# EVALUATION OF WEED MANAGEMENT PRACTICES ON MUNG BEAN (*Vigna radiata* L.) YIELD AND YIELD COMPONENTS AT TEPPI, SOUTH WEST ETHIOPIA.

**MSc THESIS**

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# Evaluation of Weed Management Practices on Mung bean (*Vigna radiata* L.) Yield and Yield Components at Teppi, South West Ethiopia.

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# DEDICATION

I dedicate this thesis manuscript to my father Ato Asmamaw Abera, and my mother Alem Aragew for nursing me with affection and love and for their dedicated partnership in the success of my life.

# STATEMENT OF THE AUTHOR

I declare that this thesis is my beneficed work and all sources of materials used for this thesis have been duly acknowledged. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CSA | Central Statistical Agency |
| D | Dominated treatment |
| DAS | Days After Sowing |
| DBH | Days Before Harvest |
| DBW | Dry Biomass Weight |
| DTF | Date of Flowering |
| DTM | Date of Maturity |
| ECX | Ethiopian Commodity Exchange |
| GBT | Gross Benefit |
| GYL | Grain Yield |
| HI | Harvest Index |
| HSW | Hundred Seeds Weight |
| LAI | Leaf Area Index |
| MARC | Melkasa Agricultural Research Center |
| NBT | Net Benefit |
| NDW | Nodulation Dry Weight |
| NPdPP | Number of Pods per Plant |
| NSPP | Number of Seed per Plant |
| PH | Plant Height |
| RD | Relative Dominance |
| SBH | Stands Before Harvest |
| WAE | Week After Emergence |

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Evaluation of Weed Management Practices on Mung bean (*Vigna radiata* L.) Yield and Yield Components at Teppi, South West Ethiopia.

Muluken Asmamaw (BSc in Horticulture), Ferdu Azerefegne (Ph.D), Professor Walelign Worku (Ph.D)

# *ABSTRACT*

*Mung bean is characterized by fast growth, low water requirement, and excellent soil fertility enhancement through nitrogen fixation. The productivity of mung beans is decreased by weeds, diseases, and insect pests. Weed competition is among the most important factors responsible for the low yield of mung bean by as much as 87%. Therefore, this study was initiated to evaluate the effect of weed management practices on yield and yield components of mung bean (Vigna radiata* L.*). Nine control options (One-hand weeding at 4 weeks after sowing, complete weed control, No-weed control, Haloxyfop-R-methyl ester at 0.3, 0.6, and 0.3 kg ai ha$^{-1}$ + One-Hand weeding at 4 weeks after sowing, pendimethalin at 1, 1.5 and 1 kg ai ha$^{-1}$ + One-Hand weeding at 4 weeks after sowing) were compared in randomized complete block design in three replications. The application of herbicides and the weeding practices significantly reduced the broadleaf, sedge, and grass weeds. The highest grain yield (0.98 ton ha$^{-1}$), total dry biomass (2.82-ton ha$^{-1}$), and plant height (43.76 cm) were obtained in complete weed control followed by application of pendimethalin at 1.5 kg ai ha$^{-1}$ (0.92 ton ha$^{-1}$), total dry biomass (2.78 ton ha$^{-1}$), plant height (50.03 cm). The lowest grain yield (0.36 ton ha$^{-1}$), total dry biomass (1.59-ton ha$^{-1}$), and plant height (64.63 cm) were recorded from the No-weed control plot. The highest number of pods per plant, number of seeds per pod, and weight of a hundred seeds were recorded in complete weed control and application of pendimethalin at 1.5 kg ai ha$^{-1}$. The results indicated that complete weed control and/or control with pendimethalin at 1.5 kg ai ha$^{-1}$ were the best management practices to maximize economic benefit. Thus, we recommend using the applications of one of the two weed control methods for the management of weeds in mung bean in Teppi, South West Ethiopia, and locations with similar agroecologies of Teppi.*

*Keywords: haloxyfop-r-methyl ester, nitrogen fixation, pendimethalin, weeds*

# 1. INTRODUCTION

Mung bean (*Vigna radiata* L.) is among the important pulses cultivated in different agroecological zones of the world (Khan *et al*., 2012). It is a short-maturity and drought-resistant crop, which confers its adaptation to adverse environmental conditions and successfully grows in rain-fed areas (Anjum *et al*., 2006). At present, mung bean cultivation spreads widely in Africa, South America, Australia, and many Asian countries (Gebre, 2015). The crop is characterized by fast growth under warm conditions and low water requirements and it is an excellent soil fertility-enhancing crop through nitrogen fixation (Yagoob and Yagoob, 2014).

In Ethiopia, mung bean is called "*Masho*" in Amharic. It is a pulse crop that was recently introduced and cultivated in a limited area on a low scale (Lambrides *et al*., 2007). Its seeds are a good source of dietary protein and contain higher levels of folate and iron than most other legumes (Keatinge *et al*., 2011). Mung bean is utilized in several ways; seeds, sprouts, and young pods are all consumed and provide a rich source of amino acids, vitamins, and minerals (Somta and Srinives, 2007). The grain contains 24.2% protein, 1.3% fat, and 60.4% carbohydrate (Hussain *et al*., 2012).

The protein and carbohydrates of mung bean are more easily digestible than proteins derived from other legumes. On the other hand, the same source indicated that mung bean fixes atmospheric $N_2$ and enriches the soil with N, a nutrient for the growth of succeeding crops. It is also known to be very healthy and packed with a variety of nutrients such as vitamin B, vitamin C, protein, manganese, and a lot of other essential nutrients required for the effective functioning of human health (Dainavizadeh and Mehranzadeh, 2013). Mung bean is low in calories and rich in fiber and easily digestible crop without causing flatulence as happens with many other legumes (Minh, 2014).

Mung bean is mainly used as food, but growing it for income generation can also be important. The varieties used for income generation may be different from those which can give a stable yield under harsh environmental conditions. Result from farming practices used for food, medicine, economic, ecological, socio-cultural, religious, and cultural needs. Mung bean is cultivated for its edible seeds, income generation, and fodder for livestock (Asfaw *et al*., 2012). The crop is mostly used for domestic consumption (food for humans and fodder for animals), to improve soil fertility, and for income generation through national markets.

Mung bean has good potential for crop rotation systems, for crops under drier farmland cultivation areas (Ashraf *et al*., 2003), and can grow in dry and irrigated conditions (Rahim *et al*., 2010). Sowing of mung bean mainly occurs during summer when sufficient rain is available for growth but it is sensitive to water logging. It is grown in several types of cultivation systems, including sole cropping, intercropping, multiple cropping, and relay cropping, where it is planted after cereals using residual moisture (Rehman *et al*., 2009). It is a warm season crop requiring 65-80 days with optimum temperature ranges from $27^{O}C$-$30^{O}C$; the time from sowing to maturity depends on the variety of the crop. Adequate rainfall is required from flowering to late pod filling to achieve high grain yield (Zare *et al*., 2013). In Ethiopia, mung bean is produced at about 48,022.34 ha with a total production of 515,686.55t and an average productivity of 10.74t $ha^{-1}$ (CSA, 2021). In 2015, Ethiopia exported a total of 30,694 metric tons (MT) of green Mung bean with a value of 35.8 million USD. The comparison of the export performance of 2014 showed the export volume and value grew by 21% and 23%, respectively. The major export destinations for Ethiopian green Mung bean are Indonesia, India, Belgium, UAE, and Singapore (ECX, 2014).

However, the challenge that Ethiopian farmers face in producing mung beans is unpredictable rainfall since mung bean productivity is highly dependent on the amount and distribution of rain. The other critical challenge is pests and diseases, affecting the yield and quality of mung beans. Apart from salinity and heat stress, water deficit and waterlogging are also the key abiotic stresses that restrict growth, development, and yield traits in mung beans. Lack of improved variety of mung bean productivity has a great impact on its grain yield, so the crop's yield remains low in addition to this the use of local varieties and the lack of improved high-yielding cultivars as well as the inadequate or non-application of inorganic fertilizers (Wondimkun, 2023).

The productivity of mung beans is decreased through biotic and abiotic stresses including weeds, diseases, insect pests, drought stress, water stress, extremely high temperature, salinity stress, and heavy metals (Waniale *et al*., 2012; Das *et al*., 2014). In Ethiopia, according to Tensay (2015), abiotic factors limiting yields of mung bean in terms of both quality and quantity are extreme drought, cold weather, untimely rain (rain after pod filling), and the type of soil used for cultivating it. Biotic factors limiting mung bean productivity include weeds, diseases, and insect pests at any growth stage (Tensay, 2015). Chadha (2010) reported that all parts of crop plant including root, stem, branches, petiole, leaves, pods, and seeds of the crops are vulnerable to disease and pest.

Weed is one of the most important factors responsible for the low yield of mung bean. Weed can reduce mung bean yield from 65.4% to 79.0% (Dungarwal *et al*., 2003). It reduces yield in quality and quantity due to competition for nutrients, light, space, water, etc., which consequently, reduces the market value of the turnout (Arif *et al*., 2006). Weed is very competitive against mung bean and therefore, weed control is essential for mung bean production (Islam *et al.*, 2019). Hand weeding is an important traditional activity made by local farmers to reduce and/or remove unnecessary plants grown with crops. All types of weeds affect and slightly reduce the crop plant, particularly climber weeds, grass, and herbs. A similar study conducted by Yadollahi *et al*. (2014), a product of mung bean decreased due to the competition ability of weed.

Different growth stages of mung beans such as emergence, flowering, and pod setting are greatly hampered by weeds. Weed infestation at these stages causes low pod setting and ultimately yield reduces (Hossain *et al*., 1990). In any crop or cropping sequence the weed density, type of the weeds, their persistence and crop management practices determine the magnitude of yield loss. The presence of weeds not only increases the production cost but also intensify disease and insect pest problem by serving as alternative hosts. Besides quantitative effects on yield, weeds deteriorate the quality of produce through the physical presence of their seeds and debris. Yield loss in crops due to weeds is influenced by several environmental, plant, and soil factors and varies across the location due to the variability of these factors. Previous studies revealed that weed interference in mung bean can reduce its grain yield by as much as 87% (Chauhan *et al*., 2017). Weed infestation can also reduce the grain quality of mung bean.

Weed management is an important key factor for enhancing the productivity of mung beans as weeds compete for nutrients, water, light, and space with crop plants during the early growth period (Chaudhari *et al*., 2016). Weeds can be controlled by different mthods including manual, mechanical, and chemical (herbicide) etc. However, manual and mechanical weeding are laborious, time-consuming, and costly. These days' herbicides are available in the markets which are capable of controlling weeds in crop fields.

Weed competition is maximal during the early stage of growth. However, the most critical period of weed competition varies with the growth behavior of the crop variety, environmental conditions, stage of growth, weed species presence, and intensity of weed infestation. Weed control is a major problem in legumes, because of the slow growth of seedlings and hence most of the fast-growing weeds smother pulse crops. Weed competition is very severe during rainy periods, particularly at the early stages (30 to 45 days after sowing) of the legume crops and hence early weed control is essential. Herbicides inhibit weed growth for a considerable period after their application as reported by Gupta (2003). However, little information is available regarding the herbicide that is suitable for either pre-emergence or post-emergence application for mung bean.

In the current study area, mung bean is mostly grown by smallholder farmers under rain fed conditions and its productivity is lower than other pulse crops. Insufficient management of the crop like weeding in low productivity of mung bean in the study areas. The prevalence of traditional crop production methods of mung bean, such as ox-plowing cannot disturb the soil weed seed banks as a result the weed seed germinates easily and competes for nutrients, minerals, light, space, and water. The suboptimal practice of farmers direct sowing without proper land preparation and hand weeding contributes to low productivity of mung bean. This study was carried out to evaluate different weed management practices to limit weed infestation and increase mung bean productivity.

## Objectives

### General Objective

- To contribute towards improved production of mung beans by employing effective methods of weed control.

### Specific Objectives

- To determine the efficacy of different weed management practices in mung bean.
- To determine the cost-effectiveness of different weed management practices in mung bean.
- To identify the effect of weed management practices on phenology, growth, yield components, and yield of mung bean at Teppi, South West Ethiopia.

# 2. LITERATURE REVIEW

## 2.1. Description of mung bean

Mung bean is native to Asia and almost 90% of the mung bean production is found in Asia, where India, China, Pakistan, and Thailand are among the most important producers (Lambrides *et al.*, 2007). It is also cultivated in Australia, the United States, and in local areas of many Caribbean, African, and Middle Eastern Countries (Singh *et al.*, 2021).. Mung beans contain about 60% carbohydrates and are rich in protein, fat, vitamins, and minerals. Mung beans not only have good nutritional value but also show hypolipidemic, cholesterol-lowering, antiallergy, antibacterial, and antitumor effects (Tong, 2020). In the world mung bean products include mung bean soups, sprouts, cakes, noodles, wine, and flour (Tong, 2020). In Ethiopia, it is only produced as a cash crop to generate income by selling it to exporters. The regional agricultural bureaus and market actors estimate that close to 90% of the total production is marketable surplus.

