FDRE Ministry of Agriculture

Pest and Vector Management Plan

for

Ethiopia Wheat Value Chain Development Project

26 April 2023,

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1. Introduction

The Ethiopia Wheat Value Chain Development Project (EWVCDP) aims to provide support to the GoE in its endeavor towards self-sufficiency in wheat production and to become a net exporter by 2025/26. In order to realize this, the EWVCDP will support the production of Irrigated wheat and its value chain through various component activities including by increasing productivity and production of wheat. Enhancing access of farmers to agricultural inputs including select seed, fertilizer and agrochemicals is among the areas of intervention. Improper use of agrochemicals is known to adversely affect the environment and public health. The adverse environmental and social impact issues related to use of agrochemicals in wheat production were assessed in the EWVCDP ESIA study carried for the region and appropriate mitigation measures recommended. In addition, reduction of adverse potential environmental and social impacts of agrochemicals necessitate the implementation of sound farming practices that minimizes the release of pollutants to the environment by applying a combination of alternative options that enhance wheat productivity. To this end the present Pesticide Management Plan will focus on outlining sound wheat production practices that minimize adverse environmental and social impacts based on Integrated Pest Management (IPM) principles.

The present Pest Management Plan relies on two fundamental documents, namely "Wheat Production Manual for Quality Seed Production" published by the Ethiopian Institute of Agricultural Research (EIAR) and "A Manual for Integrated Weed Management in Wheat" published by the Ambo Agriculture Research Centre, EIAR. These publications appear to have identified the key pests and weeds affecting the production of wheat in the Ethiopian context of various agro-climatic situations and proposes prevention and control measures based on IPM principles. These manuals are adopted with a special focus to pest management during production of wheat in the proposed four regions (i.e. Amhara, Oromia, Afar and Somali regions) to be supported by the EWVCDP.

2. Objectives and purpose of the pest management plan

2.1 Objectives

The EWVCDP Pest Management Plan will have the following objectives:

- To document pests, current and expected status and their management
- To identify capacity building needed for implementing pest management
- To propose activities that ensure success of pest management plan
- To develop monitoring and evaluation schedule for pest management activities

2.2 Purpose of the pest management plan

The purpose of the pest management plan is to ensure that pest management is carried-out in a sound manner that ensures:

- Pest infestation do not result to economic loss accruing to the farmers,
- There is protection of the environment and health of users and other humans,
- That non target organisms such as natural enemies and pollinators, 4. Products meet food safety and food quality minimum standards,

3. Integrated Pest Management

3.1 Definition and Concept of IPM

According to FAO, IPM means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human and animal health and/or the environment. It combines biological, chemical, physical and crop specific (cultural) management strategies and practices to grow healthy crops and minimize the use of pesticides, reducing or minimizing risks posed by pesticides to human health and the environment for sustainable pest management. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms. The borrower or client does not use pesticides classified as Class I a (extremely hazardous), I b (highly hazardous) or II (moderately hazardous).

According to the AfDB's ISS OS-4 on Pollution prevention and control, hazardous materials and resource efficiency, it is stated that "for projects that involve the use of pesticides, the client plans and implements an integrated pest management programme for pest-management activities for the full lifecycle of the project". The integrated pest management programme should involve pest-control methods, including cultural practices, biological control, genetic control and, as a last resort, chemical means. It also restricts that, the client does not use pesticides classified as Class Ia (extremely hazardous), Ib (highly hazardous) or II (moderately hazardous).

3.2 The principles of IPM in Ethiopia

Principles of IPM Implementation in Ethiopia involves the following:

- The basic need for IPM implementation in the country is to increase yields in a sustainable manner, and attain clean environment, safe food and healthy citizens.
- The emphasis of IPM program is on the reduction of or wherever possible, the elimination of the use of pesticides and to avoid the misuse of pesticides
- The basis of good crop management decisions is a better understanding of the crop ecosystem including that of pests, their natural enemies and the surrounding environment.
- Traditional and indigenous crop protection methods that encourage the building up of natural enemies, such as crop rotation, intercropping, host plant resistance, appropriate planting time and planting density, use of local botanicals are highly encouraged.
- Pesticides should be used only as a last resort.
- Where pesticide use is unavoidable, it is desirable to select locally registered pesticides which are both effective at controlling pests and cause minimal damage to the environment.
- The registered pesticide should be used according to Good Agricultural Practice (GAP) only when absolutely necessary for the right crop at recommended dose and at the right time.
- Farmer should use pesticide safety gear whenever they apply pesticides.

- Farmers should get training on safe use, handling and proper storage of pesticides.
- Creating awareness among the general public about the potential risks associated with pesticide use is highly essential.

