**Determination of Efficacy of Newly introduced Herbicides on Various Weed Floras in Coffee Farm under Rain Fed Production System**

**Abstract**

*Weed is the major limiting factor of coffee production in Ethiopia. Weeds in coffee cause a 65% yield reduction in the country. Nowadays, the expense of weed management has been a principal issue in Ethiopia's economic analysis of coffee production. Herbicide is the best weed management option in coffee production. Thus, the newly introduced herbicide verification trial was conducted on-site at the Hawassa Agricultural Research Center and Awada Coffee Research sub-center site in 2024, during the cropping season, to evaluate the efficacy of the newly introduced herbicide. The experiment consists of five (5) treatments of Wanda 48%SL (Glyphosate 48% g/l SL) test herbicide and XTrim 48%Sl, True killer, and Gly care 480%g/l SL, as a standard check and weedy control as a negative control. The herbicides effectively reduced weed density and improved weed control efficiency compared to weedy control. The tested herbicide Wanda 48%SL (Glyphosate 48 g/l SL) was fully controlled in the experimental plot, similar to a standard herbicide with one-time application for one season. This result suggested that one-time application at vigorous weed growth is mandatory to achieve full control throughout the season equivalent to standard control herbicides. Therefore, Wanda 48%SL (Glyphosate 48g/l SL) at 3 L/ha within 250L/ha water with one-time application per season is recommended to control weeds in coffee as an alternative management option. According to this study, all the evaluated herbicides can control coffee weeds, without different control duration. All standard checks True killer, Glycare 480% g/l SL, XTrim 48% SL, and the tested herbicide Wanda 48%SL (Glyphosate 48g/l SL) controlled weed species within 7 to 21 days.*

**Keywords:** Coffea arabica,Efficacy, Herbicides, Sidama, Wanda 48%SL, Weed density, Verification

1. **INTRODUCTION**

Coffee (*Coffea arabica* L.) is the backbone of a country's economy and the second most traded commodity in terms of volume and value, behind oil (Girma, 2011). Therefore, it is essential to maintain a balance in trade between developed and developing countries. It offers over 25% of Ethiopia's population's income, accounting for 70% of foreign exchange profits and 10% of government revenue (Tsegaye *et al*., 2000). The most consumed type of coffee is arabica, making up more than 70% of production volume and 90% of worldwide trade value (Tadesse, 2015).

The country's economy and culture are strongly influenced by coffee. Ethiopia's main export crop is arabica coffee, which makes a significant economic contribution to the country. It is the most important product for the Ethiopian industry and a major source of foreign exchange that supports the livelihoods of millions of laborers and farmers. Numerous obstacles, including weed control, recurring pests and diseases, depleting soil capacity, and unfavorable weather patterns, have an impact on coffee output. Coffee production was affected by many biotic and abiotic factors in Ethiopia. Coffee diseases cause considerable losses when not treated. According to Cerda *et al*. (2017), 57% yield loss was observed by the infection of disease-causing organisms on coffee crops. Jima *et al.* (2017) also reported that the most economically important pathogenic coffee diseases are coffee berry disease (CBD), coffee wilt disease (CWD), and coffee leaf rust (CLR), and physiological disorders like coffee branch dieback are caused by pseudomonas syringe and non-pathogenic agents. Similarly, CBD and branch dieback were causing high-yield loss of coffee production. In the same way, insect pests such as Anthestia bug and coffee blotch miners are the major ones causing considerable damage. The assessment carried out in Eastern Ethiopia indicated that diseases and insect pests are causing considerable crop losses. CBD is a major disease observed while CWD was considered a minor on a few farmers’ coffee farms. Similarly, a major insect pest that affects coffee production in Eastern Ethiopia is coffee stem borer and coffee berry borer. On the other hand, insect pests such as coffee trips, green scales, and coffee cushion scales were reported as important coffee production constraints in the country (Fekede and Gosa, 2015).

 According to Esheteu *et al.* (2007) report indicated, ineffective weed control is the primary cause of the low average coffee output, causing an average annual yield loss of 60-80%. Weeds are one of the primary factors limiting the nation's coffee production. In coffee, it has been proven to diminish output by 65% and even cause crop failure, depending on the type of weed, the stage at which coffee trees are developing, and the surrounding growth circumstances (Tadesse E, 1998). Despite this, most coffee growers rely mostly on hand cutting and digging, which promotes the growth and dispersal of the harmful competitive perennial weeds (Tadesse E, 1994). The primary obstacle to Ethiopian crop productivity, particularly during the wet season, is weed infestation. The climate encourages rapid and abundant growth of weeds and consequently, all crops are heavily infested with weeds. Farmers in the country are aware of a weed problem in their fields but often they cannot cope-up with heavy weed infestation during the peak period of agricultural activities because of labor shortage, hence, most of their fields are weeded late or left un-weeded. The expense of weed management has been a principal issue in the economic analysis of coffee production, particularly in large-scale farms in Ethiopia. This is because the weed species are found to be dominant and prevalent in the areas where they favorably and quickly re-appear within the season. Previously, several systemic herbicides have been evaluated by the Jimma Agricultural Research Center and recommended by Tigist and Tadesse (2022), and a newly introduced systemic herbicide was evaluated that beat different weed types in coffee farms of Southwest Ethiopia, in the Jimma area (Tigist B *et al.,* 2024) and Southern Ethiopia, in Sidama (Malkamu F, 2024). However, since coffee production has expanded yet now there is a scarcity of systemic herbicides to reduce losses caused due to weed infestation. Often farmers practice Weeding at one or unwedded left which increases infestation of both broad-leaf and grass weeds resulting in low productivity. Selective herbicides are effective in controlling target weeds but inefficiency may arise in case the weeds develop resistance to certain selective herbicides and due to uncontrolled factors, that may reduce the efficiency of the chemicals. According to different scholars and previous research reports, using herbicide is an essential part of weed management practice in coffee production in the southern and southwest including Sidama region Ethiopia. It also can offer the advantage of taking less time, demanding less labor, and avoiding the potential of diseases spread caused by manual slashing and digging weed management practices.  Therefore, effective systemic herbicides for controlling deep-seated rhizomes, bulbs and tubers, and above-ground running stolen off the perennial sedge and grass weeds are vital. Under such circumstances evaluation of different herbicides with different groups and modes of action is essential.

