**Determination of Efficacy of Newly Introduced Herbicides on Weed Floras in Coffee Farm under Rain-Fed Production System in Ethiopia**

**Abstract**

*Weed is the major limiting factor of coffee (Coffea arabica L.) 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*:***Coffee arabica, efficacy, herbicides, Wanda 48%SL, weed density, verification

1. **INTRODUCTION**

Coffee (Coffea arabica L.) is a perennial commercial crop and 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 and W/Mariam, 2015).

The Ethiopia's country's economy and culture are strongly influenced by coffee. The country's main export crop is arabica coffee, which makes it a significant contributor in the economic economy 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 infestation, recurring pests and diseases, depleting soil capacity, and unfavorable weather patterns, have an impact on coffee output. 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, branch dieback is causing high-yield loss of coffee production. In the same way, insect pests such as Anthestia bug, coffee blotch miners, stem borer, and berry borer are the major ones causing considerable damage. Moreover, 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, 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, depending on the type of weed, the stage at which coffee trees are developing, and the surrounding growth circumstances (Tadesse, 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, 1994). The primary obstacle to the 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. 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 et al., 2024) and Southern Ethiopia, in Sidama (Malkamu, 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 one time weeding or unwedded 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. It also can offer the advantage of taking less time, labor, and avoiding the potential of diseases spread caused by manual slashing and digging during 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 herbicides with different modes of action are essential.

Hence, the use of non-selective broad-spectrum chemicals becomes important to kill all weeds emerging before they 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 Wanda 48%SL (Glyphosate 48g/l SL) compared with already registered herbicide Gly care 48% g/l SL., XTrim, and true killer as standard control for control perennial and annual grasses and broad leaved weeds in coffee in Sidama Regional State, Hawassa Agricultural Research Center on station and Awada Agricultural Research Sub-center. 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 weeds in coffee.

**2. MATERIALS AND METHODS**

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

The verification test was conducted at Hawassa Agricultural Research Center (HARC) and Awada Agricultural Research Sub-Center (AARC) in coffee (Coffea arabica L.) farms during 2024 (Figure 1). HARC is found in Sidama Regional State at Hawassa, 288 km to southern Addis Ababa. It is located at 07° 03’52'’N latitude, 038° 28’ 52 'E longitude and with an elevation of 1700 meters above sea level (masl) The area receives a total of 1000 to 1200 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 temperatures of the areas were 16.5 °C and 29.2 °C, respectively. AARC is foundat distances of 319 km from Addis Ababa, and 45 km from Hawassa to south at Yirgalem. It is located at 6° 3' N latitude, 38° 3' E longitude, and 1740 masl altitude. The average annual minimum and maximum temperatures are 11°C, and 28 °C, with 1335 mm rainfall. 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 on-station. The trial was conducted at two locations via the 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 and annual grasses, broadleaved, and sedges weeds were abundantly growing.

Five treatments were used at the experimental sites including test herbicide WANDA48% SL (Glyphosate 48g/l SL), three standard checks (Glycare 48%g/l SL), XTrim, and True killer) as described in Table 1, and weedy check . Wanda 48% SL, Glycare 48% g/l SL, True Killer, and XTrim 48% SL The plots size was 10 m x 10 m . The testing trail was laid out over locations that, considered as replications. They are non-selective herbicides that start killing the weeds within weeks after application. The herbicides were sprayed one time within the season at the actively/vigorous growth stage of the weeds. Each of them was uniformly applied with a rate of 3 liters/ha manually using a knapsack sprayer delivering 250 liters of water/ha following the cherry harvesting time. Weeds were identified to species level and counted pretreatment by randomly throwing the quadrat. After the 7th, 14th, and 21st days of herbicide application, the weed counted as post-treatment by randomly to the plots. 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, percentage of weed inhibition (PWI) was calculated using the following formula as suggested by (Mani, et al., 1973).

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

Where, NWC =number of weeds in the weedy check NWT =number of weeds in any particular treatment. Individual and general weed control score were done using (1-9 scale ), 1= no control and 9= (100% control) through visual observation at the 7th, 14th and 21st days after treatment application by considering growth reduction, foliar chlorosis, wilting and stunting during the time of assessment. Moreover, 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) |
| WANDA 48% SL | Glyphosate | Glyphosate 48g/l SL | New | 2 |
| True Killer | Glyphosate IPA | 480g/l Glyphosate isopropyl amine salt | ET/HR/R12 7/2021 | 2 |
| XTrim 48%SL | Glyphosate | Glyphosate 480g/l | ET/HR/SM/ R224/2022 | 3 |
| Glycare 48% SL | Glyphosate IPA | 480 g/l Glyphosate isopropyl amine salt | ET/HR/SS/ R678/2022 | 2 |