Mung bean is a warm-season annual legume that is a drought-resistant crop with an optimum temperature range of 27-30°C for good production. It is a very early maturing quick crop, requiring 75-90 days to mature (Wondimkun, 2023). Seeds can be planted when the minimum temperature is above 15°C (Fujino and Matsuda, 2010). Mung bean is usually grown at low to medium elevations in the tropics as a rain-fed crop. It ranks second to drought resistance after soybean (Ghafoor *et al.*, 1998). The most important characteristic of the mung bean crop is its short life cycle and ability of biological nitrogen fixation in root nodules by a symbiotic relationship with a specific bacterium that fulfills the crop's needs for nitrogen. Because of these characteristics, mung bean is a useful crop in drier areas and has a good potential for crop rotation and relay cropping with cereals using residual moisture in the soil. It is usually sown at "Belge" lean season between February to April and "Mehere" between July to August when the rain starts to end (Wondimkun, 2023).

Mung bean plants have a growth period of 90 to 120 days with quality beans being produced by judicious choice of variety with proper application of agronomic practice. Harvesting of the seed pods is critical and must be synchronized to ensure at least 95% is at the correct state of maturity and a moisture content of 14–16% (Keith and Barbara, 2014). Currently, the global food supply is based on 30 crops, supplying 95% of our daily caloric intake, 60% of which is provided by just four crops, i.e. rice, wheat, maize, and potatoes. However, minor crops are still important at the local, regional, and national levels. In many cases, these minor crops are staples, contributing to the food supply in certain periods and to a nutritionally balanced diet. Minor crops are sometimes also well-adapted to marginal conditions (Hilgar *et al.,* 2015). Mung bean is such a minor crop that dry-land smallholder farmers can use to break the downward spiral, and increase the profitability and sustainability of their farms through improved soil fertility (Lambrides *et al.*, 2007).

## 2.2. Mung Bean Production in Ethiopia

According to ECX (2014), mung bean is being cultivated as a recently introduced crop in Ethiopia. It has been introduced to different regions of Ethiopia like Shewa, Hararge, Ilubabor, Gamogofa, Tigray, and Gondar (Keatinge *et al.,* 2011). In some moisture-stress areas of southern Ethiopia (Gofa, Konso, south Omo zone, and Konta) farmers have been producing mung bean to supplement their protein needs, effectively using the scanty rainfall, and hence its consumption is not widespread like the other pulses (Asrate *et al.*, 2012). Farmers plant mung beans in border areas to make the soil fertile without providing fertilizer on the land. In Ethiopia, mung bean landraces are similar from one village to another and cultivated by traditional farming. The recently introduced mung bean is also grown in limited areas in smaller quantities. The maximum grain yield of Mung bean was 786.8kg/ha which was harvested from the Borada research canter of the west hararge of Ethiopia (Habte, 2018). In Ethiopia, Mung bean is produced in 150,000 to 200,000 quintals per year. It is one of the countries of East Africa suffering from drought because of climate change with a high prevalence of food security. However, despite its multi-dimensional importance very little attention has been paid to its productivity improvement in the country. Dryland areas are experiencing low agricultural yields due to severe water shortages and salinity, leading to food scarcity. Mung bean is gaining attention as a short-season crop that can tolerate dry land conditions, and fix atmospheric nitrogen, decreasing soil nutrient depletion (Mohammed *et al*., 2015).

## 2.3. Morphological Description of Mung Bean

Mung bean is an annual crop cultivated mostly in rotation with cereals (Rashid, 2013). The growth habit can be dwarf, erect, determinate, non-branching, or indeterminate and semi-prostrate (Imrie, 1995). The leaves are trifoliate with large, ovate, entire leaflets that are rarely lobed, membranous leaflets with densely pubescent stems, peduncles, and petioles. Pods are born at or above the leaf canopy with sub-cylindrical, straight, or slightly curved shapes (Nawale, 2001). Mostly, mung bean is characterized by broader stipules, pale yellow flowers to greenish-yellow with axillary or terminal raceme, more ovules per pod, and a spreading pod with short brown hairs (Sangsiri, 2009). It is characterized by an upright habit and relatively synchronous flowering (Paudel, 2008). The mung bean seed coat has two layers containing an outer columnar layer that may contain deep blue, and black pigment and a green parenchyma layer, which contains various concentrations of chloroplasts (Rashid, 2013). The germination of mung bean is epigeal with the cotyledons and stem emerging from the seedbed (Arain, 2012).

## 2.4. Agroecological Requirement of Mung Bean

Mung bean is an important food legume cultivated in many tropical and sub-tropical parts of the world (Iqbal, 2010). It is also cultivated in semi-arid conditions of the tropical and warm regions of the world (Rahim *et al*., 2008; Sangsiri, 2009). It is a warm season crop requiring 90-120 days with optimum temperature ranges from 27$^{O}$C-30$^{O}$C; the time from sowing to maturity depends on the variety of the crop. Adequate rainfall is required from flowering to late pod filling to achieve high grain yield (Zare *et al*., 2013). It is mostly grown during the summer season when the temperatures and light irradiance fluctuate frequently. In some mung bean growing areas of the tropics, the early summer is characterized by a high temperature of more than 30$^{O}$C, while the late summer has a high temperature and bright sunlight (Karim *et al*., 2003). Among the ecological requirements for mung bean, temperatures and light intensity influence the photosynthetic effectiveness of the leaves in the critical stage of growth (Karim *et al*., 2003).

## 2.5. Cropping System of Mung Bean

Mung bean is cultivated mostly in intercropping and sole cropping systems. Intercropping is the practice of growing two or more crops simultaneously in the same field in a particular growing season. It has probable advantages for increasing sustainability in crop production and producing two or more crops in a particular cropping season for cultivars. According to Onuh *et al*. (2011), intercropping mung bean with other crops confers advantages such as improved soil fertility through nitrogen fixation, shading of the soil surface, and protection against erosion. It also reduces the risk of damage due to biotic and abiotic factors. The morphological or physiological differences of the crops' root systems and canopy structure help to increase the productivity of the crop (Shahbazi and Sarajuoghi, 2012). Maize and mung bean intercropping are popular with farmers (Mobasser *et al*., 2014). Other mung bean intercropping systems include patch cropping, relay cropping, and alley cropping (Mobasser *et al*., 2014). Growing a single species of crop in a field at a time is termed sole cropping or monoculture. Some authors claim that mung bean is more effective in sole cropping than intercropping system in terms of total yield and products of the crop (Lertmongko *et al*., 2012; Onuh *et al*., 2011); this was due to bigger plants, more numerous leaves per plant and abundant shoot branches. The sole crop also had more root nodules and a deeper root system, which enabled it to absorb water from greater soil depths; this encouraged better photosynthetic activity for mung beans due to free from competition with others.

## 2.6. Crop Rotation System of Mung Bean

Crop rotation increases both land and crop productivity and is important for sustainable agriculture. Annual crop legumes grown in rotation with cereals contribute to the total amount of nitrogen in the soil and improve the yield of cereals (Ahmad *et al*., 2001). However, some rotation systems can be problematic. For example, poor soil physical conditions limit successful cropping of mung bean after rice. If seeds are sown too early after rice harvest, anaerobic conditions may reduce crop establishment and decrease yield potential (Kirchhoff and So, 2005). As it is a short-duration legume, it is mainly cultivated between rice-rice, rice-wheat, rice-potato-wheat, maize-wheat, cotton, and other cash crop to increase both land and crop productivity (Ebert, 2014). Mung bean has the capability of accumulating large amounts of vegetation in a short time. So, it also could be used as compost for soil improvement and by combining its remains into the soil after pods have been harvested at maturity. This can increase soil productivity for succeeding crops (Lertmongko *et al*., 2012). But in other places, such as Ethiopia, these residues are more highly valued as fodder and are thus fed to animals instead. Adding mung bean to the cereal cropping system has the potential to increase farm income, improve human health and soil productivity, save irrigation water, and promote the long-term sustainability of agriculture (Chadha, 2010).

## 2.7. Use Values of Mung Bean

Among pulses, mung bean is an important cash crop in the world (Somta and Srinives, 2007; Pandey *et al*., 2011). It is a vital crop in developing countries where it is consumed as dry seeds, fresh green pods, or leaves due to its high protein, vitamin, and mineral content. It is also consumed as forage or green pods and seeds as vegetables (Tang *et al*., 2014; Das *et al*., 2014). Primarily, the purposes of this crop are for its protein-rich edible seeds and fresh sprouts. The seed of mung bean is mainly used for making soups, bread, and biscuits (Sehrawat *et al*., 2013). Other than food it is important to assist in the normal use of land, water resources, and enrichment of the soil through nitrogen fixation (Nawale, 2001). Adaptation to short growth duration, low water requirement, ability to increase soil fertility, and usefulness in crop rotation practices are other significances of mung bean (Das *et al*., 2014). The capacity to form important ecological relationships with the majority of invisible soil microbes for the achievement of limiting macro and micronutrients, especially in nutrient-poor ecosystems increases the productivity of crops and land (Yasmeen *et al*., 2012). The ability to improve soil fertility by fixing atmospheric nitrogen into available form with the help of rhizobia species for plant growth and development is characteristic of mung bean (Singh *et al*., 2014; Jat *et al*., 2012).

**Table 1. Estimates of the amount of nitrogen fixed by different legumes**

| Legume Species | Nitrogen fixed (kg/ha/yr) | Source |
|---|---|---|
| Faba bean | 82-174 | Peoples and Griffiths, 2009 |
| Lentil | 60-110 | Peoples and Griffiths, 2009 |
| Field pea | 85-166 | Peoples and Griffiths, 2009 |
| Mung bean | 58-109 | Singh and Singh, 2011 |

*locations have an impact on the amount of nitrogen to be fixing

The symbiotic relation of mung bean is mainly affected by soil type, plant growth rate, plant signals, root geometry, mineral elements level in the soil, shade, light, and temperature occurrence resulting in loss of crop final yield (Yasmeen *et al*., 2012). Precisely symbiotic relations have a very good ability to enhance the physical, chemical, and biological properties of soil therefore, it is considered an important component of sustainable agricultural production (Lertmongko *et al*., 2012). Bio-organic fertilizer is used as a foliar spray for improving quantitative aspects of root and shoots parts growth of mung beans (Khalilzadeh *et al*., 2012). Those who can benefit most from mung bean are the poor, especially children and women whose diets lack much-needed protein and iron (Shanmugasundaram, 2011).

Mung bean also contains a lot of minerals like calcium and potassium, which are essential for enhancing the strength of bones and teeth (Minh, 2014). Taking mung bean as food helps prevent the loss of nails, hair, and breast cancer for women (Gwag, 2010). Mung bean is rich in lecithin which reduces liver fat and regulates the normal functioning of the liver. It is also used to decrease the absorption of toxic substances, reduce the risk of hypercholesterolemia and coronary heart disease, and prevent cancer (Tang *et al*., 2014). Other properties like easy digestibility and low proportions of flatulence factors also add to its value among pulse crops

(Das *et al*., 2014). Not only dry seed but also mung bean sprouts are an important food with an excellent source of protein, calcium, and vitamin C (Gwag, 2010).

## 2.8. Economic Importance of Weeds

Despite the negative impacts of weeds both in agricultural and non-agricultural areas, their beneficial impacts on man, the environment and animals cannot be overemphasized. Some beneficial weeds repel insects and other pests through their smell. The recent surge of public interest in medicinal ethno botany stems perhaps from the exotic association of medicinal weed plants with primary tropical rainforests. They are an important source of medicines for indigenous people and have a highly significant over-representation in indigenous pharmacopeias about other plants. Sometimes weeds can serve as food because of their nutritional contents. Most of them are palatable and of acceptable quality for animal feed if they are grazed or cut when young. Wild oat patches are particularly good green forage, while other grassy weeds, such as quack grass, are also of high quality, generally similar to tame grasses. Weedy cereal crops can be cut when green, providing good livestock feed and reducing weed seed return in those areas (Ekwealor *et al*., 2019). The presence of weeds in the crop field also provides a series of agronomic and ecological benefits when they occur, especially at low densities (Scavo and Mauromicale, 2020).