 Hence, the use of non-selective broad-spectrum chemicals becomes important to kill all weeds emerging before they may cause harm to crops. Glyphosate for many years has been used as the most important non-selective herbicide to control all types of weeds before planting.

Having above mentioned points the verification test was conducted following Pesticide Testing guidelines developed by the Ethiopian Institute of Agricultural Research (EIAR) to evaluate the efficacy of newly introduced herbicides for verification was done is Wanda 48%SL (Glyphosate 48g/l SL*)*  herbicide compared with already registered herbicide Gly care 48% g/l SL., XTrim, and true killer as standard control for control perennial grasses, perennial broad leaves and annual grasses and broad leaves weeds in Coffee at Sidama Regional state, Hawassa agricultural research center on station and Awada agricultural research sub-center in Ethiopia. Wanda 48%SL (Glyphosate 48g/l SL)is a non-selective herbicide used to control all broads, grass, and sedge weeds of coffee, currently verified at Hawassa Agricultural Research Center. The objective of the study was to verify the efficacy of the new formulation Wanda 48 % SL (Glyphosate 48 g/l SL) on the control of all weeds in Coffee perennial commercial crops.

**2. MATERIALS AND METHODS**

**2.1*.* Descriptions of the Study Area**

The verification test was conducted at Hawassa Agricultural Research Center (HARC). HARC is found in Sidama regional state in Hawassa city, Ethiopia, 288 km to southern Addis Ababa. It is located at 07° 03’52'’N latitude and 038° 28’ 52 'E longitude with an elevation of 1700 meters above sea level (masl) and the area receives a total of 1000 to1200 mm rainfall in bimodal raining pattern with short rains (belg rains) coming from April to May and long rains (meher rains) coming from July to October. The mean annual minimum and maximum temperature of areas were 16.5°C and 29.2°C, respectively. Likewise, the research was carried out at the Awada Agricultural Research Sub-Center, which was founded in 1997 on a 31-ha area of land near Yirgalem town, 319 km from Addis Ababa, and 45 km south of Hawassa. It is located at 6° 3' N latitude, 38° 3' E longitude, and 1740 masl altitude. The average annual minimum temperature is 11°C, the average maximum temperature is 28°C and the average annual rainfall is 1335 mm. According to Mesfin and Bayetta (2008), the two main soil types in the center are chromatic-cambisols and eutrophic tools, both of which are excellent for producing coffee.

 

 **Figure 1.** Maps of study areas

**2.2. Materials and Procedure**

The herbicide test was conducted at Hawassa Agricultural Research Center. The trial was conducted at two locations via the on-station of Hawassa Agricultural Research Center and Awada coffee research sub-center. The study was laid out on already established coffee experimental plots with a naturally infested field where the noxious perennial grasses, perennial broad-leaf weeds perennial sedges, and annual broad-leaf weeds were abundantly growing.

 Five (5) treatments were used at the experimental site including test herbicide WANDA48% SL (Glyphosate 48g/l SL) and three standard checks (Glycare 48%g/l SL), XTrim, True killer, and weedy check were evaluated. The plots were 10m x 10m in size, both on the Hawassa agricultural research center and Awada agricultural research sub-center stations. The testing trail was laid out in non-replicated plots, where locations were considered as replications. WANDA48% SL (Glyphosate 48g/l SL) was applied with a rate of 3 liters/ha manually using a knapsack sprayer delivering 250 liters of water/ha following the harvesting time of cherry. The herbicides were sprayed one time within the season at the actively growing stage of the weeds. Weeds were counted by randomly throwing the quadrant as pre-treatment weed count. After the 7th, 14th, and 21st days of herbicide application, the weed counted as post-treatment by throwing quadrant (0.25m2) randomly to the plots. Finally, pre- and post-spray weed counts were subjected to efficacy calculation using the formula of Fleming and Retnakaran (1985) as follows:

$Efficacy \%= \begin{matrix}1-(Ta\*Cb)\\\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\(Tb\*Ca)\end{matrix} \*100$

 Where, Ta=post-treatment population in treatment, Cb= Pre-treatment population in check, Tb= Pre-treatment population in treatment, Ca= post-treatment population in check, similarly, the herbicide weed control efficiency (WCE) can be calculated by using the following formula as suggested by (Mani, *et al*., 1973). Percentage of Weed inhibition (PWI) was calculated using the following formula.

$$Percentage of weed inhiition (PWI)=\left(NWC-\begin{matrix}NWT\\\\_\\_\\_\\_\\_\\_\\_\\NWC\end{matrix} \right)\*100$$

Where, NWC &NWT are many weeds (0.25m2) in the weedy check and any particular treatment, respectively. Individual and general weed control evaluations (1-9 scale score), 1= no control and 9= (100% control) were determined through visual observation at the 7th and 14th days after treatment application by considering growth reduction, foliar chlorosis, wilting and stunting during the time of assessment. Weed Control Efficiency (WCE) was calculated based on the following formula (Surinder, 2016).

$$\begin{matrix} Weed count in weedy plot-weed count in treated plot\\WCE= \\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_\\_ \\Weed count in weedy plot\end{matrix}\*100 $$

The plot (weedy check) was used for comparison and all other management practices were applied as per their agronomic recommendations uniformly.