In order to ensure that the above principles are followed, each EWVCDP wheat production activities should go in line with the IPM. The IPM Plan should be also an integral part of the EWVCDP Regional ESIA/ESMP and consider the following components:

- Capacity building: - is a knowledge building and base for pest management and cost effective pest management strategy. Capacity building helps to understand target pest biology, ecology and behavior. That also leads towards the implementation of safe, effective and integrated pest management steps;
- Training and Awareness-Creation: The Plant Protection Directorate with Regional BoA arranges an IPM Training and Awareness-Creation workshop for the members of the irrigation scheme command areas, incorporating the abovementioned principles;
- Technical Assistance at various level: For example, the Woreda Crop Production and Protection Expert contacts the Plant Health Clinic/Plant Protection Section of the Regional Bureau of Agriculture and Natural Resource (BoANR) for technical assistance;
- Supervision: During farming operations, the development agent (DA) visits on at least a weekly basis, to monitor the presence or absence of pests, and provide advice on the management options. Management should be in accordance with the IPM components favoring traditional and indigenous pest management practices and conservation of natural enemies.
- Technical Information: The DA ensures that information is made available to the members regarding the management of pests expected in the location concerned. In the event that the need for pesticides arises, the DA provides advice on the recommended pesticides and their usage, within the list of allowable pesticides as established by the Pesticides Registration and Control Proclamation No. 674/2010 of Ethiopia, and other International regulations ratified by Ethiopia (e.g.: Stockholm Convention on POPs).

- Safety and Storage of Pesticides: Follow the FAO guidelines. Then the Federal, Regional, and Woreda Crop Production and Protection Experts with DAs will develop and implement arrangements for the safe use, handling and storage of pesticides, and the proper use, maintenance and storage of pesticide spraying equipment. Storage should follow the instructions provided. Pesticides should be kept separately, away from humans and animals in a closed, dry and secure place. Any surplus or unwanted pesticides should be reported to the DA and/or Wereda agriculture office for disposal.
- Regular Monitoring: The Woreda team of Experts and DAs will conduct routine surveillance based on monitoring plan of the IPM implementation.
- Reporting: The Woreda team will report to the Zone and the Zone to the regional BoA, which will take action if required to rectify any shortcomings arising from the use of pesticides.

4. Environmental challenges in relation to pest management

Environmental pollution: as farmers intensify farming, pesticide use is inevitable. However, high use of pesticides results to pollution of air, water and waterways, and affects many non-targets and may result to bioaccumulation. Improper use of pesticides may result to residue effects within the products value chain, reducing the quality of food products.

Knowledge of the farmers: most farm activities that affect pests and their management are depended on the knowledge the farmer has. For example, clearing of hedgerows may be common and reduces sites that natural enemies and pollinators hide and nest, particularly when pesticides are applied. However, if farmers lack such knowledge, then they would continue to carry out the activities. In addition, choice of pesticide is depended with the knowledge the farmer has on the product. Class 1 pesticides, for example, are quite toxic with high effects on environment. Protection of natural enemies and pollinators may occur if farmers link their presence to improved income

5. Key Wheat Crop Diseases and Pests

5.1 Leaf rusts

The cereal rusts *Pucciniagraminis* (causing stem rust), *P. striiformis* (causing yellow or stripe rust), *P. hordei* (causing dwarfing or leaf rust) and *P. coronata* (causing crown or leaf rust) regularly cause serious losses of wheat, barley, oats and rye throughout the world. Owing to their prime role in limiting the productivity of these cereal crops in almost every major cereal-producing country, the rust diseases deserve special and detailed attention.

Small, orange-brown lesions are key features of leaf rust infections. These blister-like lesions are most common on leaves but can occur on the leaf sheath, which extends from the base of the leaf blade to the stem node. Lesions caused by leaf rust are normally smaller, more round, and cause less tearing of the leaf tissue than those caused by stem rust.

The management of the disease includes using resistant varieties and application of foliar fungicides.

Fig 1: Leaf rust

5.1.1 Stem rust

Stem rust causes blister-like lesions on leaves, leaf sheaths, and stems. Infection of glumes and awns is also possible. The reddish-brown spores of the fungus cause considerable tearing as they burst through the outer layers of the plant tissues. Mature stem rust lesions are more elongated than those of leaf rust.

Disease management: genetic resistance, and using foliar fungicides, sowing healthy seeds of high quality is a concern of farmers and seed producers to improve crop productivity.

Fig 2: Stem rust

5.1.2 Septoria tritici blotch

This fungal disease causes tan, elongated lesions on wheat leaves. Lesions may have a yellow margin, but the degree of yellowing varies among varieties. The dark, reproductive structures produced by the fungus are key diagnostic features and can often be seen without magnification. This disease is also known as speckled leaf blotch.

Using resistant varieties, foliar fungicides, and crop rotation are the common management approaches to control the disease.