## 2.9. Negative Impacts of Weeds

Weeds are one of the main factors restricting food production in farming systems all over the world. By growing simultaneously with crops, weeds decrease productivity and even the quality of the harvested product, whether due to competition for water, sunlight, nutrients, and space, allelopathy (Monteiro *et al*., 2021), parasitism (Scavo and Mauromicale, 2020). Furthermore, weeds are the costliest category of agricultural threats, causing more than 45% of loss in yields of field crops, when compared to crop diseases 25% or insect pests 20% (Gnanavel, 2015). Yield losses caused by weeds depend on several factors, such as weed emergence time, weed density, type of weeds and crops, etc. Uncontrolled weeds can result in 100% yield loss (Chauhan, 2020). In addition, weeds interact with other biological agents of the ecosystem, acting as a host for insects and pathogens (fungi and bacteria), which can cause serious damage to crop plants (Esposito *et al*., 2021). Moreover, weeds decrease land value (especially perennial and parasitic weeds) and interfere with water management (e.g., increased losses through evapotranspiration, reduced water flow in irrigation ditches, etc. (Scavo and Mauromicale, 2020). Serious weed problems develop when a susceptible crop, a large weed seed bank in the soil (including both true seeds and vegetative propagules of perennial weeds), and a favorable environment for weed growth occur (Schonbeck, 2011). All weeds' interactions with human goals represent a permanent constraint to human activities and this justifies the employment of control tactics aimed at killing or managing as many weeds as possible. However, the complete eradication of actual (emerged plants) and potential (seed bank) weeds is unachievable (Radicetti and Mancinelli, 2021).

Weeds are problematic both in agricultural and non-agricultural areas so they potentially cause economic losses. Weeds are responsible for significant crop yield losses and financial losses in agricultural production in the order of 10% per year worldwide (Ekwealor *et al*., 2019). Their interference in crops dates back to the beginning of agriculture, and they have been able to persist, despite long-term control operations. They compete with other plants for limited resources (mainly nutrients, water, and light), and competition can be successful through the use of certain strategies. Chief among these strategies is allelopathy, where secondary compounds inhibit germination and growth of other plants, and, as a chemical defense against herbivores. Weeds can affect animals by providing an inadequate diet or a diet that is unpalatable because of chemical compounds in the weed. They can directly reduce the quality of animal products by affecting milk production and fleece or hide quality. Reproduction performance is affected by toxins that cause abortion or the killing of animals. Poisonous plants may contain one or more of hundreds of toxins from nearly major chemical groups, including alkaloids, glycosides, saponins, resinoids, oxalates, and nitrates (Kavaliauskaite and Bobinas, 2006; Ekwealor *et al*., 2019).

## 2.10. Weed Flora Composition in the Region

A survey of the weed flora in major crop fields in the South Western region is carried out during the rainy season from February to April and July to October 2016. One hundred thirty-five weed species are collected and identified from the survey of 180 fields of selected districts of the Bench Maji, Keffa, and Sheka Zones. These weed species are distributed in 135 genera within 35 families. The large majority of these, 109 are dicotyledonous species, 22 grasses, and 4 sedges. The seven major families, based on the number of taxa were: Asteraceae (15.6%), Poaceae (14.8%), Fabaceae (8.9%), Polygonaceae (5.2%), Acanthaceae (4.4%), Solanaceae (4.4%) and Amaranthaceae (3.0%) accounted for (56.3%) of the total weed flora (Getachew *et al*., 2018). Moreover, Asteraceae, Poaceae, and Fabaceae are also found to be most important in other studies in the tropics. These families are also reported to be economically important and common in different parts of the country (Gidesa *et al*., 2016). Moreover, these families are very rich in species diversity so it is usual that they contain many plant species. Asteraceae, Poaceae, and Fabaceae were also found to be most important in other studies in the tropics (Belachew and Tessema, 2015).

## 2.11. Weeding Frequency and Abundance in the Region

The weed flora in the arable fields of Bench Maji, Keffa, and Sheka Zones were dominated by a large number of species. This large number of weeds in arable fields can be attributed to the long duration of rainfall, heavy fertilization, and constant moist conditions which are required by the crops that create conducive conditions for the growth of weeds. Averaged over locations, the frequency value of the species ranged from 7-87%. The highest frequency value (87%) was recorded by *Amaranthus graecizans* followed by *Mimosa invisa* (78%) and *Amaranthus hybridus* (75%). Whereas, the least frequency value was recorded from *Galinsoga parviflora* (7%) followed by *Digitaria abyssinica*, and *Phalaris paradoxa* that recorded (4%) (Getachew *et al*., 2018). The abundance value of the species varied from 0.04 to 2.4 plants $m^{-2}$. The highest abundance value (2.4 plants $m^{-2}$) is recorded by *M. invisa* followed by *A. hybridus* (2.16 plants $m^{-2}$), *Cynodon dactylon* (1.72 plants $m^{-2}$), and *A. spinosus* (1.68 plants $m^{-2}$). Whereas, the least abundance value (0.04 plants $m^{-2}$) is recorded for *Tragus racemosus* (Getachew *et al*., 2018). Similar results are found from Roger *et al*., (2015); who reported that if the specific plant species had higher frequency and dominance value, it indicate the economic importance of it. Therefore, *Mimosa invesa* is one of the major social, environmental, and economic threats in the study area. In general, there were positive and significant correlations among frequency, abundance, and dominance that are the higher the frequency of the weed species, the higher its abundance and dominance, and vice versa (Getachew *et al*., 2018).

## 2.12. Crop Weed Competition

The life cycle of most of the weeds coincides with that of the crop they invade, thus ensuring the mixing of their seed with those of the crops (Mahroof *et al*., 2009). Due to their diversity, weeds are a major threat to agriculture and they out-compete crops for natural resource utilization (Chhodavadia *et al*., 2012). Crop weed competition has been established as a major limiting factor for its low productivity causing yield reductions to the extent of 40 to 80% depending upon the type and density of weed species present in the field. Weeds, being naturally hardy and emerging faster, cause severe competition at an early stage of the crop concerning light, nutrients, water, and space reflecting in a considerable reduction in crop yield. It becomes essential to study crop-weed competition scientifically and how it can be reduced to the maximum (Phajage *et al*., 2014).

Weed competition with mung beans persisting for 20-30 days after emergence was very critical and prolonged competition resulted in substantial yield reduction (Naeem *et al*., 1999). Weed competition is very severe during rainy periods, particularly at the early stages (30 to 45 days after sowing) of the pulse crops and hence early weed control is essential (Aktar *et al*., 2015). The initial 45 days period is considered to be the critical period concerning crop weed competition in mung bean. In general, competition between crops and weeds is more severe when the competing plants have similar vegetative habits and demands upon resources (Singh *et al*., 2018).

## 2.13. Weed Management Practices

Managing weeds has always been placed at the center of agricultural activity by farmers since ancient times (Scavo and Mauromicale, 2020). The control of weeds is a big challenge in agriculture and in many cases a complex, controversial, and expensive problem to solve (PAN, 2017). Weed management accounts for nearly one-third of the total cost of the production of field crops (Gnanavel, 2015). This agronomic practice goes beyond the control of existing weed problems and places greater emphasis on preventing weed reproduction, reducing weed emergence after crop planting, and minimizing weed competition with the crop (Ghosheh, 2010). Currently, weed management in agricultural systems branches out into two distinct directions corresponding to different approaches. On the one hand, is the widespread use of synthetic herbicides, while on the other, weed control is widely based on mechanical, cultural, and physical methods (Scavo and Mauromicale, 2020).

### 2.13.1. Preventive Weed Control

Preventing the introduction of new weed species is highly desirable and less costly than controlling them after they are established (Radosevich *et al*., 1997). Measures that should be taken to prevent the introduction of new weed species include a national quarantine system, use of weed-free crop seeds, avoidance of bringing in nursery soils containing weed seeds or vegetative parts, cleaning farm equipment, avoidance of bringing manure, mulches, etc. from other farms, keeping irrigation canals free of weeds, controlling the movement of livestock between fields and preventing weeds from setting seed (Akobundu, 1987).

### 2.13.2. Cultural Weed Control

Cultural weed management includes practices that favor crops in preference to weeds. These practices include Hand weeding, mechanical weeding, burning, flooding, mulching, and crop rotation (Ennis, 1977). Hand weeding is probably the oldest method of weed control and consists of hand pulling; slashing, hoeing, and mowing of weeds (Akobundu, 1987). This may be the only practical method available to small farmers. Other than requiring labor, it usually requires no further cash outlay. This is an advantage in situations where cash is not readily available but where labor is from the farmer's immediate family or through non-cash exchange. It may be the only method that can be used to weed broadcast-seeded crops where herbicides are not available (FAO, 1989).

Hand weeding is intensive and slow compared to other methods. It may damage crop roots. It is usually delayed until the weeds are easily seen and can be grasped. Yield losses can occur before weeds are removed. Because Hand weeding is intensive, farmers may wait until the weeds are quite large to do only one weeding; whereas two weeding when the weeds are small is better in terms of reducing yield losses. In rainy weather, Hand weeding may be difficult and possibly damage the crop. Besides, if weeds are simply piled up after pulling, some species may re-root and grow again. Some weeds are not easily removed by Hand weeding. Handheld tools will make weeding faster and easier compared to hand pulling, but have the same general advantages and disadvantages (FAO, 1989).

Mechanical weeding includes all weed control practices where a mechanical device is used for weed control with animals or fossil fuel as the source of energy. Good weed control can be achieved by a rigid harrow before and after weed emergence. Weeds are sensitive to harrowing only at cotyledons to the rosette stage because a harrow has a burial effect. Farmers usually carry out two distinct types of tillage for weed control purposes; these are delayed tillage and blind tillage (Ennis, 1977). Delayed tillage involves preparing the seedbed and waiting until weeds emerge before lightly cultivating the soil again and planting the crop seeds. Light tillage is when crop seeds are planted after the usual land preparation and lightly cultivated after weeds but before crop emergence (Akobundu, 1987; Radosevnich *et al*., 1997).

Mechanical control methods are used on a large scale but, the cost is very high, unfavorable weather and soil conditions and labor are not available at the proper time. The chemical control of weeds is effective and economical when applied in the initial stages of growth.

Burning weeding has been used to control weeds. This method is used to get rid of undesirable crop residues which may harbor diseases as well as weed seeds. It is also used in pasture areas to encourage more palatable species. It is generally not useful in most Ethiopian conditions (FAO, 1989). Most burning is done before crops are planted. It often destroys many broadleaf weeds, but it can lead to the predominance of perennial species (Anon, 1986). Uncontrolled burning is deleterious to the environment; it can cause soil erosion on slopes, and destruction to property and life (Akobundu, 1987; El Mahi, 2004).

Crop rotation plays a long-term role in weed control by preventing particular weed species from adapting themselves to the growth cycle of a specific crop (Akobundu, 1987). By changing from one crop to another, the different growth habits and associated agronomic practices will help to change the environmental and management conditions encountered by the weeds. This represents a change of strategy that will help to avoid selective pressures that may favor one species over another (Akobundu, 1987).

### 2.13.3. Biological Control

This method uses a biological agent other than man to control weeds. Multiple host agents are those that can control a variety of weed species and are largely nonspecific. Examples are goats, sheep, geese, and fish. These agents can be manipulated directly by man, are best used in non-crop situations, and will show selectivity by preferring certain species (FAO, 1989). Specific host agents are insect or disease organisms that affect a single host species (Bizualew, 2018). The influence of insects, mites, plant pathogens, and other organisms on plant growth is a natural process and has existed since the origin of plants (Anon, 1986). Biological weed control may be the most effective and environmentally friendly approach against invading plant species threatening and endangering ecosystems and wild species (Holden *et al*., 1992; Gupta, 2012; Bizualew, 2018).

### 2.13.4. Chemical Control of Weeds

Herbicides are chemical compounds used to kill or inhibit the growth of undesirable plants (Quantick, 1985). A successful herbicide should be safe for the crop with reliable performance and must not be influenced by soil or any environmental factors (El-Khair *et al*., 2019). Moreover, herbicides should have safety records for the environment and users alike (El-Khair *et al*., 2021). They act on weeds by contact or systemic action. They may be residual or non-residual. Time of application could be pre-planting, pre-emergence, or post-emergence. They could be used alone or in a mixture. Herbicides could be classified as grass or broad-leaf weed killers. However, some of them are effective in both (Ashton and Crafts, 1973). The use of post-emergence herbicides allows the growers to design effective control strategies against a particular weed spectrum in a given field (Hager and Renner, 1994).

Herbicide application occurs most frequently in row-crop farming, where they are applied before or during planting to maximize crop productivity by minimizing other vegetation. They also may be applied to crops in the fall, to improve harvesting. Herbicides can act by inhibiting cell division, photosynthesis, or amino acid production or by mimicking natural plant growth hormones, causing deformities (Ross and Childs, 1996). The potential effects of herbicides are strongly influenced by their toxic mode of action and their method of application (Duke, 1990). Effective weed control depends on the proper selection of herbicides, the type of weed flora infesting the crop, the time of application, and further use of the optimum dose of herbicide (Chum *et al*., 2010).