**Table 1**. Treatment description used at an experimental unit of the trial

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Trade Name  | Common Name | Active Ingredient (a.i) | Registration Number  | Shelf lives(year)  | Manufacturer/ Supplier  | Application stage  | Application Rate L ha-1  |
| **Herbicide** | **Water**  |
| WANDA 48% SL | Glyphosate  | Glyphosate 48g/l SL | New  | 2 | UPI SHENZHEN CO., LTD (Address: Room 807, Yaohua Chuangjian Building, 6032 Shennan Avenue, Tian 'A Community, Shatou Street, Futian District, Shenzhen, China | At vigorous growth stage of weeds. | 3 | 250 |
| True Killer  | Glyphosate IPA  | 480g/l Glyphosate isopropyl amine salt | ET/HR/R127/2021 | 2 | Jiangsu GoldenAgrochemical Co., Ltd, Add. Room 903,14TH Kaiming Street Yuahuatai District Nanjing China | 3 | 250 |
| XTrim 48%SL | Glyphosate | Glyphosate 480g/l | ET/HR/SM/R224/2022 | 3 | Anhui ZuponT Import and Export Co., LTD,Address:712 7th floor 3blook, 120 Wenshui Sushan Economic Development Zone Hefei, china  | 3 | 250 |
| Glycare 48% SL | Glyphosate IPA  | 480 g/l Glyphosate isopropyl amine salt | ET/HR/SS/R678/2022 | 2 | China Jiangsu International Economic and Technical Cooperation Group, Ltd., Address: No.5 West Beijing Road Nanjing, Jiangsu, China | 3 | 250 |
| Weedy check  | - | - | - |  | - |  | - | - |

**3. RESULTS AND DISCUSSIONS**

**3.1. Weed Infestation in Terms of Taxonomy**

The verification test was conducted under coffee orchards pre-established in different weed species belonging to the annual broad leaf, annual grasses, perennial broad leaf, perennial grass, and sedge, categories were identified. About thirty-three (33) weed species belonging to seventy (17) families were recorded from verification test fields across locations. Among the recorded weed species, 6.1% were sedge, 18.2% were grass, and 75.7% were broad-leaf weed species in order. Likewise, regarding their ontogeny, 54.6% perennial weed species (33.3% broad leaf, 15.2% grass, and 6.1% sedge), while 45.4% annual weed species (42.4% broad leaf and 3% grass) were recorded from the experimental field conducted in the 2024 cropping season pre-stabilized coffee farm at Hawassa Agricultural Research Center on-site and Awada Agricultural Research sub-center (Tables 4 and 5). According to the current finding, annual broad-leaf weed species were more prevalently isolated than perennial broadleaf, and compared to the annual and perennial broad-leaf weed species, sedge and annual grass were isolated in smaller numbers.

Of the seventeen weed families that were recognized and frequently observed in experimental fields, members of the *Poaceae*, *Amaranthaceae*, *Asteraceae*, and *Fabaceae* families were numbered three to six times numerically, while the remaining families were counted around two or one. About ten (10) families and twenty-four (24) weed species were identified by Hawassa agricultural researchers on-site, while the Awada agricultural research sub-center revealed about thirteen (13) families and nineteen weed species. The reports carried out in the Sidama Region of Southern Ethiopia (Malkamu F., 2024) and (Tigist B., 2024; Tigist B. and Tamiru S., 2023) the report from Southwest Ethiopia Jimma Zone, and weed species composition and abundance in the main coffee production systems and regions of Ethiopia (Abera D *et al*., 2022) and Survey of Weed flora composition in coffee of East Ethiopia (Hika B *et al*., 2021) were similar to the current finding. Many annual and perennial broad-leaf weed species were more frequently encountered than grass and sedge species across sites, as the study's findings indicated (Tables 4 and 5).

**Table 2**. Weed Species Observed in The Experimental Fields at Awada Site

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scientific Name  | Family  |  Common Name  | Morphology | Life Cycle  |
| *Achyranthes aspera* L. | *Amaranthaceae* | Devils horsewhip | Broadleaf | Perennial |
| *Amaranthus greecizens* L. | Pigweed  | Broadleaf | Annual |
| *Bidens pilosa*  | *Asteraceae* | Black Jack | Broadleaf | Annual |
| *Galinsoga parviflora* | Gallant Soldier  | Broadleaf | Annual  |
| *Commelina benghalensis* L. | *Commelinaceae* | Wandering Jew | Broad leaf | Perennial |
| *Merremia emarginata*  | *Convolvulaceae* | Kidneyleaf morning glory  | Broadleaf | Perennial  |
| *Cyperus brevifolius* | *Cyperaceae* | Mullumbimby couch  | Sedge  | Perennial  |
| *Cyperus rotundus*  | Purple nut sedge | Sedge  | Perennial  |
| *Euphorbia hirta* L. | *Euphorbiaceae* | AsthmaWeed | Broadleaf | Annual  |
| *Chamaecrista pumila* | *Fabaceae* | Dwarf cassia | Broadleaf | Perennial |
| *Desmodium intorutum*  | Green leaf disodium  | Broadleaf | Perennial  |
| *Medicago polymorpha* | Toothed bur clover | Broadleaf | Annual  |
| *Leucas martinicensis*  | *Lamiaceae* | White wort | Broadleaf | Annual  |
| *Marsilea quadrifolia Hook.*  | *Marsileaceae* | Water Clover | Broad leaf  | Perennial |
| *Oxalis cognuculata* L*.* | *Oxalidaceae* | Creeping wood sorrel, | Broadleaf | Annual |
| *Phyllanthusniruri* L. | *Phyllanthaceae* | Store breaker  | Broadleaf | Annual  |
| *Cynodonnlemfuensis Vanderyst* | *Poaceae* | Star grass | Grass  | Perennial  |
| *Oplismenus hirtellus* (L*.)*  | Basket grass, | Grass | Perennial |
| *Galiumm aparinae*  | *Rubiaceae* | Cleavers | Broadleaf | Annual  |