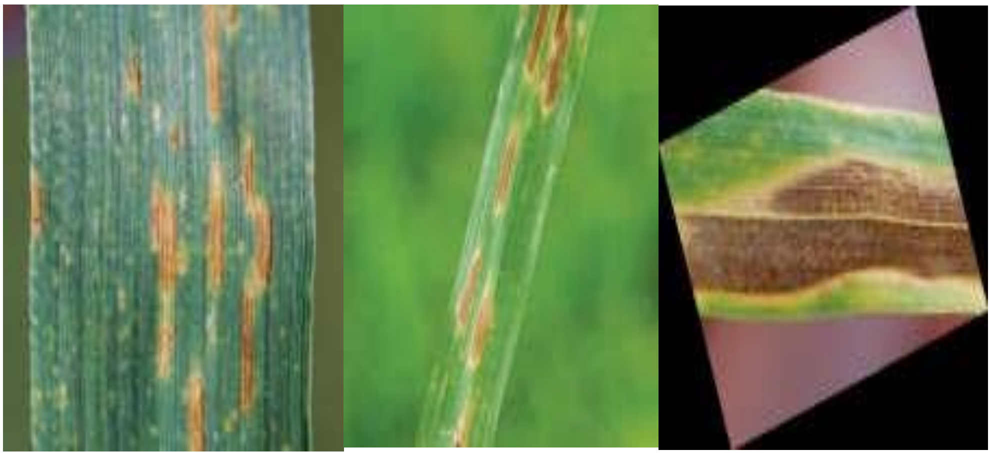

Fig 3: Septoria blotch

5.1.3 Stripe rust

Stripe rust causes yellow, blister-like lesions that are arranged in stripes. The disease is most common on leaves, but head tissue also can develop symptoms when disease is severe. This disease is sometimes referred to as yellow rust.

Using resistant varieties, foliar fungicides, and crop rotation are the common management approaches to control the disease.

Fig 4: Stripe/yellow rust

5.2 Diseases of Heads and Seeds

5.2.1 Common bunt

Wheat kernels infected by common bunt have a gray-green color and are wider than healthy kernels. Diseased kernels can be seen in developing wheat heads but are often not detected until harvest. The outer layers of diseased kernels remain intact initially but are easily broken during grain harvest, releasing masses of black, powdery spores. The fungus produces chemicals with a fishy odor, which sometimes causes this disease to be referred to as "stinking smut".

Using fungicide seed treatment and varieties that are disease-free is the common and effective solution to manage the disease.

Fig 5: Bunt of wheat. The kernels are filled with masses of black spores

5.2.2 Scab or fusarium head blight

Scab or head blight, is caused primarily by the fungus *Fusarium graminearum* but other species *F. culmorum* and *F. avenaceum* can cause the disease. These pathogens occur as soil inhabitants as well as saprophytes on crop residues and are always present. In addition to causing scab, they also cause seed decay, seedling blight, and crown root rot of wheat. They cause stalk and ear rots of corn and sorghum. Wheat heads are most susceptible to infection by airborne spores during anthesis; however, infection can occur up to the soft dough stage. Symptoms of Fusarium head blight include tan or light brown lesions encompassing one or more spikelets. Some diseased spikelets may have a dark brown discoloration at the base and an orange fungal mass along the lower portion of the glume. Grain from plants infected by Fusarium head blight is often shriveled and has a white chalky appearance. Some kernels may have a pink discoloration.

Management of the disease include

- Avoiding the most susceptible varieties and planting into maize residue;
- Applying a fungicide at early flowering if wet weather prevails before and during flowering;
- Using crop rotations in which wheat does not follow wheat, maize or sorghum; and.
- Avoiding over irrigation during full heading and especially flowering

Fig 6: Fusarium head

5.2.3 Loose smut

The normal head tissue of plants infected by loose smut is replaced by dark masses of fungal spores, giving the heads a black powdery appearance. It is possible to see heads damaged by loose smut while much of the head is still inside the boot. Only the central stem of the head is left after the spores are released. Common bunt is a seedling-infecting pathogen that has spores that are carried on the outside of the seed coat or are present in the soil. Management of the disease include fungicide seed treatment and using disease-free seeds


Fig 7: Loose Smut

5.2.4 Sooty head molds

Sooty head molds are characterized by a dark green or black mold growth on the surface of mature wheat heads. These molds are part of a naturally occurring complex of organisms that help to decay dead plant debris. Sooty molds are most common when mature wheat is subjected to repeated rains and delayed harvest. This disease also may affect plants that have been damaged by root rot. The sooty head mold growth is normally superficial. Its effect on grain is minor, but it can make for dusty harvest operations. Sooty molds can contribute to a discoloration of the grain called **black point.** The management of the disease is generally impractical or not needed.


Sooty head Molds

Fig 8: Showing Sooty head and molds

5.2.5 Stagonosporanodorum

The disease causes dark brown or purple lesions on heads. Lesions are often more intense at the top of the glume, with brown streaks or blotches extending down toward the base of the spikelet. The presence of tiny fungal reproductive structures embedded in the tissue can confirm the diagnosis but will require significant magnification.

