Irrigated Wheat Production Brochure

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Contents

1. Introduction

Wheat is one of the most important cereal crops in terms of production and consumption in Ethiopia. Wheat contributes substantially to food security, poverty reduction, raw materials for industries and employment creation. Ethiopia is a traditional wheat grower and consumer. The national demand for wheat and wheat products is growing faster than for any other food crops, partly due to the high population growth, increased urbanization, and related changing trends in food consumption patterns and preferences.

Annually about 4.6 million small-scale farmers produce over 5.0 million tons of wheat on 1.8 million hectares of land (CSA, 2018). The current average productivity of wheat is about 2.8 t/ha which has been consistently increasing for the last 30 years in stepwise manner instead of transformational way. Despite the recent increment, Ethiopia falls short of being self-sufficient in wheat production and continually remains a net importer. In 2018, Ethiopia imported 1.7 million tons of wheat grain to satisfy the need of 6.7 million tons for its domestic consumption. Ethiopia's wheat production self-sufficiency is only 75% and the remaining 25% deficit has to be imported. Such shortfall in wheat in Ethiopia is attributed to challenges and constraints faced by farmers and other players along the wheat value chain that include insufficient improved wheat technology dissemination, inadequate seed systems, diseases, pests, poor soil and water management practices, low levels of knowledge and information on new and improved varieties, as well as physical and institutional bottlenecks in the marketing chain.

2. Irrigated Wheat for Self-Sufficiency

Ethiopia's prospects for wheat self-sufficiency within few years can be possible mainly because of two scenarios such as increasing wheat productivity in rain-fed agro-ecologies and expansion of wheat production to the lowland irrigated areas. Ethiopia can attain wheat self-sufficiency, either if rain-fed wheat productivity is raised from the current 2.8 t/ha to 3.8 t/ha. This vertical yield increment on about 1.8 million ha of land could bring additional 1.8 million tons of wheat grain to

the national food basket per annum, i.e. exactly what the country has imported in 2018. Another important scenario could be Ethiopia needs to expand its wheat production area to the lowland irrigated agro-ecologies that can contribute significant amount of grain to the wheat basket. Based on the current average irrigated wheat productivity of 4.4 t/ha, Ethiopia needs to bring about 400,000 ha of additional land to make the county wheat self-sufficient. Specifically, the practical scenario should combine options of both vertical and horizontal wheat production growth.

Projection of wheat demand and production based on the current state of wheat production and interventions revealed that Ethiopia will become self-sufficient by 2023 (Figure 1). If the intervention activities and improved packages of best-fit technology promotion and diffusion are intensified, the country can achieve self-sufficiency sooner than later.

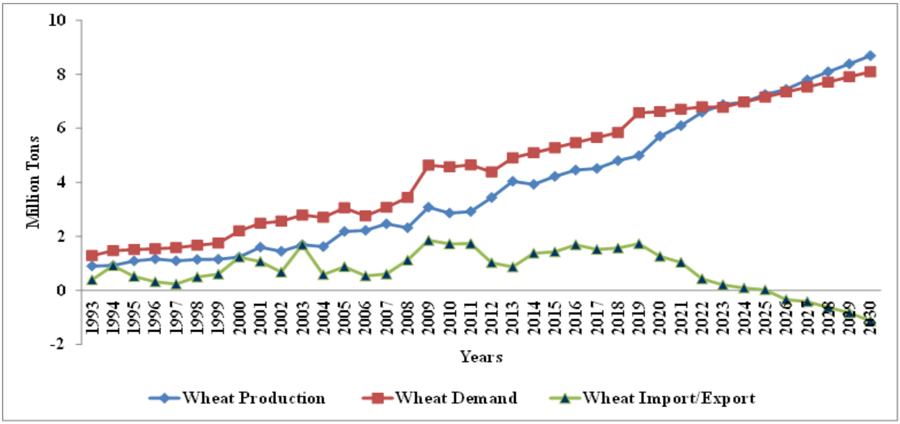


Figure 1. Projection of wheat production, demand and import showing self-sufficiency in Ethiopia