**Table 3**. Weed Species Observed in the Experimental Field at Hawassa Site

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scientific Name  | Family  |  Common Name  | Morphology | Life Cycle  |
| *Ruellia Prostrate poir* | *Acanthoceae* | Prostrate wild petunia  | Broadleaf | Perennial |
| *Achyranthes aspera* L. | *Amaranthaceae* | Devils horsewhip | Broadleaf | Perennial |
| *Alternantherria caracasana* | Khakiweed | Broad leaf | Perennial |
| *Cyathula prostrat* (L.) *Blume.* | Pasture weed | Broad leaf | Annual  |
| *Bidens pilosa*  | *Asteraceae* | Black Jack | Broad leaf | Annual |
| *Conyza bonariensis* L. | Hairy horseweed | Broad leaf | Annual  |
| *Galinsoga parviflora* | Gallant Soldier  | Broad leaf | Annual  |
| *Commelina benghalensis* L. | *Commelinaceae* | Wandering Jew | Broad leaf | Perennial |
| *Commelina latifolia* L. | Day flower | Broad leaf  | Annual |
| *Convolvulus arvensis* L. | *Convolvulaceae* | Field bindweed | Broad leaf | Perennial  |
| *Bracheria mutica* | *Poaceae* | Para grass | Grass | Perennial  |
| *Cynodon nlemfuensis Vanderyst* | Star grass | Grass  | Perennial  |
| *Digitaria abysinica* | African couch grass | Grass | Perennial |
| *Oplismenus hirtellus* (L.) | Basket grass, | Grass | Perennial |
| *Paspalum conjugatum* | Carabao grass | Grass | Perennial  |
| *Poa annua*L. | Annual bluegrass  | Grass  | Annual |
| *Antigonon leptopus Hook.*  | *Polygonaceae* | Coral vine | Broad leaf | Perennial |
| *Fallopia convolvulus*(L.) | Climbing knotweed | Broad leaf | Annual  |
| *Portulaca oleracea*  | [*Portulacaceae*](https://gobotany.nativeplanttrust.org/family/portulacaceae/) | Common purslane | Broad leaf | Annual  |
| *Galiumm aparinae*  | *Rubiaceae* | Cleavers | Broad leaf | Annual  |
| *Lantana camara*  | *Verbenaceae* | Common lantana | Broad leaf | Perennial  |

**Table 4.** Taxonomy of weed species observed in the verification test site across locations.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scientific Name  | Family  |  Common Name  | Morphology | Life Cycle  |
| *Ruellia Prostrate poir* | *Acanthoceae* | Prostrate wild petunia  | Broad leaf | Perennial |
| *Achyranthes aspera* L. | *Amaranthaceae* | Devils horsewhip | Broad leaf | Perennial |
| *Alternantherria caracasana* | Khakiweed | Broad leaf | Perennial |
| *Amaranthus greecizens* L. | Pigweed  | Broad leaf | Annual |
| *Cyathula prostrat* (L.) *Blume.* | Pasture weed | Broad leaf | Annual  |
| *Bidens pilosa*  | *Asteraceae* | Black Jack | Broad leaf | Annual |
| *Conyza bonariensis* L. | Hairy horseweed | Broad leaf | Annual  |
| *Galinsoga parviflora* | Gallant Soldier  | Broad leaf | Annual  |
| *Commelina benghalensis* L. | *Commelinaceae* | Wandering Jew | Broad leaf | Perennial |
| *Commelina latifolia* L. | Day flower | Broad leaf  | Annual |
| *Convolvulus arvensis* L. | *Convolvulaceae* | Field bindweed | Broad leaf | Perennial  |
| *Merremia emarginata*  | Kidney leaf Morning glory  | Broad leaf | Perennial  |
| *Cyperus brevifolius* | *Cyperaceae* | Mullumbimby couch  | Sedge  | Perennial  |
| *Cyperus rotundus*  | Purple nut sedge | Sedge  | Perennial  |
| *Euphorbia hirta* L. | *Euphorbiaceae* | Asthma Weed | Broad leaf | Annual  |
| *Chamaecrista pumila* | *Fabaceae* | Dwarf cassia | Broad leaf | Perennial |
| *Desmodium intorutum*  | Green leaf disodium  | Broad leaf | Perennial  |
| *Medicago polymorpha* | Toothed bur clover | Broad leaf | Annual  |
| *Leucas martinicensis*  | *Lamiaceae* | White wort | Broad leaf | Annual  |
| *Marsilea quadrifolia Hook.*  | *Marsileaceae* | Water Clover | Broad leaf  | Perennial |
| *Oxalis cognuculata* L*.* | *Oxalidaceae* | Creeping wood sorrel, | Broad leaf | Annual |
| *Phyllanthusniruri* L*.* | *Phyllanthaceae* | Store breaker  | Broad leaf | Annual  |
| *Bracheria mutica* | *Poaceae* | Para grass | Grass | Perennial  |
| *Cynodonnlemfuensis Vanderyst* | Star grass | Grass  | Perennial  |
| *Digitaria abysinica* | African couch grass | Grass | Perennial |
| *Oplismenus hirtellus* (L*.*) | Basket grass, | Grass | Perennial |
| *Paspalum conjugatum* | Carabao grass | Grass | Perennial  |
| *Poa annua*L. | Annual bluegrass  | Grass  | Annual |
| *Antigonon leptopus Hook.*  | *Polygonaceae* | Coral vine | Broad leaf | Perennial |
| *Fallopia convolvulus*(L.) | Climbing knotweed | Broad leaf | Annual  |
| *Portulaca oleracea*  | [*Portulacaceae*](https://gobotany.nativeplanttrust.org/family/portulacaceae/) | Common purslane | Broad leaf | Annual  |
| *Galiumm aparinae*  | *Rubiaceae* | Cleavers | Broad leaf | Annual  |
| *Lantana camara*  | *Verbenaceae* | Common lantana | Broad leaf | Perennial  |