Pendimethalin is a selective pre-emergence herbicide used to control broadleaf weeds and grassy weed species in several crop and non-crop areas and on residential lawns and ornamentals. Formulations include liquid, solid, granular, emulsifiable concentrate, and dry flowable. Pendimethalin is applied by broadcast, chemigation, conservation tillage, containerized plant treatment, soil incorporation, and directed spray (EPA, 1997). Pendimethalin is a dinitroaniline herbicide that controls annual grasses including barnyard grass (*Echinochloa crus*), smooth crabgrass (*Digitaria ischaemum*), large crabgrass (*Digitaria sanguinalis*), fall panicum (Panicum dichotomiflorum), giant foxtail (*Setaria faberii*), (*S. viridis*), and yellow foxtail (*Setaria glauca*). Pendimethalin can also control certain annual broadleaved weeds such as common lamb's quarters (*Chenopodium album*) and redroot pigweed (*Amaranthus retroflexus*) including acetolactate synthase and triazine-resistant biotypes (OMAFRA, 2011).

Haloxyfop-R-methyl ester is a selective post-emergence herbicide used to control grass weeds and storks bill in many broadleaf crops, orchards, and forestry (Renshaw, D.W. and M. Tasheva. 2006). It's widely utilized for controlling gramineous weeds such as Barnyard grass, Green bristle grass, Alopecurus aequalis, Crabgrass, Annual bluegrass and Mole plant seed, Broad-leaved weeds such as purslane, solanum nigrum, cocklebur, bindweed, chenopodium album and goose grass herb, and sedge weeds in soybean and peanut fields, where in the broad-leaved weeds are difficult to be controlled. Haloxyfop-r-methyl ester containing herbicide composition has the characteristics of a wide weed control spectrum, safety on crops, and high efficiency. The highest rate of haloxyfop-r-methyl ester of the herbicide applied gives good weed control as compared to the lowest rates; this could be because herbicides exhibit their herbicidal effect with increasing dosage, which results in the drastic reduction of susceptible weeds that give rise to increased dry matter accumulation resulting to high pod yield (Ibrahim *et al*., 2016).

**Table 2. Herbicides registered for use in mung beans (2010).**

| Herbicide | Trade name | Timing | Registered in Ethiopia |
|---|---|---|---|
| Imazethapyr | Spinnaker 700 WDG | Pre-plant | |
| Pendimethalin | Pendamet 450 CS | Pre-emergent | ✓ |
| Trifluralin | Treflan 480 | Pre-plant | |
| Chlorthal-dimethayl | Dacthal 900 WG | Planting | |
| Acifluorfen | Blazer | Post-emergent | |
| Butroxydim | Factor WG | Post-emergent | |
| Clethodim | Select | Post-emergent | |
| Haloxyfop-R-methyl ester | Halo Super 10.8 EC | Post-emergent | ✓ |
| Quizalofo-P-ethyl | Targa | Post-emergent | |

The State of Queensland, Department of Employment, Economic Development and Innovation, 2010

### 2.13.5. Integrated Weed Management

Integration of weed control methods is an effective and workable practice that is ecologically and economically viable to the farmers. Herbicides constitute a highly efficient technique for controlling weeds hence increasing yields, improving quality, and reducing labor in crop production (Sill, 1982). According to Arevalo *et al*. (1992); and Cook *et al*. (1993), satisfactory weed control was achieved in mung bean by application of herbicides. However, commodity prices, herbicide resistance, environmental and human health hazards associated with herbicides, difficulty in use of mechanical weeding in heavy soil as receiving heavy rains limitations to effective weed management have forced mung bean growers to implement integrated weed management (IWM) practices. These include a combination of cultural, mechanical, and chemical weed management techniques (Burnside *et al*., 1998; Nano Alemu Dab and JJ Sharma, 2018). Integration of weed control methods implies that some short or long-term strategy is being systematically employed to reduce weed infestations. It involves a degree of foresight and predictability to plan treatments and integrate them into the cropping system (Bizualew, 2018).

# 3. MATERIAL AND METHODS

## 3.1. Description of Study Area

The study was carried out at Teppi Agricultural Research Center in 2022 cropping season, the site is located in the Sheka Zone of the South West Ethiopia Peoples' Regional state. The field has latitude and longitude of 7°12′N and 35°27′E, respectively, and an altitude of 1,200 meters above sea level. The area receives a mean annual rainfall of 1678 mm with an average minimum and maximum temperature of 15.4°c and 29.5°c, respectively. The soil textural class of the experimental area is clay with a fine texture of 30-80% with a pH of 6.9-8 (neutral to moderately alkaline) (Mequannit and Tefera, 2020).

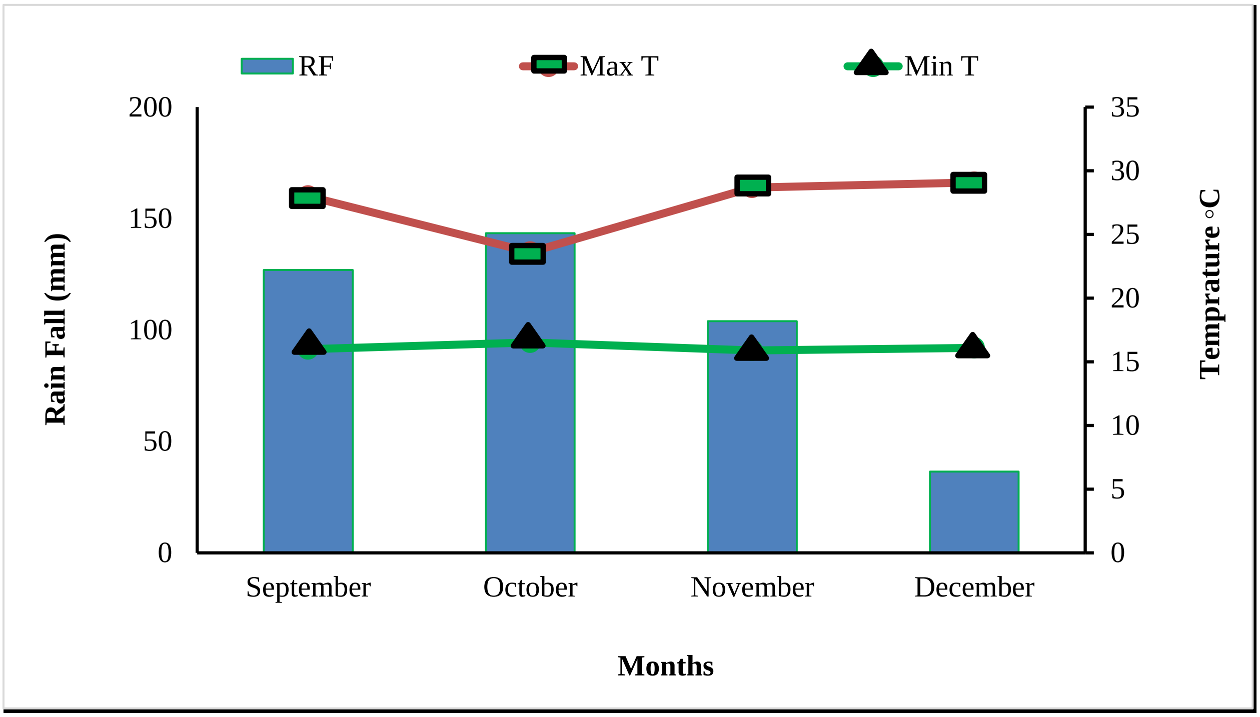


Figure 1. Rainfall (mm), minimum and maximum temperatures (°C) were recorded at Teppi during the 2022 cropping season (Source: Teppi Agricultural Research Institute Metrological Station).

### 3.2. Treatments and Experimental Design

The experiment was arranged in a Completely Randomized Block Design with three replications. The experiment had the following treatments.

T1= Control (No-weed control)

T2= Complete weed control

T3= Hand weeding at 4 WAS

T4= Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$

T5= Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$

T6= Pendimethalin at 1 kg ai $ha^{-1}$

T7= Pendimethalin at 1.5 kg ai $ha^{-1}$

T8= Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS

T9= Pendimethalin at 1 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS

### 3.3. Experimental Procedures

Pre-emergence herbicide was applied within three days after the crop sowing and post-emergence herbicides were applied at the two-leaf stage of the crop with doses mentioned in treatments. The gross plot size was 3 m × 2 m (6 $m^2$) having 10 rows and each plot contained 200 plants. The space between replications and plots was 1 m and 0.5 m with a net plot area of 2.7 m × 1.9 m (5.13 $m^2$) respectively. The spacing between intra-row spacing is 10 cm and inter-row spacing 30 cm and also has two rows for destructive sampling. N26 variety released from

Melkasa agricultural research center in 2011 used in the experimental field that grown at an altitude of 900-1,600 masl with a rainfall of 350-550 mm with recommended fertilizer rate $P_2O_5$:46, N:18 kg $ha^{-1}$. The maturity days for this crop are 65-80 with the white flower color and the grain yield accounts for 800-1,500 kg $ha^{-1}$ yield on research and the grain yield obtained from the farmer accounts for 500-1000 kg $ha^{-1}$

## 3.4. Data collected

### 3.4.1. Weed Parameters

The species of weeds present in the experimental field were recorded from weedy check plots by placing a quadrant (0.25 m × 0.25 m) randomly at two spots in each replication. The species were categorized into their botanical families with the aid of flora books (Melaku, 2008) and expertise. The weeds from the quadrant were counted and categorized (broadleaved, grass, and sedges). Data on weed density were taken 60 days after sowing and about 20 days before the expected crop harvest to avoid possible foliage and seed shedding.

$$RD\% = \frac{\text{Number of specific weed species}}{\text{Total number of weed species}} * 100\%$$

Aboveground weed dry biomass was collected from the same area as in the case of weed density data were recorded. The samples were sun-dried for three days and thereafter the samples were oven-dried at $70^{O}C$ for 48 hours to determine the weight.

The intensity of weed infestation was calculated as:

$$\text{Weed infestation} = \frac{\text{Weed species population}}{\text{Total weed population}} * 100\%$$

Weed control efficiency (WCE) (%) was calculated using the formula:

$$WCE = \frac{X - Y}{X} * 100\%$$

Where, X = Number or dry weight of weeds in the unweeded plot and Y = Number or dry weight of weeds in the treated plot.

### 3.4.2. Phenology Parameters

Crop plant stands in the net plot area were counted at harvest and converted into plants $ha^{-1}$.

Days to flowering were recorded as the number of days from sowing to the time when 50% of the ten pre-tagged plants showed their first flower.

Physiological maturity was recorded in each plot, as the number of days from sowing to 90% of the ten pre-tagged plant leaves showed yellow color and their pods turned to darker or black color.

### 3.4.3. Growth Parameters

Plant height was recorded from ten randomly taken plants per net plot area before harvesting from the base of the plant to the tip of the main stem.

The leaf area index was calculated as the ratio of total leaf area per three plants ($cm^2$) per area of land occupied by the plants. Leaf area sample was taken from the destructive sampling plants.

$$LAI = \frac{\text{Leaf area per plant } (cm^2)}{\text{Ground area (plant spacing) } cm^2}$$

The effective number of nodules and their dry weight were measured from the bulk of roots of three randomly taken plants from destructive rows in each treatment where they were carefully excavated at 50% flowering for nodulation study. Roots were carefully washed using tap water on a sieve and nodules were separated and counted. The effectiveness of the nodules was checked by cutting the nodule for color judgment as a percentage which is pink (effective) and cream white (ineffective).

The nodules were placed at 70$^{O}$C for 48 hours in an oven to determine nodule dry weight per plant.

#### 3.4.4. Yield and Yield Components

The total number of pods was counted from the ten randomly selected plants and ten randomly taken pods were used to determine the number of seeds pod$^{-1}$.

A hundred seeds were counted from the harvested bulk of each plot and their weight was recorded and adjusted to 10.5% moisture content.

The aboveground biomass of the oven-dried plants was determined from ten randomly taken plant samples from the net plot area. This was multiplied by the number of plants per net plot area and was used to calculate the harvest index as the ratio of grain yield to total aboveground dry biomass yield. The moisture content was determined for each treatment by using a moisture meter and grain yield was adjusted to 10.5% moisture content using the formula:

$$\text{Adjusted yield (kg)} = \frac{\text{Recorded seed weight x 100-M}}{\text{100-D}}$$

Where M is the measured moisture content in grain and D is the designated moisture content.

Plants from the net plot area were harvested leaving the border rows to determine grain yield per hectare.

The Harvest index was calculated using the formula:

$$HI = \frac{\text{Grain yield}}{\text{Dry biomass weight}} * 100\%$$

Yield loss was determined as a percentage of the difference between weeded plots (completely weed-free) and yield in a particular treatment.

$$YL = \frac{(Y1\text{-}Y2)}{Y1} * 100\%$$

Y1= Grain yield in the complete weed control plot and Y2= Grain yield in the treated plot.