3. Establishment and Operationalization of Innovation Platform

The TAAT wheat project has employed Innovation Platform (IP) approach as a guiding principle in its improved technology dissemination and diffusion activities. The IP is a multi-stakeholders integration

established to exchange knowledge and ideas, share resources, make synergy and take action to solve common problems in order to bring about a desired change, i.e., wheat transformation for self-sufficiency. Functionally, IPs operates at two levels: the strategic and operational. The strategic IP is providing overall guidance on critical issues pertaining to the activities at federal and regional government level, while operational IP set at grassroots to facilitate and operate all planned activities at district and local government levels. Within the IP sites improved packages of wheat technologies have been disseminated to small-scale farmers along the value chains. Within this context, six IPs were established and operationalized in Oromia, Afar and Benishengul Gumuz regions namely Fentale, Jeju, Sire, Amibera, Begi, and Mao Komo (Figure 2).

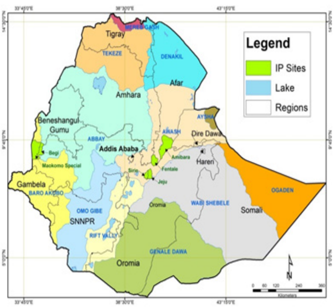


Figure 2. Innovation Platform (IP) sites of the TAAT wheat compact in Ethiopia.

3.1. Facilitation of the Innovation Platforms

Facilitation is the art of assisting team to work together effectively. In achieving this, there is also a sense of making things easier. In TAAT wheat compact there are IP facilitators for research, extension, seed, gender and famers. The IP facilitators had four main functions: facilitation, information and training, demonstration and advocacy.

3.2. Training and Capacity Buildings

Training is one of the means through which improved agricultural technologies, knowledge and skills are conveyed to the small-scale farmers. It is the principal in technology transfer process that enables farmers to use the new improved technologies accurately. The IPs commences

sustainable dissemination of improved technologies by establishing strong advisory services through continuous trainings and capacity buildings.

The training topics: improved wheat technologies, crop/soil/water management, major wheat diseases identification and their management, quality seed production and post-harvest handling, community based wheat seed production, role of gender in wheat production, wheat production business, wheat food preparation and bread baking along the value chains.

Farmers training sessions have to be very brief, participatory and more of practical. Training of SMSs and DAs have to enhance their learning so that their modified behavior and uplifted knowledge and skill could contribute to sustainable dissemination and adoption of improved packages of wheat technologies and innovations. Essentially, after the training, the SMSs and DAs are expected to perform improved wheat technology promotion efficiently and effectively, and conveyed his/her experience/knowledge to colleagues and small-scale farmers to improve wheat production and productivity in the IP sites thereby contribute to food security of the country.

As a result of the training, considerable knowledge and skill were shared, awareness of improved packages of wheat technologies has been created and wheat farmers have started asking for newly released varieties with packages of management practices. The trainings have also created good innovation networks and learning alliances among the IP stakeholders, enabling them to exchange information, expertise and experiences, to collect feedback and to improve communication gaps.

In-season Training on Improved Wheat Production, December 2018

3.3. Demonstration and Dissemination of Best-bet Wheat Technologies

Demonstration and popularization of best-bet technologies are the most important group techniques used for improved technology dissemination to small-scale farmers to increase production and uplift the rural mass from food insecurity and poverty. The purpose of using demonstration plot is to showcase that new improved practice is superior to the one being used currently, and to convince and motivate farmers to use the new practice, and to set up long-term teaching-learning situation. Therefore, demonstration due to its practical nature is a useful means to introduce new technologies and practices for a large group of interested people. It needs fewer resources. Farmers and other interested stakeholders could easily see, hear, and learn from demonstration plots and it could also stimulate adult youth, both male and female for action.