The management of the disease includes using genetic resistance, foliar fungicides, crop rotation, and fungicide seed treatment. Effective control of all pests, including diseases and insects, is essential to produce a healthy seed crop. In addition to heavy reductions in seed yields, diseases and pests damage the quality of the produce. Treating seeds with appropriate fungicides effectively checks development of soil and seed borne diseases. Applying the appropriate fungicides and insecticides in proper quantities and at the tight time can effectively control rusts and Russian Wheat Aphid. Adoption of appropriate schedules of plant protection and rouging of diseased plants and ears from time to time will further check the spread of diseases and insects; and Seed-borne pathogens may cause injury to the seed itself, or to the plant, which emerges from that seed.

5.3 Diseases of Lower Stem and Roots

5.3.1 Common root rot

Common root rot causes premature death of wheat, resulting in patches of white heads scattered throughout a field. Infected plants are dark at the base and have poor root development. A key diagnostic feature of the disease is dark-brown lesions on the thin stem extending from the base of the plant to the remnant of the seed. Healthy sub-crown internodes should be cream colored and firm. The management aspect of the disease include crop rotation and control of grassy weeds.

Fig 9: Showing Root rot

5.3.2 Fusarium root, crown, and foot rots

Fusarium root, crown, and foot rots cause patches of wheat to die prematurely, resulting in areas of white heads within a field. Infected plants are typically brown at the base and have poor root development. During advanced stages of the disease, the Fusarium fungus often produces a pink, cottony growth inside the lower portions of the stem. Often, the disease is most severe after prolonged periods of dry weather. Managing the disease include crop rotation, control grassy weeds.

Fig 10: Fusarium/crown/foot root

5.3.3 Take-all

This fungal disease causes premature death of the plant, resulting in patches of white heads in of wheat. Plants infected by take-all normally have a black discoloration of the lower stem and roots. Frequently, the disease is most severe in wet areas of afield and near field edges where the fungus survives in association with grassy weeds. The disease can easily managed by applying proper crop rotation and controlling grassy weeds.

Take-all

Fig 11: Showing Take-all disease

6. Pest Management

Pests like termites, armyworms; brown wheat mite, aphids, and jassids commonly affect wheat at different growth stages. Some wheat pests have the potential to spread to other similar agro-climatic zones where wheat is grown. Many of these pests, or groups of pests, typically undergo annual outbreaks in many countries and cause substantial crop losses. Most are not easily controlled with conventional pest management strategies. The description and control methods for these insects described hereafter may have wide application in countries where they currently are considered pests and in countries where they may yet become established.

6.1 Russian Aphids (Diuraphisnoxia)

Russian wheat aphid (RWA) established as a major aphid pest of wheat in Europe, Africa, Asia and North and South America, where it has caused crop losses of up to 80 % in heavily infested areas. In Africa, its most severe infestations have occurred on rain-fed wheat and barley in the highlands of Ethiopia. These aphids feed on the upper leaf surfaces and roll up the leaves to produce a protected microhabitat where they can feed undisturbed. Infested leaves exhibit purple or white longitudinal streaks. Heavily infested plants may appear flattened, with young tillers lying almost prostrate on the ground. When plants become unsuitable or overcrowded, winged aphids reproduce and migrate to other plants or crops.

Aphids can damage the crop directly by feeding or indirectly through their ability to vector/ transmitting Barley yellow Dwarf Virus (BYDV). BYDV is a persistent virus that can be retained by the aphid for weeks and can be transmitted in minutes to a few hours of aphid feeding.

Aphids exist in different stages like winged (alates), and wingless (apterous) sexual and asexual forms. The rapid spread takes place through asexual reproduction where females give rise directly to nymphs rather than eggs.

Management

When feeding in sufficient numbers, they can cause considerable damage, but under normal conditions, losses are not much. Using a tolerant or resistant variety is an excellent management tactic. Chemical pesticides are recommended for this pest in wheat if the level of aphids per tiller crosses 10 during vegetative phase and 5 during reproductive phase. However, there is a need to keep watch on this pest. The spray of imidacloprid @ 20 g a.i. per ha initially on border rows and if infestation is severe then in entire field will give good protection against this pest. Generally, natural enemies present in the field help in controlling the population of this pest.