**Table 5.** Weed ontogeny composition and percentage of morphological classification record across location

|  |  |
| --- | --- |
| Weed ontogeny  | **Morphological classification based on their visible plant structures** |
| Broad Leaf | Grass | Sedge |
| Frequency  | % | Frequency  | % | Frequency  | % |
| Annual  | 14 | 42.4 | 1 | 3 | 0 | 0 |
| Perennial  | 11 | 33.3 | 5 | 15.2 | 2 | 6.1 |
| **Total**  | **25** | **75.6** | **6** | **18.2** | **2** | **6.1** |

**3.2. Effect of Herbicides on Weed Density and Percentage of Weed Reduction**

Weed density and percentage of weed reduction data after herbicide application were presented in (Table 3). The current verification trial result indicated that herbicide application has affected weed density. Wanda 48% SL (Glyphosate 480 g/l SL) effectively reduced the weed density compared to weed check. The candidate herbicides Wanda 48% SL and standard check Glycare 48% g/l SL, True Killer, and XTrim 48% SL were non-selective herbicides that started to kill the weeds within weeks days after application (DAA). Wilting and change of weed species color to yellow was started at 3-5 DAA while dead or killing weed species was started on average at 5-7 DAA. About 70% of the weed population was killed after 7 DAA, while most of the weeds were killed between 7-9 DAA. More than 95% of the weed population was killed at 14 DAA, and 99.9% were at 21 DAA. The lower weed density mean value of 7 followed by 9, 13, and 17 per 100m2 was recorded from the plot treated true killer, wanda48% SL, Glycare480g/l Sland XTrim 48% SL respectively at the 21st day evaluation time after herbicide application across locations compared with weedy control. In contrast, the weedy check plots recorded the highest weed population mean value (9105/100m2) (Figure 2.). Different results on the percentage of weed inhibition or percentage of weed reduction were also recorded in the present verification trials. As a result, shown at Hawassa on site indicated by individual weed species, the weed reduction percentage mean value ranged from 65.2-85.9%, 90.3-96.3%, and 96.7-100% obtained from plots treated with Wanda 48% SL test herbicide and, True killer, Glycare and XTrim 48%SL standard check herbicides, compared with plots untreated at 7th, 14th, and 21st DAA, respectively (Table 6 and 7). Almost the same trend result was revealed at the Awada coffee research sub-center when the individual weed species reduction percentage mean value was 65.2-73.1 %, 93.1-94.3, and 99.7-99.9% at 7th,14th and 21st DAA respectively (Figure 3; Table 6&7). The tested herbicide and standard check performed well on weed density reduction and weed reduction percentage compared with untreated plots. The present finding is similar to the report of Firde T. and Bidira T. (2024) done at the Jimma zone, Southern Ethiopia on the pre-verification trial of herbicide against weeds in coffee (*Coffea arabica* L.).

**Figure 2.** Effect of herbicide on weed population across study site at time of application, 7, 14, and 21 days after application.