Demonstration of best-bet technologies enhanced farmer to farmer diffusion

3.4. Farmers Field Days

Farmers' field days are one of the important approaches to convince farmers the performance of new technologies and their expected outcome. The main aim of farmers' field day is to enhance dissemination of improved packages of wheat technology particularly through farmer to farmer technology diffusion system. The field days could bring all the IP stakeholders together for exchange of information, experience and expertise. Field days are also an important forum where farmers openly discuss their own problems and argue about elements they are satisfied and dissatisfied. It also provides an opportunity for the IPs to learn about farmers' indigenous knowledge and skills to be incorporated into the research agenda.

The field days could be an excellent forum for farmers where they can practically visualize the performance of the improved wheat technologies. The approach could also create awareness and contribute much to the adoption and dissemination of wheat technologies.

Farmers' field days

4. Wheat Production Factors

Wheat Growth Stages

There are several wheat growth stages that are important for farmers to recognize for optimal crop management and to maximize grain yield and profitability. There are several scales that describe the growth and development of wheat and the two most commonly used scales are the Feekes scale and the Zadoks scale (Table 1 and Figures 3 and 4). Wheat growth can be broadly divided into several different stages: germination/emergence, tillering, stem elongation, boot, heading/flowering, and grain-fill/ripening.

Management decisions in wheat production are growth stage dependent. Applying fertilizers, herbicides, and fungicides are most effective and profitable when applied at specific times during wheat development. If certain chemicals are applied at the wrong growth stage, they may be ineffective or even damage the crop. Understanding how to correctly identify wheat growth stages can help farmers make timely and profitable management decisions.

A degree day is a measure of heating or cooling. It is computed as the integral function of time that varies with temperature. Growing degrees (GDs) is the mean daily temperature (average of daily maximum and minimum temperatures) above a certain threshold base temperature accumulated on a daily basis over a period of time. Growing Degree Days (GDD) or led Growing Degree Units (GDUs) are a measure of heat accumulation to predict plant development rates such as the date that a flower will bloom, an insect will emerge from dormancy, or a crop will reach maturity.

$$GDD = \frac{(Tmax + Tmin)}{2} - BT$$

where Tmax and Tmin are the maximum and minimum daily temperature and Tb is the base temperature (Cao and Moss, 1989a, 1989b). In wheat crops, it has been usual to use a base temperature of 0 °C irrespective of the phonological stage (Bauer et al., 1984).

Table 1. Zadoks Scale Table

Stage	Wheat growth stage	Zadoks scale	Leaves	Root	Stem	Spike	Grain
Seedling	First leaf through coleoptile	10	x	x			
Three leaves	3 leaves unfolded	13		x			
Three tillers	Main shoot and 3 tillers	23	x				
Spike at 1cm	Pseudostem erec tion	30			x		
Two nodes	2nd detectable node	32			x	x	
Meiosis	Flag leaf ligule and collar visible	39		x		x	
Anthesis	1/2 of flowering complete	65			x	x	
2 DAA (50°C.days)	Kernel (caryopsis) watery ripe	71	x				x
14 DAA (350°C.days)	Medium Milk	75					x

Figure 3. Zadoks wheat development scale

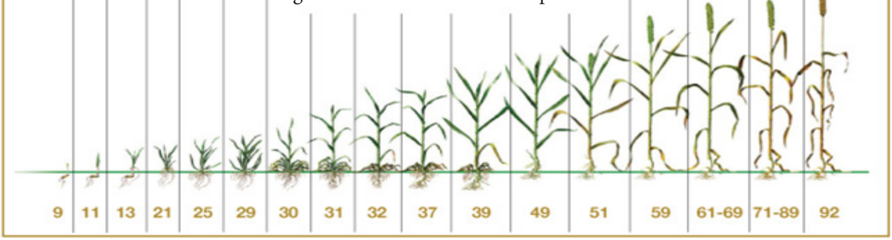
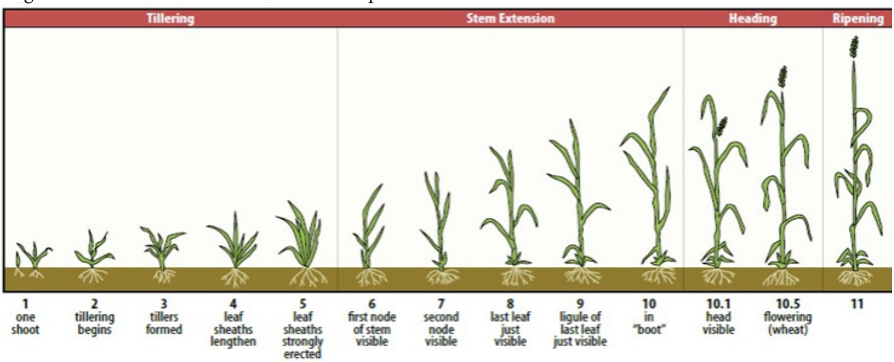