## 3.5. Data Analysis

Collected data subjected to analysis of variance (ANOVA) using SAS statistical software version 9.3 with a General Linear Model (GLM) procedure. Means were separated by LSD at a 5% probability level.

### 3.5.1. Cost Benefit Analysis

The economic analysis was performed using the partial budget analysis procedure described by (CIMMYT, 1988). The price of mung bean was the average open market price at Teppi, which was 60 ETB per kg. The net income and other economic analyses are based on the formula developed by CIMMYT and are given as follows:

The total field profit (gross field benefits [GFB]) (ETB $ha^{-1}$) was calculated by multiplying the field/farm price obtained by farmers when they sell their crops by the adjusted yield.

GFB = Adjusted grain yield (AGY) × the field/farm price of the crop.

Total variable cost (TVC) (ETB $ha^{-1}$) was calculated by adding up the costs that vary due to treatment differences including the chemical cost, chemical spraying, and weeding practice. The costs of other inputs and production practices, such as labor costs for land preparation, planting, harvesting, and threshing, were considered the same for all treatments or plots. Net benefit (NB) (ETB $ha^{-1}$) was calculated by subtracting the TVCs from GFB for each treatment.

NB= GFB – TVC

By dividing the change in NB by the change in TVC and multiplying by 100, the marginal rate of return (MRR) (%) was calculated.

$$MRR = \frac{\Delta\ NB}{\Delta\ TVC} \times 100\%$$

# 4. RESULTS AND DISCUSSIONS

## 4.1. Weed parameters

### 4.1.1. Weed species

The experimental field was infested with different types of weed species, which include grass, sedge, and broadleaf weeds (Table 3). Twelve weed species distributed in eight families identified infesting mung bean from the study area. The four major families, based on the number of taxa were: Asteraceae (47.7%), Poaceae (8.7%), Polygonaceae (1%), and Amaranthaceae (7.3%) which accounted for (64.7%) of the total weed flora. Cyperaceae accounted only for 7.1% of the total weed flora. This result is in line with Getachew *et al*. (2018) who reported that Asteraceae, Poaceae, Polygonaceae, and Amaranthaceae were the most abundant weeds in the Teppi area. These families were also reported to be economically important and common in different parts of the country (Gidesa *et al*., 2016).

The experimental field was found to be infested with different species of grass, sedge, and broad-leaved weeds as presented in the table below (Table 3). The grass weeds were: *Cynodon dactylon*, while the broad-leaved weeds were: *Amaranthus spinosus, Bidens pilosa, Commelina benghalensis, Cuscuta campestris, Dichondra repens, Galinsoga parviflora, Parthenium hysterophorus, Portulaca oleracea, Portulaca quadrifida,* and *Rumex obtusifolius*, and the sedge weed was: *Cyperus esculentus*. The most dominant weed species was *G. parviflora* with a value of (34.2%) followed by *B. pilosa* (11.50%). Whereas, *R. obtusifolius* and *P. hysterophorus* were the least dominant weed species found in the experimental plots during sampling periods.

**Table 3. Weed flora and their relative dominance recorded in the experimental field of mung bean in 2022 main cropping season**

| Weed species | Family | Life Form (Category) | WD ($m^{-2}$) | RD (%) |
|---|---|---|---|---|
| *Amaranthus spinosus* L. | Amaranthaceae | Annual (Broadleaf) | 44 | 7.3 |
| *Bidens pilosa* L. | Asteraceae | Annual (Broadleaf) | 67 | 11.1 |
| *Commelina benghalensis* L. | Commelinaceae | Annual(Broadleaf) | 57 | 9.4 |
| *Cuscuta campestris* Yuncker. | Convolvulaceae | Annual (Broadleaf) | 19 | 3.1 |
| *Cynodon dactylon* L. | Poaceae | Perennial (Grass) | 53 | 8.7 |
| *Cyperus esculentus* L. | Cyperaceae | Perennial (Sedge) | 43 | 7.1 |
| *Dichondra repens* J. Forst. and G. Forst. | Convolvulaceae | Perennial (Broadleaf) | 38 | 6.3 |
| *Galinsoga parviflora* Cav. | Asteraceae | Annual (Broadleaf) | 206 | 34 |
| *Parthenium hysterophorus* L. | Asteraceae | Annual (Broadleaf) | 13 | 2.1 |
| *Portulaca oleracea* L. | Portulacaceae | Annual (Broadleaf) | 25 | 4.1 |
| *Portulaca quadrifida* L. | Portulacaceae | Annual (Broadleaf) | 34 | 5.6 |
| *Rumex obtusifolius L.* | Polygonaceae | Perennial (Broadleaf) | 7 | 1.2 |

RD= Relative dominance, WD= Weed density

#### 4.1.2. Weed density ($m^2$) at 60 days after sowing

The weed management practices significantly ($p < 0.001$) affected the weed density (Appendix i Table 1). Significantly the highest total grass, sedge, and broadleaf weeds density (606.0 $m^{-2}$) was recorded from the No-weed control plot, which was followed by Hand weeding at 4 WAS (291.7 $m^{-2}$) (Table 4). This resulted in the highest weed dry matter production (Table 7). This was because of the unchecked growth of weeds at all stages of crop growth. The lowest grass, sedge, and broadleaf weeds density (0.0 $m^{-2}$) were recorded from complete weed-free plots followed by pendimethalin at 1.5 kg ai $ha^{-1}$ (50.0 $m^{-2}$) herbicide applied plots. This result is in line with the findings of Faruq *et al*. (2018) who observed that the highest weed density of mung bean was recorded in weedy check and the lowest was observed in weed-free treatments.

**Table 4. The effect of weed management practices on weed density at 60 days after sowing at Teppi in 2022 main cropping season**

| | Weed density (m²) | | | |
|---|---|---|---|---|
| Treatment | Broadleaf | Sedge | Grass | Total |
| Control (No-weed control) | 568.0 a | 18.7 a | 19.3 a | 606.0 a |
| Complete weed control | 0.0 g | 0.0 f | 0.0 f | 0.0 g |
| Hand weeding at 4 WAS | 259.0 b | 16.7 ab | 16.0 b | 291.7 b |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha⁻ | 196.0 c | 11.3 cd | 14.0 bc | 221.3 c |
| Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$ | 74.7 e | 8.0 de | 11.3 cd | 94.0 e |
| Pendimethalin at 1 kg ai $ha^{-1}$ | 162.7 cd | 11.3 cd | 11.3 cd | 185.3 d |
| Pendimethalin at 1.5 kg ai $ha^{-1}$ | 38.0 f | 5.3 e | 6.7 e | 50.0 f |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 139.3 d | 12.7 bc | 12.0 c | 164.0 d |
| Pendimethalin at 1 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 57.3 ef | 8.7 cde | 8.7 de | 74.7 ef |
| LSD (0.05) | 33.7 | 4.2 | 3.1 | 33.1 |
| CV (%) | 11.7 | 23.5 | 16.4 | 10.2 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, CV= Coefficient of variance LSD (0.05)= Least significant difference at 5% probability level.

#### 4.1.3. Weed density ($m^{-2}$) at 20 days before harvest

The weed management practices significantly ($p<0.001$) affected the weed density (Appendix ii Table 2). Different weedicides reduced the growth of weeds in mung beans (Table 5). The highest grass, sedge, and broadleaf weeds population (682.7 $m^{-2}$) was recorded in the control treatment (No-weed control) which, resulted in the highest weed dry matter production (Table 7) and this might be due to the unchecked growth of weeds at all stages of crop growth. Among the different herbicides, the highest grass, sedge, and broadleaf weeds population (289.3 $m^{-2}$) was counted in pendimethalin at 1 kg ai $ha^{-1}$, which was statistically similar to Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ applied plot (288.0 $m^{-2}$). The lowest grass, sedge, and broadleaf weeds population (0.0 m⁻²) was recorded in complete weed control plots followed by pendimethalin at 1.5 kg ai ha⁻¹ (153.3 m⁻²) herbicide applied plot. This result is in line with Getachew *et al*. (2017) who reported that uncontrolled weed infestation resulted in significantly higher weed density in cowpeas.

**Table 5. The effect of weed management practices on weed density 20 days before harvest at Teppi in 2022 main cropping season**

| Treatment | Weed density ($m^2$) | | | |
|---|---|---|---|---|
| | Broadleaf | Sedge | Grass | Total |
| Control (No-weed control) | 608.7 $^{a}$ | 28.7 $^{a}$ | 45.3 $^{a}$ | 682.7 $^{a}$ |
| Complete weed control | 0.0 $^{f}$ | 0.0 $^{c}$ | 0.0 $^{e}$ | 0.0 $^{f}$ |
| Hand weeding at 4 WAS | 290.7 $^{b}$ | 28.0 $^{a}$ | 37.3 $^{b}$ | 356.0 $^{b}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha⁻ | 229.3 $^{c}$ | 25.3 $^{ab}$ | 33.3 $^{bc}$ | 288.0 $^{c}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$ | 162.7 $^{d}$ | 23.3 $^{b}$ | 28.0 $^{c}$ | 214.0 $^{d}$ |
| Pendimethalin at 1 kg ai $ha^{-1}$ | 228.7 $^{c}$ | 25.3 $^{ab}$ | 35.3 $^{bc}$ | 289.3 $^{c}$ |
| Pendimethalin at 1.5 kg ai $ha^{-1}$ | 114.0 $^{e}$ | 22.7 $^{b}$ | 16.7 $^{d}$ | 153.3 $^{e}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 188.7 $^{cd}$ | 22.7 $^{b}$ | 32.0 $^{bc}$ | 243.3 $^{d}$ |
| Pendimethalin at 1 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 155.3 $^{de}$ | 23.3 $^{b}$ | 32.7 $^{bc}$ | 211.3 $^{d}$ |
| LSD (0.05) | 44.1 | 3.8 | 7.3 | 43.4 |
| CV (%) | 11.6 | 9.8 | 14.6 | 9.3 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, CV= Coefficient of variance LSD (0.05)= Least significant difference at 5% probability level.

### 4.1.4. Weed infestation and Weed control efficiency

The weed management practices significantly ($p<0.001$) affected the weed infestation and weed control efficiency (Appendix iii Table 3). The lowest weed intensity of infestation was recorded in complete weed control treatment followed by pendimethalin at 1.5 kg ai $ha^{-1}$ in both 60 days after sowing and 20 days before harvest (Table 6). The highest weed intensity of infestation was recorded in the No-weed control plot followed by Hand weeding at 4 WAS in both 60 days after sowing and 20 days before harvest.

Meanwhile, the highest weed control efficiency was found in complete weed control treatment in both 60 days after sowing and 20 days before harvest. The second highest weed control efficiency was found in pendimethalin at 1.5 kg ai $ha^{-1}$ in both 60 days after sowing and 20 days before harvest and the third highest weed control efficiency was found in pendimethalin at 1 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS in both 60 days after sowing and 20 days before harvest. The lowest weed control efficiency was recorded in the No-weed control plot followed by Hand weeding at 4 WAS. Likewise, Chaudhari *et al*. (2016) reported that the highest weed control efficiency was recorded under weed-free treatment.

**Table 6. The effect of weed management practices on weed infestation and weed control efficiency of mung bean at Teppi in 2022 main cropping season**

| | WI (%) | | WCE (%) | |
|---|---|---|---|---|
| Treatment | 60 DAS | 20 DBH | 60 DAS | 20 DBH |
| Control (No-weed control) | 35.9 $^{a}$ | 28.0 $^{a}$ | 0.0 $^{g}$ | 0.0 $^{g}$ |
| Complete weed control | 0.0 $^{g}$ | 0.0 $^{f}$ | 100.0 $^{a}$ | 100.0 $^{a}$ |
| Hand weeding at 4 WAS | 17.3 $^{b}$ | 14.6 $^{b}$ | 59.4 $^{f}$ | 44.7 $^{f}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-}$ | 13.1 $^{c}$ | 11.8 $^{c}$ | 63.4 $^{ef}$ | 48.4 $^{f}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$ | 5.6 $^{e}$ | 8.9 $^{d}$ | 80.4 $^{c}$ | 71.3 $^{c}$ |
| Pendimethalin at 1 kg ai $ha^{-1}$ | 11.0 $^{d}$ | 11.9 $^{c}$ | 67.2 $^{e}$ | 55.8 $^{e}$ |
| Pendimethalin at 1.5 kg ai $ha^{-1}$ | 3.0 $^{f}$ | 6.3 $^{e}$ | 93.0 $^{b}$ | 87.3 $^{b}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 9.7 $^{d}$ | 10.0 $^{d}$ | 72.5 $^{d}$ | 64.0 $^{d}$ |
| Pendimethalin at 1 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 4.4 $^{ef}$ | 8.6 $^{d}$ | 82.1 $^{c}$ | 71.8 $^{c}$ |
| LSD (0.05) | 1.6 | 1.8 | 5.0 | 5.5 |
| CV (%) | 8.4 | 9.1 | 4.2 | 5.2 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, DAS= Days after sowing, DBH= Days before harvest, WCE= Weed control efficiency, WI= Weed infestation, CV= Coefficient of variance LSD (0.05)= Least significant difference at 5% probability level.