**3. RESULTS AND DISCUSSIONS**

**3.1. Weed Infestation**

The verification test was conducted in pre-established coffee (Coffea arabica L.) orchards. Species belonging to the annual and perennial broadleaf, grass, and sedge were identified. About 33 weed species belonging to 17 families were recorded across locations. Among the recorded weed species, sedge, grass, and broad-leaf weed species were 6.1%, 18.2%, and 75.7%, respectively. 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. Of the seventeen weed families observed in the experimental fields, members of the *Poaceae, Maranthaceae, Asteraceae*, and *Fabaceae* families were numbered three to six, while the remaining families were counted around two or one species. About 10 families and 24 weed species were identified from Hawassa Agricultural Research on-site, while the Awada agricultural research sub-center revealed 13 families and 19 weed species. Similar reports have been done in Sidama Region of Southern Ethiopia (Malkamu, 2024) and the Southwest Ethiopia Jimma Zone (Tigist, 2024; Tigist and Tamiru, 2023), and main coffee production systems and regions of Ethiopia (Abera et al., 2022). Survey of weed flora composition in coffee of East Ethiopia (Hika 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 field of Awada site

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scientific name  | Family  |  Common name  | Morphology | Life cycle  |
| *Achyranthes aspera* L. | *Amaranthaceae* | Devils horsewhip | Bl | P |
| *Amaranthus greecizens* L. | Pigweed  | Bl | A |
| *Bidens pilosa* L. | *Asteraceae* | Black Jack | Bl | A |
| *Galinsoga parviflora* | Gallant Soldier  | Bl | A  |
| *Commelina benghalensis* L. | *Commelinaceae* | Wandering Jew | Bl | P |
| *Merremia gangetica* (L.) *Cuf.* | *Convolvulaceae* | Kidneyleaf morning glory  | Bl | P  |
| *Cyperus brevifolius (Rottb.) Endl. ex Hassk* | *Cyperaceae* | Mullumbimby couch  | S | P  |
| *Cyperus rotundus* L*.* | Purple nut sedge | S  | P  |
| *Euphorbia hirta* L. | *Euphorbiaceae* | AsthmaWeed | Bl | A  |
| *Chamaecrista pumila (Lam.) V.Singh* | *Fabaceae* | Dwarf cassia | Bl | P |
| *Desmodium intortum (Mill.) Urb.* | Green leaf disodium  | Bl | P  |
| *Medicago polymorpha* L. | Toothed bur clover | Bl | A  |
| *Leucas martinicensis (Jacq.) R.Br* | *Lamiaceae* | White wort | Bl | A  |
| *Marsilea quadrifolia Hook.*  | *Marsileaceae* | Water Clover | Bl | P |
| *Oxalis cognuculata* L*.* | *Oxalidaceae* | Creeping wood sorrel, | Bl | A |
| *Phyllanthusniruri* L. | *Phyllanthaceae* | Store breaker  | Bl | A  |
| *Cynodon nlemfuensis Vanderyst.* | *Poaceae* | Star grass | G | P  |
| *Oplismenus hirtellus* (L*.)*  | Basket grass, | G | P |
| *Galiumm aparinae* L. | *Rubiaceae* | Cleavers | Bl | A  |

*Note: Bl=broadleaf, G=grass, S=sedge, A=annual & P=perennial*

**Table 3**. Weed species observed in the experimental field of Hawassa site

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Scientific name  | Family  |  Common name  | Morphology | Life cycle  |
| *Ruellia prostrata Poir.* | *Acanthoceae* | Prostrate wild petunia  | Bl | P |
| *Achyranthes aspera* L.  | *Amaranthaceae* | Devils horsewhip | Bl | P |
| *Alternanthera caracasana Kunth.* | Khakiweed | Bl | P |
| *Cyathula prostrata (L.) Blume.* | Pasture weed | Bl | A  |
| *Bidens pilosa* L. | *Asteraceae* | Black Jack | Bl | A |
| *Conyza bonariensis* L. | Hairy horseweed | Bl | A  |
| *Galinsoga parviflora Cav.* | Gallant Soldier  | Bl | A  |
| *Commelina benghalensis* L. | *Commelinaceae* | Wandering Jew | Bl | P |
| *Commelina latifolia* L. | Day flower | Bl | A |
| *Convolvulus arvensis* L. | *Convolvulaceae* | Field bindweed | Bl | P  |
| *Brachiaria mutica (Forssk.) Stapf* | *Poaceae* | Para grass | G | P  |
| *Cynodon nlemfuensis Vanderyst* | Star grass | G | P  |
| *Digitaria abyssinica (Hochst. ex A.Rich.) Stapf* | African couch grass | G | P |
| *Oplismenus hirtellus* (L.) | Basket grass, | G | P |
| *Paspalum conjugatum P.J. Bergius* | Carabao grass | G | P  |
| *Poa annua*L. | Annual bluegrass  | G | A |
| *Antigonon leptopus Hook. & Arn* | *Polygonaceae* | Coral vine | Bl | P |
| *Fallopia convolvulus*(L.) | Climbing knotweed | Bl | A  |
| *Portulaca oleracea* L. | [*Portulacaceae*](https://gobotany.nativeplanttrust.org/family/portulacaceae/) | Common purslane | Bl | A  |
| *Galium aparine*L. | *Rubiaceae* | Cleavers | Bl | A  |
| *Lantana camara* L. | *Verbenaceae* | Common lantana | Bl | P  |