Figure 4. The Feekes scale of wheat development



Increase in wheat productivity can be achieved by integration of its production factors. The major wheat production factors are outlined as follows.

4.1. Site Selection and Seedbed Preparation

Wheat can be successfully grown in most parts of Ethiopia on all soil types that are well drained and productive. But, wheat grows best in deep, well-drained and fertile clay loam or sandy loam soils. The primary purposes of land preparation are to create soil structure favorable for crop growth, incorporate residues and control weeds, insects and diseases. Seedbed preparation has a significant impact on seedling emergence and yields. For irrigated wheat production in Ethiopia, tillage should be used to prepare a new seedbed that is free of clods and cotton stubble.

Land should be prepared early to allow weeds to dry and possibly decompose before planting, and moderate soil moisture is necessary to avoid big clods which do not break down easily. Farmers should strive for a firm seedbed, which could promote good seed to soil contact and results in rapid germination and uniform stand establishment.

Wheat crop requires one deep plowing, 2 times harrowing to break the soil clods into smaller mass and land leveling. Avoid tillage when the soils are too wet, because this contributes to soil compaction and tillage pan formation which can cause problems later in the growing season.

There are three types of problems related to seedbed preparation at sowing:

- the land may not plowed properly; clods or crusts hinder sowing at a uniform depth and even germination,
- when land preparation is too long before planting, weeds have an advantage over the crop,
- placement of the seeds at the wrong depth.

Seedbed Preparation, sowing and ridging of wheat

4.2. Improved Variety Choice

As wheat yields have increased, about half of that increase has been due to improved varieties while the remaining half being associated with improved management. In situations where environmental conditions are highly variable, proper and careful varietal choices can realize high yields leading to good profit. Thus, improved variety choice is a key factor for producing a high-yielding irrigated wheat crop and sets the production base for maximizing the return on investment for irrigation water.

Wheat variety development in Ethiopia has primarily been targeted at rain-fed production agro-ecologies in the past decades. However, over the past 10 years there has been increased interest in irrigated wheat variety development, and so far more than nine bread and one durum varieties were released for production (Table 2).

Irrigated wheat production in Ethiopia should fit to the relatively cool season of the area which ranges from October to January. Thus, another important characteristic to consider during variety choice is its days to maturity and tillering ability. Early maturing varieties are more likely to escape damage from high temperature, hot winds, and rust diseases that are more prevalent later in the season.

Wheat varieties vary widely in their ability to tiller, while tillering capacity is further influenced by sowing date and soil fertility. For example, Fentale-2 and Ga'ambo varieties are known for their higher tillering ability compared with varieties such as Fenatle-1 and Kakaba that have a lower tillering ability.

Table 2. List of released and adapted irrigated wheat varieties

No.	Variety	Seed color	Year of release	Maturity days	Altitude (masl)	Yield (t/ha)	Type
1	Fentale-2	White	2017	85	350-1200	5.5-6.5	Bread
2	Amibera-2	White	2017	85	350-1200	5.0-6.0	Bread
3	Fentale-1	White	2015	85	350-1200	5.0-5.7	Bread
4	Amibera-1	White	2015	87	350-1200	5.0-5.1	Bread
5	Werer-2	White	2013	80-85	350-1200	4.0-4.5	Bread
6	Lucy	Red	2013	82	350-1200	4.0-5.0	Bread
7	Ga'ambo	White	2011	90	650-2400	4.0-5.0	Bread
8	Werer-1	White	2008	85-90	350-1200	3.0-3.5	Durum
9	Danda'a	White	2010	110	350-2600	7.0-7.5	Bread
10	Kakaba	White	2010	90	350-2200	6.0-7.0	Bread

