, Central Statistical Agency, Agricultural Sample Survey 2011/2012 (2004 E. C.) (September- December 2011). Volume I. Report on Area and Production of Major Crops (Private Peasant Holdings, MEHER season). Statistical Bulletin, May 2012, Addis Ababa, Ethiopia.
- [6] Mulugeta A., Tesfaye K. and Dagne K. 2014. The Importance of Legumes in the Ethiopian Farming System and Overall Economy: An Overview. American Journal of Experimental Agriculture. 7 (6): 347-358.
- [7] FAOSTAT. 2012. Food and Agricultural Organization Statistical Database, Crop Production Index. Rome, Italy: FAO.
- [8] Asfaw S., Shiferaw B., Simtowe F., Muricho G., Abate T., and Ferede, S. 2010. Socioeconomic Assessment of Legume Production, Farmer Technology Choice, Market Linkages, Institutions and Poverty in Rural Ethiopia. *Research Report no. 3. Patancheru 502 324* (pp. 84). Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics.
- [9] Sunil CM., Shekara BG., Ashoka P., Murthy KK., and Madhukumar V. 2011. Effect of integrated weed management practices on nutrient uptake in aerobic rice. *Research on Crops*, 12 (3), 629–632.
- [10] Santosh G., Uerra A. and Lewis GP. 2018. An ewspcies of *Cicer* (Leguminosae-Papilionoideae) from the Canary Islands, *Kew Bulletin* 40 (in press).
- [11] Van Reeuwijk LP. 1992. Procedures for soil analysis. 3rd edition. International Soil Reference and Information Center Wageningen (ISRIC). The Netherlands, Wageningen.
- [12] Dewis J. and Freitas F. 1970 Physical and chemical methods of soil and water analysis. *FAO Soils Bulletin* 10. FAO, Rome.
- [13] Olsen S R., Cole V., Watanabe FS. and Dean LA. 1954. Estimations of available phosphorus in soils by extractions with sodium bicarbonate. U.S. Dept. Of Agric. Cric. 939, USDA, Washington, DC.
- [14] Das TK. and Yaduraju NT. 1999. Effect of weed competition on growth, nutrient uptake, and yield of wheat as affected by irrigation and fertilizers. *Journal of Agricultural Science*, 133 (1): 45-51.
- [15] Cottenie A. 1980. Soil and plant testing as a basis of fertilizer recommendations. *FAO soil bulletin* 38/2. Food and Agriculture Organization of the United Nations, Rome.
- [16] Gomez KA. and Gomez AA. 1984. Statistical Procedures for Agricultural Research. J. Wiley and Sons, Singapore.
- [17] CIMMYT (International Maize and Wheat Improvement Center). 1988. *from agronomic data to farmer recommendations: An economics training manual* (Completely revised ed.). Mexico.
- [18] Tekalign T. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working document, No International Livestock Research Center for Africa, Addis Ababa.
- [19] Fisseha I. 1992. Macro and micronutrient distribution in Ethiopian Vertisols landscapes. Ph.D. Dissertation submitted to Institute für Bodenkunde und Standortslehre, University of Hohenheim, Germany. P. 201. (2) (PDF) *Description, characterization and classification of the major soils in Jinka Agricultural Research Center, South Western Ethiopia*.
- [20] Lewis DC. Peverill KL., Sparrow LA. and Reuter DJ. (eds.). 1999. Sulphur. In: Soil Analysis: An Interpretation Manual, CSIRO Publishing, Collingwood, Australia. 221-228.
- [21] Tamado T. and Milberg P. 2000. Weed flora in arable fields of eastern Ethiopia with emphasis on the occurrence of *Parthenium hysterophorus*. *Weed Research* 40: 507 - 521.
- [22] Amir K., Muhammad Z K., Khalid N., Ishaq AM. and Wiqar A. 2013. Effect of Various Herbicides and Manual Control on Yield, Yield Components, and Weeds of Maize. *Pak. J. Weed Sci. Res.*, 19 (2): 209-216.
- [23] Patel BD., Patel VJ., Patel, JB. and Patel R B. 2006. Effect of fertilizers and weed management practices on weed control in chickpea (*Cicer arietinum* L.) under middle Gujarat conditions. *Indian Journal of crop Sciences*, 1: 180-183.
- [24] Mishra JS. and Singh VP. 2008. Integrated weed management in dry-seeded irrigated rice (*Oryza sativa*. L). *Indian Journal of Agronomy*.
- [25] Holst N., Rasmussen I. and Bastiaans L. 2007. Field weed population dynamics: a review of model approaches and populations. *Weed Research*, 47: 1-14.
- [26] Nassar A. 2008. Response of two barley varieties to mineral and biological nitrogenous fertilizer and weed control treatments. *Journal of Agricultural Sciences*, 33 (1): 29-51.
- [27] Nano A. and Janmejai S. 2018. Assessment of Integrated Weed Management Practices on Weed Dynamics, Yield Components and Yield of Faba bean (*Vicia faba* L.) in Eastern Ethiopia. *Turkish Journal of Agriculture - Food Science and Technology*, 6 (5): 570-580.

- [28] Getachew M., Sharma JJ., Lisanework N. and Tamado T. 2015. Effect of integrated weed management practices on weeds infestation, yield components and yield of Cowpea (*Vigna unguiculata* (L.) Walp.) in Eastern Wollo, Northern Ethiopia. *American Journal of Experimental Agriculture*, 7 (5): 326-346.
- [29] Egan JF, Barlow KM, Mortensen DA. 2014. A meta-analysis of the effects of 2,4-D and dicamba drift on soybean and cotton. *Weed Sci* 62: 193–206.