*Note: Bl=broadleaf, G=grass, S=sedge, A=annual & P=perennial*

**Table 4. W**eed observed in the verification test site

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

*Note: Bl=broadleaf, G=grass, S=sedge, A=annual & P=perennial*

**Table 5.** Weed ontogeny and morphology percentage record across locations

|  |  |
| --- | --- |
| Weed ontogeny  | **Morphological classification based on their visible plant structures** |
| Broadleaf | 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 6. The verification trial result indicated that herbicide application affected weed density. The candidate herbicide Wanda 48% SL (Glyphosate 480 g/l SL) effectively reduced the weed density compared to weed check. Wilting and change of weed species color to yellow was started at 3-5 DAA, while dead or killed weed species was observed on average at 5-7 DAA. About 70% of the weed population was killed at 7 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 100 m2, were recorded from the plots treated with true killer, wanda48% SL, Glycare480g/l Sl, and XTrim 48% SL, respectively, at the 21st day after herbicide application across locations compared with weedy control. In contrast, the weedy check plots recorded the highest weed population mean value (9105/100 reduction was recorded in the present verification trials. at Hawassa, the weed reduction percentage mean value ranged from 65.2-85.9%, 90.3-96.3%, and 96.7-100% were obtained from plots treated with Wanda 48% SL, True killer, Glycare and XTrim 48%SL, compared with untreated plots at 7th, 14th, and 21st DAA, respectively (Table 6 and 7). Almost the same trended result was revealed at the Awada Coffee Research Sub-center when the individual weed species reduction percentage mean values were 65.2-73.1 %, 93.1-94.3%, and 99.7- 99.9% at 7th,14th, and 21st DAA, respectively (Figure 2; Tables 6 & 7). The tested herbicide and standard check performed well on weed density reduction compared with untreated plots. The present finding is similar to the report of Firde and Bidira (2024) on the pre-verification trial of herbicides against weeds in coffee (Coffea arabica L.).

**Figure 2.** Effect of herbicide on weed population across study sites at the 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* L. | 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 gangetica* (L.) *Cuf.* | 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 (Rottb.) Endl. ex Hassk* | 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* L*.* | 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 (Lam.) V.Singh* | 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 intortum (Mill.) Urb.* | 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* L. | 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 (Jacq.) R.Br* | 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 |
| *Cynodon nlemfuensis 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* L. | 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 prostrata 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 |
| *Alternanthera caracasana Kunth.* | 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 prostrata (L.) Blume.* | 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* L. | 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 Cav.* | 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 |
| *Brachiaria mutica (Forssk.) Stapf* | 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 |
| *Cynodon nlemfuensis 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 abyssinica (Hochst. ex A.Rich.) Stapf* | 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 |
| *Oplismenus hirtellus* (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 P.J. Bergius* | 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 |
| *Antigonon leptopus Hook. & Arn* | 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 |
| *Fallopia convolvulus*(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* L. | 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 |
| *Galium aparine*L. | 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* L. | 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. The result showed that herbicides showed good performance on general weed control compared with weedy check. The weed control percentage mean values ranging from 71.1% to 99.9% were obtained from the plots treated with Wanda 48%Sl (Glyphosate 48% g/l SL) at 7th, 14th, and 21st day after herbicide application across locations, which were all most similar, with the weed control percentage mean values of XTrim 48%SL (65.2% to 99.8%), Gly Care 480g/l SL (70.1% to 99.8%), and True Killer (73.2% to 99.9%)(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 (2024) in the Sidama region and Tigist and Tamiru (2023) in the Jimma zone.

**Figure 3**. Effect of herbicides on general weed control in time interval.

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

The tested candidate herbicide recorded a 99.85% weed control efficiency mean value, which is almost similar to the average values 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 has 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 (2024) on verification trial of new herbicides against broadleaf, grass, and sedge of the coffee farm in Sidama region, Southern Ethiopia, and with Firde and Bidira (2024) on pre-verification trial of herbicides against weeds in coffee at Jimma, Southwest Ethiopia.

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

|  |  |
| --- | --- |
| Experimental site  | Treatment evaluation at 21DAA over test locations from 1m2 area  |
| 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, DAA: days after application and ARC: agricultural research center*

**4. CONCLUSION AND RECOMMENDATION**

The present verification trials of WANDA 48g/l SL (Glyphosate IPA 48g/l SL) revealed promising results in controlling annual and perennial sedge, grasses, and broadleaf weed species in coffee (Coffea arabica L.). The herbicide effectively reduced the weed density compared with the weedy control. The newly introduced candidate herbicide WANDA 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 provides full control between 14-21 days after application. The newly 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 checks, likewise, over a 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 is advised for use on the farm to minimize the broadleaved, grassy, and sedge populations that are critical to coffee production. 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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