#### 4.1.5. Weed dry biomass (gm)

The weed management practices significantly ($p<0.001$) affected the weed density (Appendix iv Table 4). The weed biomass under the different weed control treatments was significantly different (Table 7). Both at 60 days after sowing and 20 days before harvest, the lowest dry biomass of weeds were recorded in complete weed control treatment. The second lower weed biomass was recorded in pendimethalin at 1.5 kg ai $ha^{-1}$ treatment and the third lower weed biomass was recorded in Pendimethalin at 1 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS. In line with this result, Chaudhari *et al*. (2016) reported that the lowest weed dry weight was from weed-free conditions, which was because of the lowest weed counts.

The highest weed dry weight was obtained from No-weed control treatment in both 60 days after sowing and 20 days before harvest followed by Hand weeding at 4 WAS weeding control treatment at both 60 days after sowing and 20 days before harvest. Similarly, Chaudhari *et al*. (2016) reported that among the different treatments the highest dry weight of weeds was recorded under the weedy check treatment. Likewise, Nano and Janmejai (2018) reported that the higher weed dry weight in weedy check was due to higher weed density that provided an opportunity for the weeds to compete vigorously for nutrients, space, light, water, and carbon dioxide resulting in higher biomass production.

**Table 7. The effect of weed management practices on above-ground weeds dry biomass (gm) of mung bean at Teppi in 2022 main cropping season**

| | Weed dry biomass (gm/m$^{-2}$) | |
|---|---|---|
| Treatment | 60 DAS | 20 DBH |
| Control (No-weed control) | 61.3 $^{a}$ | 52.0 $^{a}$ |
| Complete weed control | 0.0 $^{f}$ | 0.0 $^{g}$ |
| Hand weeding at 4 WAS | 24.7 $^{b}$ | 28.4 $^{b}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 22.3 $^{bc}$ | 26.5 $^{bc}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 12.1 $^{e}$ | 14.7 $^{ef}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 20.1 $^{cd}$ | 22.6 $^{cd}$ |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 4.2 $^{f}$ | 6.4 $^{f}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 16.8 $^{d}$ | 18.5 $^{de}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 11.0 $^{e}$ | 14.4 $^{e}$ |
| LSD (0.05) | 4.2 | 4.7 |
| CV (%) | 12.7 | 13.3 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, DAS= Days after sowing, DBH= Days before harvest, CV= Coefficient of variance LSD (0.05)= Least significant difference at 5% probability level.

## 4.2. Phenology Parameters

### 4.2.1. Days to 50% plant flowering

Days flowering was significantly ($p<0.001$) affected by weed management practice (Appendix v Table 5). Plants grown with complete weed control flowered early (50 days) followed by herbicide application Pendimethalin at 1.5 kg ai $ha^{-1}$ (51 days) as compared to the other treatments (Table 8). However, there was no statistical difference between pendimethalin at 1 kg ai $ha^{-1}$ and Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS about (53 days). The possible reason for the earlier flowering of mung bean in weed-free check than the other treatment was due to lower weed infestation in weed-free treatment.

The maximum value (56.7 days) was recorded under Control (No-weed control). The reason for delayed or late flowering of mung bean in weedy check was due to weed infestation during the growth of mung bean than the other treatments. The shading of mung beans by the canopy of weeds in the weedy check reduced the penetration of sunlight prolonged the vegetative growth and resulted in late flowering. In line with this result, Sunday and Udensi (2013) identified that the plants in Non-weeded plots took the longest time to reach 50% flowering in cowpeas. Similarly, Nano and Janmejai (2018) also reported that delayed days to flowering in faba beans were recorded under weedy check than the other treatments. Mengesha *et al*. (2015) also indicated that days to flowering in weed-free plots were significantly earlier than the other treatments, which indicates the number of days to flowering was significantly delayed due to weed infestation throughout the crop growth over other treatments. This might have reduced the vegetative growth and delayed the transition to the reproductive period (Mengesha *et al*., 2015).

**Table 8. The effect of weed management practices on days to 50% flowering (DTF) and maturity of mung bean at Teppi in 2022 main cropping season**

| Treatment | DTF | DTM |
|---|---|---|
| Control (No-weed control) | 56.7 [a] | 76.0 [a] |
| Complete weed control | 50.0 [f] | 70.0 [f] |
| Hand weeding at 4 WAS | 55.7 [a] | 75.0 [ab] |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha⁻ | 54.3 [b] | 74.0 [bc] |
| Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$ | 52.7 [cd] | 71.7 [de] |
| Pendimethalin at 1 kg ai $ha^{-1}$ | 53.3 [bc] | 73.3 [c] |
| Pendimethalin at 1.5 kg ai $ha^{-1}$ | 51.0 [ef] | 70.7 [ef] |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 53.7 [bc] | 72.7 [cd] |
| Pendimethalin at 1 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 52.0 [de] | 71.0 [def] |
| LSD (0.05) | 1.3 | 1.6 |
| CV (%) | 1.5 | 1.3 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, CV= Coefficient of variance, DTF= Date of flowering, DTM= Date of maturity, LSD (0.05) = Least significant difference at a 5% probability level.

### 4.2.2. Days to 90% physiological maturity

Days to physiological maturity significantly ($p<0.001$) affected by weed management practices (Appendix v Table 5). Mung bean in the complete weed control treated plots matured earlier (70 days) than the other treatments (Table 8). The mung bean under weed-free treatment matured early due to exposure of the crop to sunlight minimizing the vegetative growth of the crop. The control treatment (No-weed control) needed 76 days to reach 90% physiological maturity. The severe competition in the weedy check treatment prolonged the number of days required to reach physiological maturity compared with other treatments.

In the weedy check treatments, the weeds had a shading effect on the mung bean that reduced sunlight interception and caused a delay in days to physiological maturity. In line with the current result, Mengesha *et al*. (2015) also indicated that common bean reached 90% physiological maturity significantly earlier when weeds were controlled with two times hand-hoeing, compared with the other treatments that had a high density of weeds. The shading out of crop plants by the weeds might have reduced sunlight penetration, thereby prolonging the vegetative growth and resulting in delayed flowering and physiological maturity of common beans. Likewise, Sunday and Udensi (2013) reported that the plants under Not-weeded plots took the highest time to reach 90% physiological maturity in cowpeas. Similarly, Mitiku *et al*. (2012) reported that with the increase in the density of Parthenium, the duration required by the common bean plants to reach physiological maturity was prolonged.

## 4.3. Growth Parameters

### 4.3.1. Number of stands per hectares

Stand count significantly ($p<0.001$) affected by weed management practices (Appendix vi Table 6). The weed management options evaluated in this study significantly affected the number of stands per plot 20 days before harvest (Table 9). The highest number of stands before harvest was (304,444 plants/$ha^{-1}$) for plots treated with complete weed control. However, it was statistically similar to the numbers of stands obtained from pendimethalin at 1.5 kg ai $ha^{-1}$ (300,000 plants/$ha^{-1}$) herbicide-treated plot. The lowest stand (258,889 plants/$ha^{-1}$) was observed on the control treatment which was not weeded. The higher population density of the mung bean plants in plots that were treated with Hand weeding and herbicides could be because of the reduction in weed competition that enhanced the growth and development of the plants. Njoka *et al*. (2005) also reported that the mortality of plants increased with the increase in the plant density in the common bean. Similarly, Idris (2008) reported reduced plant competition and plant mortality at lower plant populations of faba bean.

**Table 9. The effect of weed management practices on stand counts of mung at Teppi in 2022 main cropping season**

| Treatment | SBH ($ha^{-1}$) |
|---|---|
| Control (No-weed control) | 258,889 $^{g}$ |
| Complete weed control | 304,444 $^{a}$ |
| Hand weeding at 4 WAS | 267,222 $^{f}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-}$ | 276,111 $^{e}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$ | 288,333 $^{bc}$ |
| Pendimethalin at 1 kg ai $ha^{-1}$ | 276,667 $^{de}$ |
| Pendimethalin at 1.5 kg ai $ha^{-1}$ | 300,000 $^{a}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 283,333 $^{cd}$ |
| Pendimethalin at 1 kg ai $ha^{-1}$ + Hand weeding at 4 WAS | 291,667 $^{b}$ |
| LSD (0.05) | 7139.6 |
| CV (%) | 1.5 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, CV= Coefficient of variance, LSD (0.05) = Least significant difference at a 5% probability level, SBH= Stands before harvest.

### 4.3.2. Plant height (cm)

Plant height was significantly ($p<0.001$) affected by the weed management practices (Appendix vi Table 6). The longest plant height (64.6 cm) was recorded in the control treatment (No-weed control) (Table 10). The second longest plant height (61.6 cm) was recorded in the Hand weeding at 4 WAS treatment but statistically was similar to Haloxyfop-R-methyl ester at 0.3 kg ai $ha^{-}$, Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$ and Pendimethalin at 1 kg ai $ha^{-1}$ herbicides application. The increment of mung bean heights under non-weeded treatments might be due to higher competition of crops with weeds to expose their canopy to sunlight. This result is in agreement with the report of Getachew *et al*. (2017) who observed an increase in the plant height of cowpea in the presence of severe weed interference.

Whereas the shortest plant height (43.8 cm) was recorded in complete weed control. In agreement with this result, Mengesha *et al*. (2015) reported that plants, that were kept weed-free throughout the season, were significantly shorter than the plants in plots in weedy check and once weeded at three or four weeks after emergence, and they asserted this finding to no or little competition posed by the weeds resulting in sturdy plants. The possible reason for the shorter height of mung bean under weed-free treatment was due to the absence of competition with weeds and instead of increasing in height, the crop produced a larger number of branches.

**Table 10. The effect of weed management practices on height (cm) of mung bean at Teppi in 2022 main cropping season**

| Treatment | PH (cm) | LAI |
|---|---|---|
| Control (No-weed control) | 64.6 $^{a}$ | 1.8 $^{e}$ |
| Complete weed control | 43.8 $^{d}$ | 3.6 $^{a}$ |
| Hand weeding at 4 WAS | 61.6 $^{ab}$ | 2.1 $^{de}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 59.6 $^{ab}$ | 2.2 $^{cde}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 57.5 $^{ab}$ | 2.5 $^{bcd}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 58.2 $^{ab}$ | 2.3 $^{cde}$ |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 50.0 $^{cd}$ | 3.2 $^{ab}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 56.4 $^{bc}$ | 2.3 $^{cde}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 55.8 $^{bc}$ | 2.8 $^{bc}$ |
| LSD (0.05) | 7.4 | 0.6 |
| CV (%) | 7.6 | 14.1 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, CV= Coefficient of variance, LAI= Leaf area index, LSD (0.05) = Least significant difference at a 5% probability level, PH= Plant height.

### 4.3.3. Leaf area index

The leaf area index (LAI) was significantly ($p<0.001$) affected by the weed management practices (Appendix vi Table 6). The highest LAI of 3.6 was obtained in the complete weed control treatment, while the lowest value of 1.8 was obtained from the Control treatment (No-weed control) (Table 10). In line with this result, Gashaw (2021) found that the largest value of the total leaf area of the faba bean from complete weed control treatment may be due to the longer and wider leaves. In addition, the weed-free plots had more stands due to higher branching capacity that might have led to an increase in the number of leaves and thereby increase in the total leaf area.

### 4.3.4. Number of nodules and nodules dry weight (mg)

The number of nodules and nodules dry weight were significantly ($p<0.001$) affected by weed management practices (Appendix vi Table 6). The highest number of nodules and their dry weight were recorded in the complete weed control plot followed by pendimethalin at 1.5 kg ai $ha^{-1}$ (Table 11). The lowest number of nodules and their dry weight were recorded in plots that were not weeded (control plot). Raman and Krishnamurthy (2005) and Patel *et al.* (2007), revealed that Hand weeding carried out at 20 and 40 DAS recorded the highest number of nodules, dry weight of nodules, and grain yield in chickpeas. Most of the nodules were pink (active) indicating that the weeding practices did not affect the effectiveness of the nodules.