 **Table 6. Effect of Herbicide on Individual Weed Control at Awada Research Site**

|  |  |
| --- | --- |
|  Weed Species  |  Treatment Evaluation Time at Awada Research Site  |
| Wanda 48% SL | True Killer | Glycare 480g/l SL | XTrim 48% SL |
| 7th DAA  | 14th DAA | 21DAA |  7th DAA |  14th DAA | 21DAA |  7th DAA | 14th DAA | 21DAA | 7th DAA | 14thDAA | 21DAA |
| SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC |
| *Achyranthes aspera* L. | 7.2 | 80 | 9 | 100 | 9 | 100 | 7.6 | 84.4 | 9 | 100 | 9 | 100 | 7.2 | 80.0 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 |
| *Amaranthus greecizens* L. | 7.2 | 80 | 9 | 100 | 9 | 100 | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7.2 | 80.0 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 9 | 100 |
| *Bidens pilosa*  | 7 | 77.8 | 9 | 100 | 9 | 100 | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 9 | 100 |
| *Galinsoga parviflora* | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 |
| *Commelina benghalensis* L. | 4 | 44.4 | 7.1 | 78.9 | 9 | 100 | 4 | 44.4 | 7.8 | 86.7 | 9 | 100 | 4 | 44.4 | 7 | 77.8 | 9 | 100 | 4 | 44.4 | 7 | 77.8 | 9 | 100 |
| *Merremia emarginata*  | 7 | 77.8 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 9 | 100 |
| *Cyperus brevifolius* | 4.5 | 50 | 7.5 | 83.3 | 9 | 100 | 4.5 | 50 | 7.8 | 86.7 | 9 | 100 | 4.5 | 50.0 | 7 | 77.8 | 9 | 100 | 4 | 44.4 | 7 | 77.8 | 8.9 | 98.9 |
| *Cyperus rotundus*  | 4.5 | 50 | 7.5 | 83.3 | 8.9 | 98.9 | 4.5 | 50 | 7.7 | 85.6 | 8.9 | 98.9 | 4.5 | 50.0 | 7.2 | 80 | 8.9 | 98.9 | 4 | 44.4 | 7 | 77.8 | 8.9 | 98.9 |
| *Euphorbia hirta* L. | 6.5 | 72.2 | 8.5 | 94.4 | 9 | 100 | 7 | 77.8 | 8.5 | 94.4 | 9 | 100 | 6.5 | 72.2 | 8.8 | 97.8 | 9 | 100 | 6 | 66.7 | 8.6 | 95.6 | 9 | 100 |
| *Chamaecrista pumila* | 6.5 | 72.2 | 9 | 100 | 9 | 100 | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 9 | 100 | 6 | 66.7 | 9 | 100 | 9 | 100 |
| *Desmodium intorutum*  | 4 | 44.4 | 6.2 | 68.9 | 8.9 | 98.9 | 4 | 44.4 | 6.1 | 67.8 | 9 | 100 | 4 | 44.4 | 6.2 | 68.9 | 8.9 | 98.9 | 4 | 44.4 | 6 | 66.7 | 9 | 100 |
| *Medicago polymorpha* | 7 | 77.8 | 9 | 100 | 9 | 100 | 7.2 | 80 | 9 | 100 | 8.9 | 98.9 | 7 | 77.8 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 8.7 | 96.7 |
| *Leucas martinicensis*  | 7 | 77.8 | 9 | 100 | 9 | 100 | 7.2 | 80 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 9 | 100 |
| *Marsilea quadrifolia Hook.*  | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 6.1 | 67.8 | 9 | 100 | 9 | 100 |
| *Oxalis cognuculata* L*.* | 7.5 | 83.3 | 8.5 | 94.4 | 9 | 100 | 7.5 | 83.3 | 8.6 | 95.6 | 9 | 100 | 7.5 | 83.3 | 8.5 | 94.4 | 9 | 100 | 6.6 | 73.3 | 8 | 88.9 | 9 | 100 |
| *Phyllanthusniruri* L. | 6.5 | 72.2 | 8.5 | 94.4 | 8.9 | 98.9 | 7 | 77.8 | 8.6 | 95.6 | 9 | 100 | 6.5 | 72.2 | 8.5 | 94.4 | 8.9 | 98.9 | 6.1 | 67.8 | 8.2 | 91.1 | 9 | 100 |
| *Cynodonnlemfuensis Vanderyst* | 5.6 | 62.2 | 9 | 100 | 9 | 100 | 5.6 | 62.2 | 9 | 100 | 9 | 100 | 5.6 | 62.2 | 9 | 100 | 9 | 100 | 5.6 | 62.2 | 9 | 100 | 9 | 100 |
| *Oplismenus hirtellus* (L*.)*  | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7.5 | 83.3 | 9 | 100 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 6.5 | 72.2 | 9 | 100 | 9 | 100 |
| *Galiumm aparinae*  | 7 | 77.8 | 8.5 | 94.4 | 9 | 100 | 7 | 77.8 | 9 | 100 | 9 | 100 | 7 | 77.8 | 8.5 | 94.4 | 9 | 100 | 6.1 | 67.8 | 8 | 88.9 | 9 | 100 |
| *Mean*  | **6.4** | **71.1** | **8.5** | **94.3** | **9** | **99.8** | **6.6** | **73.2** | **8.6** | **95.1** | **9** | **99.9** | **6.3** | **70.2** | **8.5** | **94.0** | **9** | **99.8** | **5.9** | **65.2** | **8.4** | **93.1** | **9** | **99.7** |

*Where: DAA= days after application, SS=score scale (1-9) and PWC=percent weed control (%)*