- [30] Khan IG., Hassan MI., Khan MI. and Khan I A. 2004. Efficacy of some new herbicidal molecules on grassy and broadleaf weeds in wheat-II. *Pakistan Journal of Weed Science Research*, 10: 33-38.
- [31] Raize M., Azim MM., Mahmood TZ. and Jamil M. 2006. Effect of Various Weed Control Methods on Yield and Yield Components of Wheat under Different Cropping Patterns. *International Journal of Agriculture and Biology*, 8: 636–640.
- [32] Bibi KBM., Hassan G. and Noor MK. 2008. Effect of herbicides and wheat (*Triticum aestivum* L.) population on control of weeds in wheat (*Triticum aestivum* L.). *Pakistan Journal of Weed Science Research*, 14: 111-119.
- [33] Prasad M., Meena M. and Kishor S. 2017. Effect of integrated weed management practices on vegetative growth characters in Onion (*Allium cepa* L.), *International Journal Pure Applied Biological science*, 5 (4): 607-611.
- [34] Sunday O. and Udensi E. 2013. Evaluation of pre-emergence herbicides for weed control in Cowpea (*Vigna unguiculata* (L.) Walp.) in a Forest -Savanna Transition Zone. *American Journal of Experimental Agriculture*; 3 (2): 767-779.
- [35] Chattha MU., Ali A. and Bila M. 2007. Influence of planting techniques on growth and yield of spring-planted sugarcane (*Saccharum officinarum* L.). *Pak. J. Agri. Sci.*, 44 (3): 452-455.
- [36] Getachew M., Sharma JJ., Lisanework N. and Tamado T.. 2016. Growth and Yield Response of Cowpea (*Vigna Unguiculata* L. Walp.) to Integrated Use of Planting Pattern and Herbicide Mixtures in Wollo, Northern Ethiopia. *Advances in Crop Science and Technology*; 7 (5): 326-346.
- [37] Taslima Z., Abul, H., Rahman, M., Richard, W. and Bell, M. 2018. Efficacy of herbicides in non-puddled transplanted rice under conservation agriculture systems and their effect on the establishment of the succeeding Crops. *Acta Scientifica Malaysia*, 2 (1): 17-25.
- [38] Singh A., Vashist KK., and Kang JS. 2005. Chemical weed control in irrigated desi gram (*Cicer arietinum* L.). *Indian Journal of Weed Science*. 35 (1 and 2): 136-138.
- [39] Mahajan G. and Chauhan B. 2015. Weed control in dry direct-seeded rice using tank mixtures of herbicides in South Asia. *Crop Protection*, 72: 90-96.
- [40] Abdullah G., Hassan, IA., Khan, S A. and khan, H. 2008. Impact of planting methods and herbicides on weed biomass and some agronomic traits of maize. *Pak. J. Weed Sci. Res.* 14, 121-130.
- [41] Tamado T., Dawit D. and Sharma JJ. 2015. Effect of Weed Management Methods and Nitrogen Fertilizer Rates on Grain Yield and Nitrogen Use Efficiency of Bread Wheat (*Triticum aestivum* L.) in Southern Ethiopia, *East African Journal of Sciences* 9 (1): 15-30.
- [42] Ghadirri H. and Bayat ML. 2004. Effect of row and plant spacings on weed competition with Pinto Beans (*Phaseolus vulgaris* L.). *Journal of Agricultural Science and Technology* 6: 1–9.
- [43] Borrás L., Slafer GA. and Otegui ME. 2004. Seed dry weight response to source-sink manipulations in wheat, maize, and soybean: a quantitative reappraisal. *Field Crop Res.*, 86: 131–146.
- [44] Amare M., Woldewahid G. and Sharma JJ. 2009. Sesame crops versus weeds: when is the critical period of weed control? *Proc. African Crop Science Conference*. 9, pp. 591–593.
- [45] Khalid U., Shad KK. and Muhammad AK. 2010. Impact of tillage and herbicides on weed density and some physiological traits of wheat under rice-wheat cropping system. *Sarhad Journal Agriculture*, 26 (4): 475.
- [46] Sarkar AR., Swapan K P. and Uttam P. 2017. Effect of water and weed management in Boro rice (cv. BRRI dhan28) in Bangladesh. *Archives of Agriculture and Environmental Science* 2 (4): 325-329.
- [47] Alfonso LF., Giacomani V G. Ponce C., María del C., Ghozeisi H. 2017. Adsorption of organophosphorus pesticides in tropical soils: The case of karst landscape of northwestern Yucatan. *Chemosphere*. 166; 292-299.
- [48] Waktole M., Sharma JJ. and Nigussie D.. 2013. Integrated weed management and its effect on weeds and yield of haricot bean at Haramaya, Ethiopia. *Ethiopian Journal of Weed Management*, 6: 97-111.
- [49] Singh G., and Sekhon HS. 2013. Integrated weed management in Pigeon pea [*Cajanus cajan* (L.) Millsp.]. *World Journal of Agricultural Sciences* 9 (1): 86 - 91.
- [50] Prakash V., Pandey AK., Singh RB. and Mani VP. 2000. Integrated weed management in garden pea under mid-hills of north-west Himalayas. *Ind. J. Weed Sci.* 32 (1-2): 7-11. 46..
- [51] Zhu Y., Roesijadi G., Jones S. Snowden B. and Lesley J. 2010. *Macroalgae as a Biomass Feedstock: A Preliminary Analysis*. United States: N. p., Web. doi: 10.2172/1006310.
- [52] Dawit D., Sharma JJ. and Tamado Tana. 2011. Evaluation of Herbicides and Their Combinations for Weed Management in Bread Wheat (*Triticum Aestivum* L.) In Southern Ethiopia. *International Journal of Novel Research in Life Science*; 1 (1): 31-47.