**Table 11. The effect of weed management practices on the number of nodules and nodules dry weight of mung bean at Teppi in the 2022 main cropping season**

| Treatment | Number of nodules (per plant) | Nodulation dry weight (mg/plant) |
|---|---|---|
| Control (No-weed control) | 14.7 $^{f}$ | 0.1 $^{f}$ |
| Complete weed control | 37.3 $^{a}$ | 0.3 $^{a}$ |
| Hand weeding at 4 WAS | 19.3 $^{e}$ | 0.1 $^{ef}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 20.7 $^{de}$ | 0.2 $^{de}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 31.7 $^{b}$ | 0.2 $^{bc}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 23.3 $^{d}$ | 0.2 $^{cd}$ |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 36.3 $^{a}$ | 0.2 $^{ab}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 23.3 $^{d}$ | 0.2 $^{cd}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 27.0 $^{c}$ | 0.2 $^{bc}$ |
| LSD (0.05) | 3.3 | 0.0 |
| CV (%) | 7.4 | 15.8 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level, CV= Coefficient of variance, LSD (0.05) = Least significant difference at a 5% probability level.

## 4.4. Yield and Yield Components

### 4.4.1. Number of pods per plant

Number of pods per plant was significantly ($p<0.001$) affected by weed management practices (Appendix vii Table 7). Complete weed control treatments provided the highest values for the number of pods per plant (25.5) followed by pendimethalin at 1.5 kg ai ha$^{-1}$ (23.7) compared to all other wedding treatments (Table 12). The lowest number of pods per plant (11.6) was observed on the control treatment (No-weed control). The higher number of pods per plant in weed-free check might be due to the absence of competition for moisture, nutrients, and light from weeds as the plots were kept weed-free throughout the cropping season. Mengesha *et al*.

(2015) reported higher number of pods per plant of common bean in weed-free check treatment might be due to the absence of competition from weeds as the plots were kept weed-free throughout the cropping season. In addition, the development of a vigorous and higher number of leaves might have helped the crop to improve the photosynthetic efficiency that may have nourished a large number of pods (Hodgson and Blackman, 2005). Early weeding at two weeks after emergence also enhanced the number of pods per plant, which could be attributed to better competition of the crop for growth resources against weeds. Likewise, Ayaz, (2001) and Mengesha *et al*. (2015) stated that the number of pods produced per plant or maintained up to the final harvest depends on several environmental and management practices. Similar results were reported on chickpeas (Fathi *et al*., 2010; Tepe *et al*., 2011; Rashid *et al*., 2013) and mung beans (Khan *et al*., 2016) where weed interference decreased the number of pods per plant. Similarly, Zaher *et al*. (2014) observed that increasing the number of weeding significantly increased the number of pods per plant. Akter *et al*. (2013) also obtained a higher number of pods per plant with weeding at three stages with than no weeding treatment.

### 4.4.2. Number of seeds per pod

Number of seeds per pod was significantly ($p<0.001$) affected by weed management practices (Appendix vii Table 7). The highest number of seeds per pod (10.1) was recorded under complete weed control practices whereas the lowest number (7.7) of seeds per pod was recorded with no-weed control treatment (Table 12). Weed control with pendimethalin at 1.5 kg ai ha$^{-1}$ produced the second-highest number of seeds per pod (9.2). In line with this, Mengesha *et al*. (2015) found that common beans kept weed-free throughout the season had the highest number of seeds per pod, which was statistically at par with one-time Hand weeding performed two weeks after emergence and two-times weeding at two and five weeks after emergence. The weed-free plots produced the highest number of seeds per pod due to the absence of competition for nutrients, moisture, and light from the weeds and the presence of vigorous leaves that might have improved the photosynthetic efficiency of the crop. In line with this, Akter *et al*. (2013) reported a higher number of seeds per pod in three stages of weeding than no weeding treatment. Similar results were also reported by Zaher *et al*. (2014) where they observed increasing the frequency of weeding significantly increased the number of seeds per pod. Similarly, Khan *et al*. (2005) reported a higher number of seeds per pod with good weed control and integrated management of all inputs. Chattha *et al*. (2015) also obtained the highest number of seeds per pod of mung bean with good weed control.

**Table 12. The effect of weed management practices on yield and yield components of mung bean at Teppi in 2022 main cropping season**

| Treatment | NPdPP | NSPPd | HSW (gm) | DBW (ton/ha$^{-1}$) |
|---|---|---|---|---|
| Control (No-weed control) | 11.6 $^{e}$ | 7.7 $^{c}$ | 6.4 $^{f}$ | 1.6 $^{c}$ |
| Complete weed control | 25.5 $^{a}$ | 10.1 $^{a}$ | 8.7 $^{a}$ | 2.8 $^{a}$ |
| Hand weeding at 4 WAS | 11.8 $^{e}$ | 7.9 $^{c}$ | 6.5 $^{ef}$ | 2.1 $^{bc}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 12.6 $^{de}$ | 7.9 $^{c}$ | 6.6 $^{de}$ | 2.3 $^{ab}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 17.7 $^{bc}$ | 8.6 $^{bc}$ | 7.4 $^{b}$ | 2.6 $^{ab}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 13.3 $^{de}$ | 8.3 $^{bc}$ | 6.7 $^{d}$ | 2.6 $^{ab}$ |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 23.7 $^{a}$ | 9.2 $^{ab}$ | 8.6 $^{a}$ | 2.8 $^{a}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 15.2 $^{cd}$ | 9.0 $^{b}$ | 6.8 $^{c}$ | 2.6 $^{ab}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 19.7 $^{b}$ | 9.0 $^{b}$ | 7.5 $^{b}$ | 2.6 $^{ab}$ |
| LSD (0.05) | 3.1 | 1.0 | 0.2 | 0.6 |
| CV (%) | 10.6 | 6.8 | 1.3 | 13.4 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level. CV= Coefficient of variance, LSD (0.05) = Least significant difference at 5% probability level.

### 4.4.3. Hundred seed weight

Hundred seed weight was significantly ($p<0.001$) affected by weed management practices (Appendix vii Table 7). The highest number of hundred seed weight of mung bean (8.7 gm) was recorded under treatments that were kept weed-free throughout the season (Table 12). However, it was statistically similar with hundred seed weight of mung bean protected from weeds by pendimethalin at 1.5 kg ai $ha^{-1}$ (8.6 gm), followed by Haloxyfop-R-methyl ester at 0.6 kg ai $ha^{-1}$, and pendimethalin at 1 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS. The higher hundred seed weight in weed-free treatments might be due to reduced competition with weeds for growth resources, which might have enhanced the availability of nutrients and better translocation of photosynthesis from source to sink and resulted in a higher accumulation of photosynthesis in the seeds. These results were in line with the result of Zaher *et al*. (2014) who stated that increasing the number of weeding significantly increased thousand seed weight.

Akter *et al*. (2013) also reported that the thousand seed weight of mung beans increased as the frequency of weeding increased. The lowest number of hundred seed weight (6.4 gm) was recorded under non-weeding treatment that was not statistically different from the hundred seed weight obtained from Hand weeding at 4 WAS. Similarly, Peer *et al*. (2013) obtained the lowest number of hundred seed weight of soybean in weedy check plots. This is consistent with Madukwe *et al*. (2012) who stated that cowpea plants in unweeded plots gave the lowest hundred seed weight.

### 4.4.4. Dry biomass weight

Dry biomass weight was significantly ($p<0.001$) affected by weed management practices (Appendix vii Table 7). The highest dry biomass weight (2.8 ton $ha^{-1}$) was recorded from a complete weed control plot while the lowest (1.6 ton $ha^{-1}$) was from a no-weed control plot (Table 12). There was no statistical difference between the remaining herbicide treatments on dry biomass weight. The higher aboveground dry biomass in these treatments might be due to the efficient utilization of the resources by the crop. In line with this result, Akter *et al*. (2013) reported that the highest biological yield (4.7 ton $ha^{-1}$) was obtained in plants from two-stage weeding and the lowest (2.7 ton $ha^{-1}$) from no-weeding. Similarly, Nano and Janmejai (2018) observed that the highest aboveground dry biomass was obtained from weed-free checks compared with the other treatments in faba bean.

On the other hand, the weedy check produced significantly lower aboveground dry biomass yield (1.6 ton $ha^{-1}$) was obtained. The second lower aboveground dry biomass yield (2.1 ton $ha^{-1}$) was obtained from Hand weeding at 4 WAS. Similar findings were found by Zaher *et al*. (2014) who stated that increasing number of weeding significantly increased above-ground dry biomass.

#### 4.4.5. Grain yield

Grain yield was significantly ($p<0.001$) affected by weed management practices (Appendix vi Table 7). The highest grain yield (GYL) (1.0 ton $ha^{-1}$) was obtained as a result of complete weed control treatment (Table 13). The grain yield obtained as a result of complete weed control was not statistically different from the yield obtained by pendimethalin at 1.5 kg ai $ha^{-1}$ herbicide application (0.9 ton $ha^{-1}$). The higher weed control efficiency in these treatments resulted in better growth and development and led to the development of higher yield components. Therefore the higher number of pods per plant, seeds per pod, and thousand seed weight (Table 14) might have contributed to the significantly higher grain yield in these treatments. Similar results were obtained by Tamang *et al*. (2015) who reported that increase in grain yield with an increase in the weeding frequency of green gram.

Chhodavadia *et al*. (2012) also found that the lowest dry weight of weed, highest weed control efficiency, and the highest grain yield were recorded under two-hand weeding and weed-free than weedy treatment. On the other hand, the lowest grain yield (0.4 ton ha$^{-1}$) was recorded from a no-weed control plot. The lowest grain yield in the weedy check was a result of intense weed competition that resulted in a lower number of pods per plant, seeds per pod, a lower thousand seed weight, and the final low yields.

**Table 13. The effect of weed management practices on grain yield of mung bean at Teppi in 2022 main cropping season**

| Treatment | Grain yield (ton/ ha$^{-1}$) |
|---|---|
| Control (No-weed control) | 0.40 $^{f}$ |
| Complete weed control | 1.00 $^{a}$ |
| Hand weeding at 4 WAS | 0.50 $^{e}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 0.60 $^{d}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 0.80 $^{bc}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 0.70 $^{c}$ |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 0.92 $^{a}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 0.74 $^{bc}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at WAS | 0.80 $^{b}$ |
| LSD (0.05) | 0.1 |
| CV (%) | 7.9 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level. CV= Coefficient of variance, LSD (0.05) = Least significant difference at 5% probability level

### 4.4.6. Harvest index and yield loss

#### 4.4.6.1. Harvest index

Harvest index was significantly ($p<0.001$) affected by weed management practices (Appendix viii Table 8). The complete weed control treatment resulted in a higher harvest index (34.9%) but was statistically similar to (33.2%) obtained from pendimethalin at 1.5 kg ai $ha^{-1}$ herbicide application (Table 14). The highest harvest indexes from these treatments were due to the higher ability of the crop to convert the dry matter into economic yield. Higher harvest index because of weed control had been reported on sorghum (Jamil *et al*. 2005), cowpea (Getachew *et al*. 2017), on wheat (Marwat *et al*. 2005). Likewise, Zhu *et al*. (2010) reported that partitioning efficiency (harvest index) is determined by the amount of biomass energy allocated to vegetative vs. reproductive structures. The lower value for the harvesting index (22.5%) was recorded under a no-weed control plot. In line with this, Zaher *et al*. (2014) also reported that harvest indexes were lower in weedy check treatment.

#### 4.4.6.2. Yield loss

Yield loss was significantly ($p<0.001$) affected by weed management practices (Appendix viii Table 8) The highest yield loss (63.5%) was observed in no-weed control plots compared to complete weed control, followed by Hand weeding at 4 WAS (52.7%) (Table 14). The highest yield loss in the weedy check was due to high weed infestation throughout the season. In agreement with this result, Dungarwal *et al*. (2003) reported that weed infestation throughout the crop life cycle resulted in about 65.4 to 79.0% reduction in the potential grain yield of mung bean.

**Table 14. The effect of weed management practices on harvest index and yield loss of mung bean at Teppi in 2022 main cropping season**

| Treatment | Harvest index (%) | Yield loss (%) |
|---|---|---|
| Control (No-weed control) | 22.5 $^{c}$ | 63.5 $^{a}$ |
| Complete weed control | 34.9 $^{a}$ | 0.0 $^{g}$ |
| Hand weeding at 4 WAS | 22.9 $^{c}$ | 52.7 $^{b}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 25.3 $^{bc}$ | 42.7 $^{c}$ |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 28.8 $^{b}$ | 23.1 $^{def}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 26.3 $^{bc}$ | 31.3 $^{d}$ |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 33.2 $^{a}$ | 14.6 $^{f}$ |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 28.5 $^{b}$ | 24.8 $^{de}$ |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 29.2 $^{b}$ | 21.7 $^{ef}$ |
| LSD (0.05) | 3.9 | 8.7 |
| CV (%) | 8.1 | 16.4 |

Any two means not sharing a letter in common in a column differ significantly at a 5% probability level. CV= Coefficient of variance, LSD (0.05) = Least significant difference at 5% probability level.