Fig 12: Aphids feeding on wheat (left) and Symptoms of BYDV on flag leaves in wheat (Right)

6.2 Hessian fly

The Hessian fly *(Mayetiola destructor)* has long been a wheat pest in regions adjacent to the Mediterranean Sea in northern Africa, southern Europe and western Asia. Hessian fly can be found in small numbers in most wheat fields at harvest. If the wheat stubble is destroyed after harvest, the fly dies and the life cycle is broken. Often Hessian flies begin depositing eggs very soon after seedling emergence. Once the pest is established on a new wheat plant, their eggs hatch within a few days and the tiny maggots migrate into the whorl of small wheat plants, ultimately locating below ground at the stem’s base, where they enter the pupa stage. While feeding, the larvae injure the plants by rupturing leaf or stem cells. They cause the plant to form an area of nutritive tissue around the base to enhance their feeding, which can result in tiller stunting and dieback. A heavy infestation on early-stage plants may greatly reduce plant stand. The damage caused by the maggots of the pest are mainly on vegetative growth, which might reduce the activity of photosynthesizing machinery resulting to stunting growth. The maggots during feeding also inject toxic substances resulting to inhibition of plant growth. These toxin acts as inhibitors to the plants and overall hormonal action of plants disturbs resulting to poor growth.

Management

Because the Hessian fly life cycle depends largely on the presence of wheat stubble, rotations that prevent to plant new wheat into or near a previous wheat crop's stubble will be an effective way to prevent infestations. Since the Hessian fly is a weak flier, putting distance between the location of new wheat plantings and the previous season's wheat fields can be a successful method of preventing new infestations. Disking wheat stubble after harvest effectively kills the Hessian fly. It is also possible to control the damage caused by the pest using resistant and tolerant wheat varieties. Long residual foliar pyrethroid insecticides applied shortly after wheat emerges at, or before, the two to three-leaf stages have been very effective in controlling Hessian fly.

Fig 13: Adult Hessian fly

6.3 Termites (Odontotermisobesus, Microtermisobesi)

Termites attack the crop at various growth stages, from seedlings to maturity. The severely damaged plants look wilted and dried. On partially damaged roots,, the plants show yellowing.

Management

For effective management, recommended insecticides such as endosulfan, chlorpyriphos and carbosulfan can be used both for seed treatment and for broadcast of treated soil in standing crop.

6.4 Armyworm (Mythimna separate)

Armyworm infests small grains, usually wheat crop in the season. They can cause serious defoliation, injury to the flag leaf, and cause head drop. Armyworm populations fluctuate greatly from year to year and across areas of the country. The larvae are found in the cracks of soil and hide during the day but feed during night or early morning. In wet and humid weather, they may feed during daytime also. Armyworm is the only caterpillar found in large numbers in small grains. They are active at night, hiding under plant litter such as old corn stalks and at the base of wheat plants during daylight hours. After dark, they feed on foliage from the bottom of the plant upward. As they eat the lower foliage or as it is destroyed by leaf pathogens, the armyworm larvae feed higher, eventually reaching the flag leaf. If populations are high, large caterpillars may also feed on the stem just below the head.

Management

Management of armyworm is based on scouting, thresholds, and resulting application of insecticides when necessary. Infestations of armyworms are not easily detected by casual observation because caterpillars hide during the day. Fortunately, several signs of armyworm infestation occur, and caterpillars can be monitored if the correct technique is used. Any field with significant bird activity should be scouted. Signs of armyworm leaf feeding and caterpillar droppings can also be good indicators. Feeding is sometimes inconspicuous because small caterpillars do not eat much and feeding signs are often concentrated on the lower part of the plant.

Fig 14: Armyworm on wheat leaf

7. Weeds Management in wheat production

Farmers frequently experience considerable wheat yield losses due to weed competition. World average crop losses due to weed competition ranges from 10 to 65% depending upon weed species, their density and environmental factors. In Ethiopia, yield loss of above 36% was recorded in wheat due to uncontrolled weed growth. To reduce negative effect of weeds in wheat fields, the most often utilized weed management methods are cultural and chemical control. Because of overlapping of operations with other crops, farmers' family labor is insufficient during main cropping season for timely and adequate wheat field weed management. Weeding wheat fields by hand is drudgery and also normally done late in the season after weeds have reduced the crop plant growth. It is particularly difficult because of the heavy rain of main cropping season, which makes going into the field and practicing field activities impossible.

Furthermore, despite its limitations in terms of availability and environmental safety, herbicide technology has been found to be useful in managing weeds in wheat fields when farmers are busy on other agricultural practices and for large-scale farms. Currently, Pallas Super has performed better in the country as selective post-emergence grass and broad-leaved herbicide in wheat fields. The above mentioned weed control methods could be good inputs as component of IWM in wheat field. However, extension personnel, development agents and farmers in Ethiopia have not customarily been provided with detailed information on the use of IWM strategy. Therefore, this user manual on IWM strategy for wheat growers is prepared to reduce weeds infestation and improve productivity of the crop.

7.1 Major Weed Species in Wheat Production System

Heavy infestation of broad, narrow or both leaf nature weed species on wheat fields can adversely affect productivity of the crop plant. The occurrence of weed species types and their infestation levels vary from field to field largely guided by farm land handling history on the wheat field. The major narrow and broad-leaved weed species occurring in wheat fields are listed alphabetically in Tables 1 and 2 and also described on Figures 1 and 2, respectively.