Irrigated wheat varietal evaluation at Werer research center

4.3. Use of Certified Quality Seed

Utilizing good quality wheat seed for planting is the basis for obtaining excellent germination and stand establishment. Good quality seed is true to variety, free of other crop seeds, weeds, foreign material, disease, and has plump, dense kernels of high germination. Certified seed should have at least 97% purity and 85% germination. Actually, a high thousand kernel weight (TKW) is a better measure of seed quality. A 36-40 gram TKW, which translates to 26,315 seeds per kg is an appropriate TKW for a seed lot.

Wheat farmers once they have purchased certified seed of the new variety may prefer to recycle own-saved seed for a longer period than the expected seed renewal rates of 3-4 years. It is important to note that certified quality seed gives more yield than the normal seed. When quality seed is sown, quality product is harvested that can be easily traded in the market.

4.4. Sowing time

Appropriate sowing time of crops could results in higher economic yield without involving extra cost as it helps varieties to express their full growth potential. Irrigated wheat production in lowland areas of Ethiopia should fit into the relatively cool season which ranges from October to January.

Early planting produce greater number of spikes, heavier grains and highest grain yield while late planting affected these characters adversely. Wheat varieties perform better if it is sown in October or 1st week of November. Early sown crops mature earlier than those sown later. Timely sowing of irrigated wheat results in highest yield and is most likely to escape injury from heat stress and diseases which become more prevalent as the season advances. The most temperature sensitive stage of wheat is spike and spikelet initiation; when grain numbers are being determined. Late sowing predisposes the plant to high temperature and results in poor tillering, reduced yield and production of inferior quality grains.

Early sowing in October could result in higher yields as compared with late sowing in late November. Wheat yield was reduced by 35.0% and 46.0% in sowing of mid- and late- November as compared to early October sowing. Therefore, each successive delay in sowing beyond 30 October progressively decreased wheat grain yield significantly. If wheat crop is sown late after their recommended sowing dates the crop flowers late in the season exposing the plants to heat stress, diseases and pests during the grain filling period which can result in grain yield losses of up to 80-100 kg/ha/day (WARC, 2015).
There is a range of irrigated wheat variety maturity groups that farmers can select from including early, medium and late maturity. Regardless of the varieties' maturity group, early to late October is the optimum sowing time for irrigated wheat in Ethiopia. Specifically, early sowing within the optimum range is better suited for late maturing varieties like Danda'a. When compelled for late sowing within the optimum range early maturing varieties like Fentale-2, Ga'ambo and Kakaba can be used. But, avoid late sowing in late November at all.

4.5. Sowing depth

Wheat production is greatly affected by sowing depth. Sowing depth significantly influenced the seedling emergence, crop stand establishment and vigor index. Sowing depth also play a crucial role to ensure plants develop sufficient anchorage to minimize the effects of lodging. Shallow sowing reduces the capacity of the wheat plants to develop adequate secondary root structures and anchor points and predisposes the crop to lodging.

The proper depth of sowing should provide good contact between wheat seed and soil; allow the seed to take up water for germination, permit the seedling to reach the surface before depleting its food reserves while protecting the seed from desiccation or birds. Thus, the suitable depth of sowing for wheat is 4 cm to profuse tillering and strong crown root development. Deep sowing delays emergence, resulting in weaker seedlings and poor tillering capacity and low yield.

4.6. Row spacing

Row spacing can exhibit substantial effects on growth, yield and yield related attributes of wheat. Proper spacing can help to optimize tillering capacity and improve the yield components of wheat. Optimum row spacing is important not only for higher grain yield but also for reducing lodging.