**Table 7. Effect of Herbicide on Individual Weed Control at Hawassa Research Site**

|  |  |
| --- | --- |
|  Weed Species  |  Treatment Evaluation Time at Hawassa Research Site  |
| Wanda 48% SL | True Killer | Glycare 480g/l SL | XTrim 48% SL |
| 7th DAA  | 14th DAA | 21DAA |  7th DAA |  14th DAA | 21DAA |  7th DAA | 14th DAA | 21DAA | 7th DAA | 14thDAA | 21DAA |
| SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC | SS | PWC |
| *Ruellia Prostrate poir* | 8 | 88.9 | 8.8 | 97.8 | 9 | 100 | 7.7 | 85.6 | 8.8 | 97.8 | 9 | 100 | 8.0 | 88.9 | 8.8 | 97.8 | 9 | 100 | 6.2 | 68.9 | 8.5 | 94.4 | 9 | 100 |
| *Achyranthes aspera* (L.) | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 6.0 | 66.7 | 8.4 | 93.3 | 9 | 100 |
| *Alternantherria caracasana* | 7.7 | 85.6 | 8.7 | 96.7 | 9 | 100 | 7.7 | 85.6 | 8.7 | 96.7 | 9 | 100 | 7.7 | 85.6 | 8.7 | 96.7 | 9 | 100 | 6.0 | 66.7 | 8.3 | 92.2 | 9 | 100 |
| *Cyathula prostrat* (L.) | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.9 | 87.8 | 8.8 | 97.8 | 9 | 100 | 6.6 | 73.3 | 8.5 | 94.4 | 9 | 100 |
| *Bidens pilosa*  | 8 | 88.9 | 8.7 | 96.7 | 9 | 100 | 7.6 | 84.4 | 8.7 | 96.7 | 9 | 100 | 8.0 | 88.9 | 8.7 | 96.7 | 9 | 100 | 6.5 | 72.2 | 8.4 | 93.3 | 9 | 100 |
| *Conyza bonariensis* L. | 8 | 88.9 | 8.8 | 97.8 | 9 | 100 | 7.5 | 83.3 | 8.6 | 95.6 | 9 | 100 | 8.0 | 88.9 | 8.7 | 96.7 | 9 | 100 | 5.5 | 61.1 | 8.3 | 92.2 | 9 | 100 |
| *Galinsoga parviflora* | 8 | 88.9 | 8.9 | 98.9 | 9 | 100 | 7.7 | 85.6 | 8.7 | 96.7 | 9 | 100 | 8.1 | 90.0 | 8.8 | 97.8 | 9 | 100 | 6.4 | 71.1 | 8.2 | 91.1 | 9 | 100 |
| *Commelina benghalensis* L. | 6.3 | 70.0 | 7.6 | 84.4 | 8.6 | 95.6 | 6 | 66.7 | 7.3 | 81.1 | 8.6 | 95.6 | 6.5 | 72.2 | 7.4 | 82.2 | 8.8 | 97.8 | 4.6 | 51.1 | 7.1 | 78.9 | 8.8 | 97.8 |
| *Commelina latifolia* (L.) | 6.4 | 71.1 | 7.6 | 84.4 | 8.5 | 94.4 | 6 | 66.7 | 7.2 | 80.0 | 8.5 | 94.4 | 6.5 | 72.2 | 7.4 | 82.2 | 8.9 | 98.9 | 4.5 | 50.0 | 7.0 | 77.8 | 8.9 | 98.9 |
| *Convolvulus arvensis* L. | 8.5 | 94.4 | 8.6 | 95.6 | 9 | 100 | 7.5 | 83.3 | 8.6 | 95.6 | 9 | 100 | 8.5 | 94.4 | 8.6 | 95.6 | 9 | 100 | 6.6 | 73.3 | 7.9 | 87.8 | 9 | 100 |
| *Bracheria mutica* | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.8 | 86.7 | 8.4 | 93.3 | 9 | 100 | 7.8 | 86.7 | 8.7 | 96.7 | 9 | 100 | 6.5 | 72.2 | 8.3 | 92.2 | 9 | 100 |
| *Cynodonnlemfuensis Vanderyst* | 6.5 | 72.2 | 8.8 | 97.8 | 9 | 100 | 6.5 | 72.2 | 8.5 | 94.4 | 9 | 100 | 6.5 | 72.2 | 8.8 | 97.8 | 9 | 100 | 5.2 | 57.8 | 8.2 | 91.1 | 9 | 100 |
| *Digitaria abysinica* | 7.8 | 86.7 | 8.8 | 97.8 | 8.9 | 98.9 | 7.8 | 86.7 | 8.6 | 95.6 | 8.9 | 98.9 | 7.8 | 86.7 | 8.0 | 88.9 | 8.9 | 98.9 | 6.4 | 71.1 | 7.8 | 86.7 | 8.9 | 98.9 |
| *Oplismenushirtellus* (L*.*) | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.8 | 86.7 | 8.5 | 94.4 | 9 | 100 | 7.8 | 86.7 | 8.7 | 96.7 | 9 | 100 | 7.0 | 77.8 | 8.4 | 93.3 | 9 | 100 |
| *Paspalum conjugatum* | 8.2 | 91.1 | 8.8 | 97.8 | 9 | 100 | 8.2 | 91.1 | 8.6 | 95.6 | 9 | 100 | 7.9 | 87.8 | 8.6 | 95.6 | 9 | 100 | 6.6 | 73.3 | 7.8 | 86.7 | 9 | 100 |
| *Poa annua*(L.) | 7.7 | 85.6 | 8.8 | 97.8 | 9 | 100 | 7.7 | 85.6 | 8.4 | 93.3 | 9 | 100 | 7.7 | 85.6 | 8.7 | 96.7 | 9 | 100 | 6.5 | 72.2 | 8.2 | 91.1 | 9 | 100 |
| *AntigononleptopusHook.*  | 7.6 | 84.4 | 8.7 | 96.7 | 9 | 100 | 7.6 | 84.4 | 8.7 | 96.7 | 9 | 100 | 7.8 | 86.7 | 8.6 | 95.6 | 9 | 100 | 6.5 | 72.2 | 8.4 | 93.3 | 9 | 100 |
| *Fallopiaconvolvulus*(L.) | 7.8 | 86.7 | 8.8 | 97.8 | 9 | 100 | 7.8 | 86.7 | 8.5 | 94.4 | 9 | 100 | 7.8 | 86.7 | 8.5 | 94.4 | 9 | 100 | 6.0 | 66.7 | 7.9 | 87.8 | 9 | 100 |
| *Portulaca oleracea*  | 8 | 88.9 | 8.8 | 97.8 | 9 | 100 | 7.9 | 87.8 | 8.8 | 97.8 | 9 | 100 | 8.1 | 90.0 | 8.6 | 95.6 | 9 | 100 | 6.0 | 66.7 | 8.4 | 93.3 | 9 | 100 |
| *Galiumm aparinae*  | 8 | 88.9 | 8.9 | 98.9 | 9 | 100 | 7.8 | 86.7 | 8.3 | 92.2 | 9 | 100 | 8.3 | 92.2 | 8.3 | 92.2 | 9 | 100 | 6.7 | 74.4 | 8.0 | 88.9 | 9 | 100 |
| *Lantana camara*  | 7.7 | 85.6 | 8.8 | 97.8 | 9. | 100 | 7.7 | 85.6 | 8.1 | 90.0 | 9. | 100 | 7.8 | 86.7 | 8.5 | 94.4 | 9. | 100 | 6.8 | 75.6 | 8.6 | 95.6 | 9. | 100 |
| **Mean**  | **7.7** | **85.4** | **8.7** | **96.3** | **9.0** | **99.9** | **7.5** | **83.5** | **8.5** | **94.0** | **9.0** | **99.9** | **7.7** | **85.9** | **8.5** | **94.6** | **9.0** | **99.8** | **6.1** | **68.3** | **8.1** | **90.3** | **9.0** | **99.8** |