## 4.5. Cost-benefit analysis

The highest net benefit (56,686.7 ETB ha$^{-1}$) was obtained by complete weed control which was statistically similar to the net benefit obtained by pendimethalin at 1.5 kg ai ha$^{-1}$ herbicides (53,533.7 ETB ha$^{-1}$) (Table 15). This was due to the higher grain yield recorded with these weed management treatments. The lowest net benefit (21,446.5 ETB ha$^{-1}$) was obtained by no-weed control treatment and the second lowest value (26,180 ETB ha$^{-1}$) was from the application of one-hand weeding. The highest gross benefit (58,686.7 ETB ha$^{-1}$) accrued from the complete weed control treatment was (36.5%) higher than the lowest gross benefit (21,446.5 ETB ha$^{-1}$) obtained from the no-weed control treatment. This was due to the lowest grain yield (0.4 ton ha$^{-1}$) from weed competition in no-weed control treatment. The study showed that complete weed control and pendimethalin at 1.5 kg ai ha$^{-1}$ treatments were more profitable than the rest.

**Table 15. Cost-benefit analysis for weed management practices of mung bean at Teppi in 2022 main cropping season**

| Treatment | AVY (kg/ha$^{-1}$) | AY (kg/ha$^{-1}$) | TVC (ETB) | GB (ETB) | NB (ETB) | MRR (%) |
|---|---|---|---|---|---|---|
| Control (No-weed control) | 440 | 400 | 0 | 24,000 | 24,000 | - |
| Complete weed control | 1021 | 1000 | 3,000 | 60,000 | 57,000 | 1,100 |
| Hand weeding at 4 WAS | 540 | 500 | 2,800 | 30,000 | 27,200 | D |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-}$ | 640 | 600 | 1,100 | 36,000 | 34,900 | D |
| Haloxyfop-R-methyl ester at 0.6 kg ai ha$^{-1}$ | 850 | 800 | 2,000 | 48,000 | 46,000 | 1,233 |
| Pendimethalin at 1 kg ai ha$^{-1}$ | 730 | 700 | 1,400 | 42,000 | 40,600 | D |
| Pendimethalin at 1.5 kg ai ha$^{-1}$ | 954 | 920 | 2,000 | 55,200 | 53,200 | 2,100 |
| Haloxyfop-R-methyl ester at 0.3 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 768 | 740 | 1,900 | 44,400 | 42,500 | D |
| Pendimethalin at 1 kg ai ha$^{-1}$ + Hand weeding at 4 WAS | 840 | 800 | 2,200 | 48,000 | 45,800 | 1,100 |

AVY= Average yield, AY= adjusted yield, D= Dominated treatment, the treatment which has higher costs but lower net benefits, GB= Gross benefit, MRR= Marginal rate of return, NB= Net benefit, TVC= Total variable cost, WAS= Weeks after sowing, ETB= Ethiopian birr, Cost of pendimethalin and haloxyfop-r-methyl ester 1,200 and 3,000 ETB kg$^{-1}$ respectively, Spraying ETB 200 kg$^{-1}$, Cost of labour ETB 150 Man day$^{-1}$, Sale price of mung bean ETB 75 kg$^{-1}$, Field price of mung bean ETB 60 kg$^{-1,}$ Cost of harvesting, Threshing and Winnowing ETB 150 100 kg$^{-1}$, Packing and Material cost ETB 50 100 kg$^{-1}$ and Transportation ETB 40 100 kg$^{-1}$.

# 5. SUMMARY AND CONCLUSION

Mung bean (*Vigna radiata* L.) is a short-maturity and drought-resistance crop, which confers its adaptation to adverse environmental conditions and successfully grows in rain-fed areas. Biotic factors limiting mung bean productivity include weeds, diseases, and insect pests at any growth stage. Several Growth stages of mung bean such as emergence, flowering, and pod setting are greatly hampered by weeds. From the above-listed constraints weed is one of the most important factors responsible for the low yield of mung bean. Weed can reduce the yield of mung bean from 65.4% to 79.0% if they are not removed during the critical period of competition.

Therefore, this experiment was conducted with nine weeding options (one-Hand weeding at 4 WAS, complete weed control, No-weed control, Haloxyfop-R-methyl ester at 0.3, 0.6 and 0.3 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS, pendimethalin at 1, 1.5 and 1 kg ai $ha^{-1}$ + One-Hand weeding at 4 WAS). The mung bean N-26 variety was used in a randomized complete block design with three replications. The study showed that complete weed control was the most effective weed management option for mung bean in reducing weed density followed by using pendimethalin at 1.5 kg ai $ha^{-1}$ herbicides treatments. Days to 50% flowering were significantly decreased in complete weed control and pendimethalin at 1.5 kg ai $ha^{-1}$ weed management practice. The days to 90% physiological maturity under complete weed control and pendimethalin at 1.5 kg ai $ha^{-1}$ treated plot was shortened. On the other hand, the number of days to physiological maturity was delayed due to increased weed competition in the case of no-weed control than the other treatments.

The highest number of pods per plant, number of seeds per plant, and hundred seed weight were recorded by complete weed control and pendimethalin at 1.5 kg ai $ha^{-1}$ treatments, and the lowest number of pods per plant, number of seeds per plant, weight of hundred seeds were observed by no-weed control treatment. The highest grain yield was obtained from complete weed control and pendimethalin at 1.5 kg ai $ha^{-1}$ treatments. The lowest was recorded from the No-weed control plot. The increase in the yield parameters is due to reduced competition for space, light, water, and nutrients by limiting weed infestation; thus, increasing the uptake of different nutrients.

The study showed that weed management improves the productivity of mung bean in Teppi, South West Ethiopia People's Region, Ethiopia. The use of complete Hand weeding and the herbicide pendimethalin at 1.5 kg ai $ha^{-1}$ were more effective and profitable. However, the study should be tested on different agroecologies, with different weed management options to come up with the best choice for enhancing the production and productivity of mung beans and thereby optimizing net returns. It is recommended that the use of frequent Hand weeding and pendimethalin at 1.5 kg ai $ha^{-1}$ for the management of weeds in mung bean.

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# 7. APPENDICES

**Appendix i. Table 1. Mean squares of analysis of variance for weed density (60 DAS) of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| Source of variation | D.F. | Mean square | | | |
|---|---|---|---|---|---|
| | | Weed density | | | |
| | | Broadleaf | Sedge | Grass | Total |
| Replication | 2 | 486.8 ns | 2.4 ns | 0.6 ns | 525.0 ns |
| Treatment | 8 | 88,487.0*** | 6.02*** | 93.7*** | 98,711.5*** |
| Error | 16 | 379.2 | 96.4 | 3.3 | 365.2 |
| Total | 26 | 89,353 | 104.82 | 97.6 | 99,601.7 |

DF= Degree of freedom

**Appendix ii. Table 2. Mean squares of analysis of variance for weed density (20 DBH) of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| Source of variation | D.F. | Mean square | | | |
|---|---|---|---|---|---|
| | | Weed density | | | |
| | | Broadleaf | Sedge | Grass | Total |
| Replication | 2 | 827.1 ns | 7.3 ns | 32.1 ns | 1,149.8 ns |
| Treatment | 8 | 84,114.0*** | 221.6*** | 529.4*** | 102,067.7*** |
| Error | 16 | 648.8 | 4.8 | 18.0 | 629.1 |
| Total | 26 | 85,589.9 | 233.7 | 579.5 | 103,846.6 |

DF= Degree of freedom

**Appendix iii. Table 3. Mean squares of analysis of variance for weed infestation and weed control efficiency of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| Source of variation | D.F. | Mean square | | | |
|---|---|---|---|---|---|
| | | Weed infestation | | Weed control efficiency | |
| | | 60 DAS | 20 DBH | 60 DAS | 20 DBH |
| Replication | 2 | 0.0 ns | 0.0 ns | 19.3 ns | 155.1 ** |
| Treatment | 8 | 346.4*** | 171.9 | 2527.5*** | 2480.6*** |
| Error | 16 | 0.9 | 1.0 | 8.2 | 10.0 |
| Total | 26 | 347.3 | 172.9 | 2,555 | 2,645.7 |

DAS= Days after sowing, DBH= Days before harvest, DF= Degree of freedom

**Appendix iv. Table 4. Mean squares of analysis of variance for weed dry biomass of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| | D.F. | Mean square | |
|---|---|---|---|
| | | Weed dry biomass | |
| Source of variation | | 60 DAS | 20 DBH |
| Replication | 2 | 9.0 ns | 10.4 ns |
| Treatment | 8 | 949.9*** | 669.8*** |
| Error | 16 | 5.9 | 7.4 |
| Total | 26 | 964.8 | 687.6 |

DAS= Days after sowing, DBH= Days before harvest, DF= Degree of freedom

**Appendix v. Table 5. Mean squares of analysis of variance for date of flowering and date of maturity of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| | | Mean square | |
|---|---|---|---|
| Source of variation | D.F. | DTF | DTM |
| Replication | 2 | 0.26 ns | 0.48 ns |
| Treatment | 8 | 13.65*** | 12.23*** |
| Error | 16 | 0.59 | 0.89 |
| Total | 26 | 14.50 | 13.60 |

DF= Degree of freedom, DTF= Date of flowering, DTF= Date of maturity

**Appendix vi. Table 6. Mean squares of analysis of variance for crop stand, plant height, leaf area index, number of nodules, and nodules dry weight of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| Source of variation | D.F. | Mean square<br>CST | PH | LAI | NN | NDW |
|---|---|---|---|---|---|---|
| Replication | 2 | 6481630 ns | 19.35 ns | 0.05 ns | 6.37 ns | 9.04E-04 ns |
| Treatment | 8 | 663888903*** | 116.08*** | 0.97*** | 181.45*** | 1.03E-02*** |
| Error | 16 | 17013854 | 18.23 | 0.13 | 3.66 | 7.57E-04 |
| Total | 26 | 687,384,387 | 153.66 | 1.15 | 191.48 | 1.17E-02 |

CST= Crop stand, DF= Degree of freedom, LAI= Leaf area index, NDW= Nodules dry weight, NN= Number of nodules, PH= Plant height

**Appendix vii. Table 7. Mean squares of analysis of variance for the number of pods per plant, number of seeds per pods, hundred seed weight, dry biomass weight, grain yield, and harvest index of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| Source of variation | D.F. | Mean square | | | | |
|---|---|---|---|---|---|---|
| | | NPdPP | NSPPd | HSW | DBW | GYL |
| Replication | 2 | 4.09*** | 0.01 ns | 0.07*** | 0.21 ns | 8.67E-04 ns |
| Treatment | 8 | 47.93*** | 1.75*** | 2.29*** | 0.47*** | 0.12*** |
| Error | 16 | 17.81 | 0.34 | 0.01 | 0.11 | 2.94E-03 |
| Total | 26 | 69.83 | 2.10 | 2.37 | 0.79 | 0.12 |

DF= Degree of freedom, DBW= Dry biomass weight, GYL= Grain yield, HI=Harvest index, HSW= Hundred seed weight, NPdPP= Number of pod per plant and NSPPd= Number of seed per pod

**Appendix viii. Table 8. Mean squares of analysis of variance for harvest index and yield loss of mung bean due to weed management treatments at Teppi in 2022 main cropping season**

| Source of variation | D.F. | Mean square | |
|---|---|---|---|
| | | HI | YL |
| Replication | 2 | 21.51*** | 109.9** |
| Treatment | 8 | 53.94*** | 1153.7*** |
| Error | 16 | 5.10 | 25.1 |
| Total | 26 | 80.55 | 1,288.7 |

DF= Degree of freedom, HI= Harvest index, YL= Yield loss

Appendix-figures

**Figure 2. Land plowing and designing**

**Figure 3. Mung bean seed sowing and seedling stage**

**Figure 4. Quadrant in the plot for weed parameter and flowering stage**


**Figure 5. Mung bean at maturity stage and measuring moisture content by moisture test machine**


**Figure 6. Measuring of above-ground biomass of mung bean**


**Figure 7. Measuring of mung bean grain yield by a sensitive balance**

# BIOGRAPHICAL SKETCH

The author was born on July 14, 1998, in South West Ethiopia Peoples' Regional State, Sheka Zone in Yeki Woreda. He attended his elementary school education at Teppi Elementary School from 2006 to 2013 and Secondary School education from 2014 to 2017 at Teppi Secondary and Preparatory School.

He also attended Mettu University from 2018 to 2021 and graduated with B.Sc. Degree in the horticulture science field of specialization. Soon after graduation, he served as a graduate assistant lecturer at Mettu University of the Oromia National Regional State, until he joined Hawassa University in October 2022 to study for his Master of Science degree in Crop Protection.