Wider row spacing is vital for maximizing light interception, penetration, distribution in crop canopy and allowing for thicker stems and stronger anchorage of the crowns. However, at the widest row spacing (30 cm) wheat grain yield was lower than the medium (25 cm) and narrow (20 cm) row spacing in irrigated wheat experiments conducted by Werer Research Center. There was no significant difference in grain yield between the 20 cm and 25 cm row spacing. Therefore, selecting the most suitable 20 to 25 cm row spacing for the target plant population will produce the highest yield.

4.7. Sowing method

Selection of suitable sowing method for wheat plays an important role in placement of seed at proper depth which ensures better emergence and good subsequent crop growth. There are two options of wheat sowing methods such as drill and broadcast. Drill sowing is the recommended method because of its uniform seed distribution at desired depth, which usually results in higher germination, uniform stands and higher grain yield. Drilling has an advantage over broadcasting, as it helps in cultural operations, mechanized weed control, herbicides application and requires less seed and facilitates roguing and field inspection.

4.8. Seed Rate

Seed rate is one of the most important agronomic factors which need great emphasis for maximum wheat yield. Optimum seed rate is most important for maximum yield of wheat. The optimum seed rates for wheat vary with variety, location and method of planting. If more seed rate is used, plant population will be more and there will be competition among plants for water, nutrients and sunlight resulting in low

quality and low yield. If less seed rate is used yield will be less due to lesser number of plants per unit area. With lower seeding rates the plants will tiller more than with higher seeding rates.

Hence, seed rates of 120 to 130 kg/ha produced maximum grain yield in irrigated areas of Ethiopia. As planting date is delayed the seeding rate should be increased to compensate for the lack of tillering associated with delayed planting.
For seed production purpose, lower seed rate may be used because lower seed rates lead to higher multiplication factors (Nelson, 1986). Higher multiplication factors lead to rapid seed increase (more seed harvested per kilogram of seed planted). Low seed rates do not only increase the multiplication factor, but also often improve seed quality because a lower number of plants per unit of land receive better nutrition, thus producing better quality seed.

4.9. Nutrient Requirements of Irrigated Wheat

Wheat crop needs certain mineral elements in adequate quantities for good growth and development. These nutrients are generally supplied from the soil and from the added fertilizers. In general, Ethiopian soils formed from old weathered rocks are inherently deficient in Nitrogen (N) and Phosphorus (P) content, while can supply adequate amounts of the secondary and micronutrients.

The main causes of nutrient deficiencies in wheat are:

- Not enough fertilizer was applied in the previous years of harvest and caused nutrient depletion in the soil,
- Fertilizer applied is lost to leaching, run-off, volatilization or fixation,
- Fertilizer is applied when the crop cannot use it well,
- Excessive competition with weeds for nutrients,
- Soil pH makes certain nutrients unavailable,
- Waterlogging results in nitrogen deficiency

Purpose of fertilizer application:

- To supplement the natural soil nutrient supply to satisfy the demand of crops with high yielding potential,
- In intensive cropping systems, unsupplemented soil cannot satisfy crop requirements,
- To compensate for the nutrients lost by the removal of plant products or by leaching or other losses.

Wheat grain yield of 4.5 t/ha removes 100 and 50 kg N and P_2O_5 per ha, respectively, while wheat above ground dry biomass (grain + straw) yield of 9.0 t/ha removes 130 and 60 kg N and P_2O_5 per ha, respectively. The N and P removed by the crops gain/seed and (straw if removed) are lost permanently from the fields. Therefore, that much of N and P have to be replenished to sustain wheat production. Hence, N and P fertilizers application is based on expected yield, cropping system, soil texture, and soil profile N and P contents. The accepted 'rule of thumb' is wheat requires 28.8 kg N/ha per tonne of grain produced. That much N is derived from soil and applied fertilizer.

Nitrogen Management in Wheat

Adequate nutrients at each stage of development are essential for maximum economic yields of wheat. Nitrogen requirement of wheat is important from emergence to grain filling stage. Nitrogen is the one nutrient element required in the highest dose by wheat. It is also the most element with most pronounced response by wheat.