*Where: DAA= days after application, SS=score scale (1-9) and PWC=percent weed control (%)*

**3.4. Effect of Herbicide on General Weed Control**

General weed control was evaluated via visual observation based on a 1-9 scale and percent weed control after 7,14 and 21 days of herbicide application. Accordingly, all test herbicides effectively controlled the annual and perennial broad leaves, grasses, and sedge weeds which predominantly infested the experimental plots across locations. As present herbicide verification observation result showed that herbicide showed good performance on general weed control compared with weedy check. The weed control percentage range mean value 71.1% to 99.9% obtained from the plots treated with Wanda 48%Sl (Glyphosate 48% g/l SL) herbicide at 7th, 14th, and 21st day evaluation time after herbicide application across locations, which were all most similar, with the weed control percentage mean value 65.2% to 99.8% of XTrim 48%SL, 70.1% to 99.8% of Gly Care 480g/l SL, and 73.2% to 99.9% of True Killer were obtained from the plots treated standard check herbicide across location, respectively (Figure 3). The present verification trial result suggested that it has the same efficacy level as a standard check which is in line with the findings of (Malkamu F., 2024) in the Sidama region and (Tigist B.and Tamiru S., 2023) done in the Jimma zone in southern and southwest Ethiopia for weed control in the coffee farm.

**Figure 3**. Effect of Herbicides on General Weed Control in Time Interval.

**3.5. Effect of Herbicide on Weed Control Efficiency**

The tested herbicide discovered a 99.85% weed control efficiency mean value, which is almost similar to the average of 99.75%, 99.8%, and 99.85% obtained from standard check herbicides namely XTrim48%SL, Glycare 480% g/l SL, and True Killer across locations respectively (Table 8). This result indicates that the test herbicides have the same weed control efficacy as standard checks, and the farmers can use either one of them depending on the availability of the herbicides for different weed species of sedge, grass, and broadleaf during the active growth stage of the weed in the coffee farms of non-organic producers. This finding agrees with the report of Malkamu F (2024) Verification trial of new herbicides against broad leaf, grass, and sedge of the coffee farm at Sidama region, Southern Ethiopia, and Firde T and Bidira T (2024) pre-verification trial of herbicide against weeds in coffee (*Coffea arabica* L.) at Jimma, Southwest Ethiopia.

**Table 8.** Herbicides weed control efficiency rate (WCE %).

|  |  |
| --- | --- |
| Experimental site  | **Treatment Evaluation Time per Location of 1m2 Area at 21 Days After Application** |
| Wanda 48g/l SL |  True Killer  |  Gly care 480g/l SL  | XTrim 48%SL | Nill (Weedy check) |
| WD  | WCE  | WD | WCE | WD | WCE | WWD | WCE | WD | WCE |
| Hawassa ARC on-site  | 0.12 | 99.9 | 0.07 | 99.9 | 0.18 | 99.8 | 0.25 | 99.7 | 9012 | - |
| Awada ARC on-site  | 0.09 | 99.8 | 0.11 | 99.8 | 0.13 | 99.8 | 0.17 | 99.8 | 9105 | - |
| **Mean** | **0.11** | **99.85** | **0.09** | **99.85** | **0.16** | **99.8** | **0.21** | **99.75** | **9058.5** | **-** |

*Where WD: weed density; m2: meter square; WCE: weed control efficiency percentage and ARC: agricultural research center*

**4. CONCLUSION AND RECOMMENDATION**

The present verification trials of the WANDA 48g/l SL (Glyphosate IPA 48g/l SL**)**revealed promising results controlling perennial sedge, perennial grasses, perennial broad-leaf weeds, annual grass, and annual broad-leaf weeds species in coffee. The herbicide effectively reduced the density compared with the weedy control. The newly introduced candidate herbicide WANDA 48g/l SL (Glyphosate IPA 48g/l SL**)**starts weed killing after 5-7 days as compared with standard control herbicides (True killer, Gly care 48%g/l SL, and XTrim 48%SL) the same wise and provide full control between 14-21 days after application. The tested herbicide was found effective in providing weed-free coffee for a single season with one application per season. This indicated that this herbicide can reduce the weed population equivalent to the standard check, likewise at a season. Repeated application after a month is not required to achieve full control throughout the season. This indicates that the herbicide has long-lasting effects on weed control in coffee fields.

Therefore, as a weed management option for coffee, if it is financially feasible and accessible to farmers, the new chemical WANDA 48 g/l SL (Glyphosate IPA 48 g/l SL) is advised for use in the farm weed population of broadleaved, grassy, and sedge weeds that are critical to production. In this case, the weeds are aggressive because of the continuous application of selective herbicides and the resulting development of resistance and inefficiency. Furthermore, most farms in the coffee-potential districts are commercial or adjacent to commercial, making hand weeding inappropriate and challenging during the critical phase of weeding. It is difficult or maybe impossible to provide timely weed management for such large-scale production farms, where hand weeding is expensive, time-consuming, and labor-intensive.

Thus, it is very wise to recommend the herbicide WANDA 48g/l SL (Glyphosate IPA 48g/l SL**)**as an alternative herbicide for use against major post-emergency annual and perennial broadleaved, grass, and sedge weeds in the current study area of coffee growing and similar agro-ecologies of non-organic-coffee-producers.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE) Author(s)**

Hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

**COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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