	Scientific name	Common name	Local names	
			Amharic	Oromifa
1	*Avena abyssinica*	Ethiopian oat	Sinar	Sinara
2	*Avena fatua*	Wild oat	Sinar	Sinara
3	*Bromus pectinatus*	Brome grass	Genchi	Wavillo
4	*Cyperus rotudus*	Nutsedge	Engicha	Ingicha
5	*Lolium temulentum*	Ryegrass	Enkirdad	Qartama

6	*Phalaris paradoxa*	Canarygrass	Asendabo	Asandabo

Table 1: Major narrow leaved weed species in wheat fields

Figure 15. Pictures of narrow-leaved weeds in wheat; A) *Avena abyssinica* B) *Avena fatua* C) *Bromus pectinatus* D) *Cyperus rotudus* E) *Lolium temulentum* F) *Phalaris paradoxa* G) *Setaria pumila* H) *Snowdenia polystachya*

	Scientific name	Common name	Local names	
			Amharic	Oromifa
1	*Argemone ochroleuca*	Munita	Nechi lebash	*Argemone ochroleuca*
2	*Bidens pilosa*	Devil’s needles	Chegogit	*Bidens pilosa*
3	*Chenopodium album*	Lamb squarters	Amedmado	*Chenopodium album*
4	*Convolvulus arvensis*	Bind weed	Timilmil	*Convolvulus arvensis*
5	*Datura stramonium*	Jimsonweed	Atsefaris	*Datura stramonium*
6	*Galinsoga parviflora*	Galinsoga	Abadebo	*Galinsoga parviflora*
7	*Guizotia scabra*	Sunflecks	Mechi	*Guizotia scabra*
8	*Persicaria nepalense*	Knotweed	Yetija siga	*Persicaria nepalense*
9	*Plantago lanceolata*	Buckhorn plantain	Askir	*Plantago lanceolata*

Table 2. Major broad-leaved weed species in wheat fields

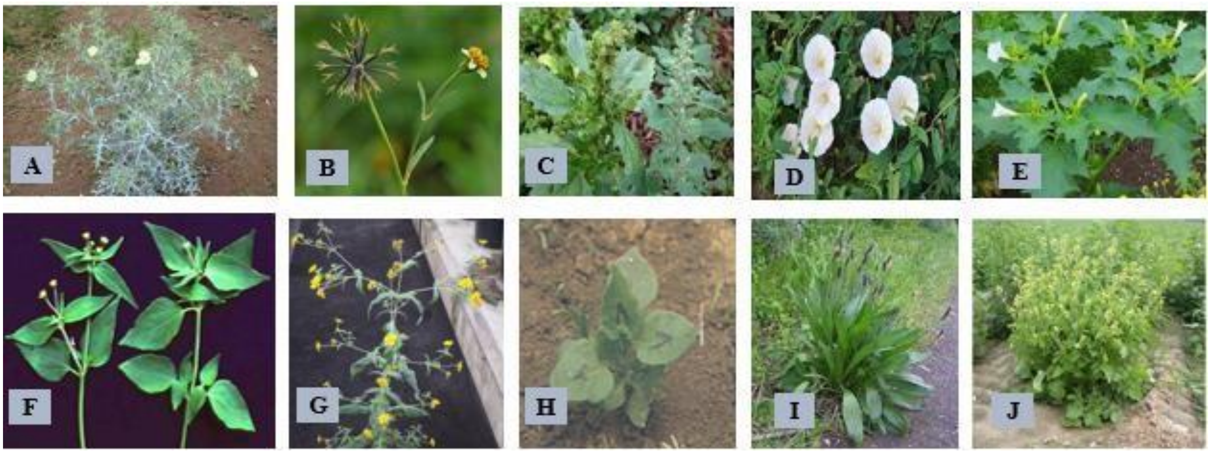

Figure 16. Pictures of broad-leaved weeds in wheat; A) *Argemone ochroleuca B*) *Bidens pilosa* C) *Chenopodium album* D) *Convolvulus arvensis* E) *Datura stramonium* F) *Galinsoga parviflora* G) *Guizotia scabra* H) *Persicaria nepalense* I) *Plantago lanceolata* J) *Raphanus raphanistrium*

7.2 Critical Weed-free Period

Weed competition is most serious when the crop is young or at active growth stage. Weeds at this period must be removed by any means or in economic language it is the shortest time span in the ontogeny of crop growth when weeding result in the highest economic returns. Most of wheat-weed competition is during the first 20-30 days after sowing (DAS) at low to mid altitudes and 30-40 DAS at high altitudes.