Addition of nitrogen to the soils:

- Organic manures (farm yard manure, green manure and compost, etc.)
- Chemical fertilizers (urea, NPS).
- Fixation of atmospheric N_2 by legumes in crop rotation.

Nitrogen losses from soils

- Denitrification: waterlogged fields, warm, very wet and poor aeration favors denitrification
- Volatilization: urea (NH_2-Co-NH_2) is a volatile source of nitrogen.

- Crop removal: Nitrogen removed by grain and (straw if removed) are a permanent loss from the soil, no nutrient recycling.
- Leaching: nitrate is much more susceptible to leaching than ammonium. Leaching proceeds much faster in sandy soils than in clay soils
- Erosion/run-off

Nitrogen use efficiency

Nitrogen use efficiency is obtaining of greater nitrogen nutrient uptake and crop yield with equal or less amounts of nitrogen fertilizer applied. Higher use efficiency in crop production would permit reducing fertilizer application rate without reducing yield.

How can we achieve high nitrogen use efficiency?

- By appropriate time, method, rate and source of applications.

Time of application: split application 1/3 at sowing and the remaining 2/3 topdressing at tillering stage), before irrigation,

Rate of application: 150 kg /ha of urea

Method of application: urea must be incorporated into the soil after side dressing.

Urea does not store well. Do not attempt to store opened bags from one year to the next.

Phosphorus Management in Wheat

Phosphorus requirement of wheat is important from germination to about dough stage. At germination and emergence phosphorus is from the reserve stored (endosperm) in the seed. The need for phosphorus in wheat is particularly critical during the establishment stages. Wheat plants do not tiller well under phosphorus deficiency.

Phosphorus problem is three-fold

- The amount of inherent phosphorus is very low in most soils
- Most of phosphorus present in the soil is in unavailable form
- Added soluble forms of phosphorus are quickly "fixed" by many soils

Rate of application: 100 kg/ha of NPS (19-38-7),

Time of application: all at planting, before irrigation,

Method of application: Band placement; phosphorus is immobile in

the soil i.e., P moves only 1-2 mm to plant roots for uptake. Thus, plants acquire most of their P by 'root interception'; roots take-up P as they grow through the soil. Plants roots must grow to the P, but P will not come to the plant roots. Thus, band placement of P in the root zone is very important for efficient utilization.

Organic fertilizers

Organic sources of fertility play a major role in wheat production. Every attempt should be made to use locally available organic sources of fertility. When well decomposed, the organic materials should be spread uniformly over the land prior to planting. The possible organic sources of fertility for irrigated wheat production are farm yard manure, crop residues, compost, vermi-compost and green manure. In order to supply 50 kg/ha of nitrogen, 8 t/ha of manure or 5 t/ha of good quality compost should be applied to wheat crop. If these organic sources of nitrogen are not available in sufficient quantities, chemical fertilizers should be used in addition to whatever manure or compost is applied.

Integrated nutrient supply and management

Integrated nutrient supply aims at sustainable productivity with minimum deleterious effect of chemical fertilizers on the soil health. Combined use of organic and inorganic sources of fertility are promising, since they appear to improve wheat yield over the long-term by more than the additive, partly through nutrient release in a better synchrony with plant demand. Many farmers already recognize these effects and combine where possible, small amounts of high quality organic with inorganic nutrients.

4.10. Irrigation Water Management

Crop water requirement

Crop water requirement is the amount of water required by a crop during its entire production period i.e., from sowing to harvest in specific site and climate, when adequate soil water is maintained by rainfall and/or irrigation so that water does not limit plant growth and crop yield. It is the amount of water required to compensate the evapotranspiration loss from the cropped field. Technically, the values for crop water requirement and crop evapotranspiration are identical; crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration (ETc) refers to the amount of water that is lost through evapotranspiration. Irrigated wheat in arid and semi-arid areas of Ethiopia is characterized by high temperature, low humidity and high wind speed which result in very high evapotranspiration loss. Actually, water requirement for irrigated wheat depends on variety, growth stage, canopy density, climatic conditions, irrigation and crop management. Wheat grown under optimal conditions i.e., well-fertilized, well-irrigated, disease-free, uniform and optimum canopy requires 450 to 650 mm of total water per growing season in Ethiopia.