7.3 Weed Management in Wheat Production

To reduce weed competition and increase wheat productivity, different weed management techniques have been used. These include preventive measures, cultural control, chemical control and integrated weed management.

7.3.1. Preventive measures

Weeds in wheat fields can be prevented by sowing weed-free crop seeds, using well-decomposed farmyard manure, harvesting the crop separately from the weeds, and thoroughly cleaning agricultural instruments prior to use on specific farm land. Another preventive measure is to use a clean threshing area.

7.3.2 Cultural control methods

It includes crop rotation, field preparation, planting methods (depth, seed rate and planting time) adjustment and hand weeding.

a. Crop rotation

Wheat rotational cultivation with legumes or oil crops over a long period of time reduces the population of highly competent weeds in the crop field. This includes sowing wheat after oil crops such as sunflower, rapeseed and Niger seed as well as pulse crops such as soybean, common bean and cowpea to reduce weeds and also improve soil structure and fertility.

b. Field preparation

Ploughing three times, minimize quantity of weeds in wheat fields. The first ploughing should be done to destroy perennial weeds during dry season, the second ploughing done before seed sowing to control emerged weeds and the third ploughing made at seed sowing to create smooth seed bed.

c. Planting methods

In wheat fields, weed population can be decreased by seeding improved cultivar with high canopy coverage at the desired rate and at appropriate time. Wheat production and productivity can be increased by smothering weeds when the crop seeds sown at 150 kgha-1 rate in third to fourth week of June. In addition, application of 150 kgha-1 NPS at sowing, and split application of 250 kgha-1 Urea at tillering and booting stages help wheat plants to outcompete weeds.

d. Hand weeding

Hand weeding within 30 to 40 DAS gives good weed control, but it may not be ideal option under dense occurrence of the weed plants, wheat-weed mimicry and large area fields. If herbicide application is possible, supplementary hand weeding should be carried out at 15 days after the herbicidal treatment to remove escaped weeds.

7.3.2 Chemical control

To control various weed species in wheat fields, a large number of post emergence herbicides, both narrow and broad-spectrum, have been recommended (Table 3). The type of herbicide used in a wheat field is determined by the dominantly occurring weed type.

	Trade name	Common name	Rate (lha1)	Application Time		Targeted weeds
1	Apic	Clodinafop-propargyl	0.33	2-4	1-5	Nl
2	Asta	Fenoxaprop-P-ethyl	0.66	2-4	2-4	Nl
3	Atlantis OD 37.5	Iodosulfuron-methylsodium + Mesosulfuron-methyl	0.33	2-3	2-4	Bl + Nl
4	Current 8 EC	Clodinafop-propargyl	0.80	2-4	1-5	Nl
5	Illoxan 28% EC	Diclofop-methyl	1.4	2-4	4-5	Nl
6	Lancelot 450 WG	Aminopyralid + florasulem	0.03	2-4	2-6	Bl
7	Palister		0.5	2-3	2-4	Bl + Nl
8	Pallas 45 OD	Pyroxylam	0.5	2-3	2-4	Bl + Nl
9	Pallas Super^{tm}320 WG	Halauxifen-Methyl + pyroxulam	0.09	2-3	2-4	Bl + Nl
10	Pride 100 SC	Bispyribac-Sodium	2	2-5	2-5	Bl
11	Richway 750 WDG	Tribenuron Methyl	0.02	2-4	2-5	Bl

Table 3. Herbicides list and guide for controlling weeds in wheat fields
Note: Bl= broad leaf, Nl= narrow leaf

7.4. Integrated weed management in wheat

No any single method is likely to offer long-lasting solution to serious problem of weeds in wheat fields. Therefore, combining preventive measures, cultural practices and herbicides application found to be preferable for effective, economic and season-long weed management. The IWM package in wheat field includes frequent ploughing, sowing improved variety, fertilizer application and post-emergence herbicide application supplemented with hand weeding in such sequential order with proper timing of the activities (Table 4).

For instance, IWM package practiced in wheat field by Ambo Agricultural Research Center included thrice oxen ploughing, sowing “Wane” variety at 150 kgha-1 seeding rate on third week of June in 20 cm distant rows, application of 150 kgha-1 NPS at sowing, application of Pallas 45 OD at 0.5 lha-1 rate on 30 days after emergence, and split application of 250 kgha-1 urea at tillering and booting stages. The IWM package had provided better weed control efficiency and yield than traditional farmer’s practice (application of 2-4 D supplemented with once hand weeding). It was resulted 21% yield increment as compared to farmers’ practice on six locations at Ambo area. Indirect weed controlling farm practices that favor the crop good establishment relative to weed plant such as fallowing, crop rotation and sowing of weed free seed shall be given due attention as components of IWM in wheat fields.

	Season	**Weed control methods**
1	Fallow period	- Land clearing by cutting weeds before seed setting and removing them from the field - Dry season ploughing to reduce adverse effects of noxious weeds such as *Convolvulus arvensis* - Cleaning farm tools and machineries
2	Before planting	- Crop rotation - Repeated laughing
3	At planting	- Sowing improved variety, weed free seed, at recommended rate, time, pattern and spacing - Application of recommended NPS at sowing
4	After emergence	- Application of Pallas 45 OD at 0.5 lha on 30 days after sowing - Application of recommended Urea at tillering and booting stages - Removal of weeds left from herbicides effect

Table 4. Integrated weed management recommendation for wheat production system

7.5 Spray Calibration

Uniformly applying herbicides at proper rates is essential for effective weed management. A slight variation in the application rate with some herbicides may result in poor control of the weeds or injury to the crop or environmental pollution, causing loss of time, effort and money.

Steps:

- Measure out precisely one liter of water in a measuring jug and put it into the knapsack.
- Find a suitable area to spray on, ideally a dry, hard surface on which water would show up on. Do not use a surface which is uneven as this can result in different application rates.
- Make sure you have a handy marker to show the distance you have travelled and then start spraying the contents of the knapsack whilst continuously walking forwards in a straight line.
- Keep walking and spraying until the knapsack is completely empty and mark where you have stopped.
- Measure out how many square meters you have covered whilst spraying.
- For instance, let us say that on 2 meter width and 20 meter length place or 40 m2 area the spray covered by the one liter water.
- Check what your sprayer capacity has. For example, knapsack sprayer with 20 liters' water holding capacity can be encountered.
- Multiply the sprayer capacity by square meter covered. For example, 20 L (knapsack capacity) x 40 m2 (area covered with 1L) = 800 m2. This is the area which the full knapsack can cover.
- Then to work out how much herbicide to be add to the knapsack tank, divide the product rate Lha-1 by 10000 and then multiply by the area covered with a full knapsack.
- For example, using the above knapsack sprayer and a Pallas 45 OD product that has a rate of 0.5 Lha-1 the formula would be 0.5 divided 10000 multiplied by 800 which gives you 0.04 L or 40 ml.
- Add in to knapsack clean water (10 L), 40 ml Pallas 45 OD product at middle and then fill 10 L of water to make spray solution.
- Finally, agitate to mix the product with water and spray the solution uniformly.

8. Strengthening of Capacities in Pest Management in the four participating Regions

To ensure success in management of pest problems in the target districts of the four participating regions (i.e. Oromia, Amhara, Afar and Somali regions) which should result to improved wheat productivity and production, the following plan is suggested. In addition, the plan includes cost estimates for its implementation.

Table 5: Suggested activities to strengthen national and ASAL capacities on pest management

	Capacity building interventions	Activities	Estimated Budget
1	Training	Training of trainers for Development Agents, Crop Development and Protection officers from Federal, Regional, Zonal and Woreda Agriculture offices on the following areas: - Knowledge of pests and their management - Knowledge of IPM and its socioeconomic value - Pesticide handling - IPM	50,000 USD
2	IPM implementation demonstrations	• Training farmer groups on pests and their management • Demonstration of effective IPM at farm level; use of IPM • Farmer Field schools (IPM-FFS) • Implement best IPM practices for selected pests and sectors Monitor pest impact • Establish surveillance unit for priority pests • Evaluate success of the IPM plan to confirm achievement of benefits	30,000 USD
3	Awareness materials	• Develop & publish brochures, newletters and other materials for awareness creation • Use mass media to communicate the importance of IPM and achievements Develop documentaries and relay them on national TVs for awareness on value of IPM •	10,000 USD
4	Climate change	• Monitor pest problem throughout the project period to determine impact of climate change • Monitor new pest introductions	10,000 USD

8.1 Monitoring and Evaluation of proposed PMP

Table 6: Activities for monitoring of suggested PMP activities

	Activity	Performance indicator, from project initiation
1	Training of trainers and training of different stakeholders	• Names and evidence of trained officers and training programs
2	IPM demonstration farms, IPM FFS	• Established FFS • Data on crop performance, pest management options, yields on monthly basis • Names of farmers visiting the demonstration farms
3	IPM adoption	• Number of farmers practicing IPM annually

9. References:

1. D. Negassa, et.al, 2022. A Manual for Integrated Weed Management in Wheat, Ambo Agricultural Research Centre, Ambo, Ethiopia.
2. H. Mekonnen, et.al, 2014. Wheat Production; Manual for Quality Seed Production, Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa.
3. Ministry of Agriculture, 2020. Integrated Pest Management Plan for Ethiopia Emergency Locust Response Project (EELRP), Addis Ababa.
4. Ministry of Agriculture, 2010. Pest Management Plan for Kenya Arid and Semi-Arid Lands SWAp: A Chapter of the ESMF of Kenya Arid and Semi-Arid Lands SWAp. Nairobi, Kenya