Irrigation scheduling:
Irrigation scheduling is the process of determining when to irrigate and how much water to apply per irrigation events. Irrigation scheduling plays a key role in increasing crop production and controlling soil salinity in arid and semi-arid areas. Inappropriate irrigation scheduling could lead to soil salinization, low water and crop productivity. Following proper irrigation scheduling crop stress, more frequent or excess irrigation must be avoided. Stressing the crop at any stage of development reduces yield. This yield loss cannot be recovered by irrigating at a later time.
In order to avoid crop water stress, do not allow soil water to fall below 60% of plant available water, i.e., refill point or threshold level. Once below 60% of plant available water capacity, crop uses more energy in extracting the remaining soil water. Plant growth and yield potential will decrease considerably if soils are allowed to dry down beyond this threshold level.
Make sure water is available for 2 to 3 days before the crop reaches its refill point. The reproductive growth phase typically coincides with an increase in temperature and an acceleration of plant water use. Any delay in water application can cause significant yield losses.

There are many methods of irrigation scheduling for wheat. Fixed interval method of irrigation scheduling is one of the common methods used by farmers, i.e., irrigating the crop in recommended interval of days depending on the soil, environment and crop parameters. For wheat grown on heavy and light soils 100 and 75 mm irrigation water applied at 10 and 5 days interval are the recommended practices, respectively. Another method useful for irrigation scheduling is use of equipment to measure the soil moisture exactly needed to replace the lost moisture. Instruments such as parshall flume and moisture probes that can determine the amount of and the time to apply irrigation water on farmers' fields are being demonstrated.

Irrigation Methods

Surface irrigation is the common method of irrigation used to grow wheat in Ethiopia. This method requires proper design of irrigation area with regard to size, slope and levelness of the field for unrestricted irrigation water movement in the soil using gravity. Surface irrigation method also require the knowledge about soil type or characteristics such as texture, water intake rate and water holding capacity. The capital cost for field leveling and construction of reservoir might be expensive but the operational costs are low. Basically there are three surface irrigation systems namely basin irrigation, border irrigation and furrow irrigation. Furrow irrigation is the extensively used irrigation system for wheat production in Ethiopia

Wheat Critical Irrigation Stages: Wheat growth can be broadly divided into several different stages: germination/emergence, tillering, stem elongation, boot, heading/flowering, and grain filling and ripening stages. The most critical irrigation stages are crown root initiation, tillering, jointing, booting, flowering, milk and dough stages. Yield losses from water stress at these critical stages cannot be recovered by later irrigations. Particularly, wheat is most sensitive to inadequate soil water during the flowering stage. Inadequate soil water during flowering stage results in flower abortion. The last irrigation to refill the root zone may be needed between the soft dough and hard dough stages on loamy sand soils. No irrigation water is needed once the heads have completely turned color from green to brown since the crop is mature at this point and yields have been established.

Furrow irrigated raised bed

Raised bed machine is used to plant wheat in row on furrow-beds. The bed planting technology is gaining acceptance by wheat farmers because of its multi-faceted advantages including saving of irrigation water, reduces waterlogging due to excessive rain or irrigation, reduces soil crusting suitable for saline and sodic soils, improves fertilizer use efficiency due to localized application, reduces lodging of crops and improves grain yield. The machine plants four rows of wheat on 90 cm wide bed-furrow system.

Bed planting of wheat using raised bed machine

4.11. Crop Protection

4.11.1. Disease management

There are over 10 major diseases that are known to attack irrigated wheat in Ethiopia. These diseases are effectively controlled through the use of integrated disease management strategies. But in the absence of appropriate control measures, these diseases can reduce wheat grain yield and quality.

Integrated disease management options include:

- Use of disease resistant wheat varieties,
- Green bridge management / volunteer wheat control
- Seed treatments
- Use of certified wheat seed
- Fungicide application
- Wheat disease control by crop rotation,
- Scouting

Use of disease resistance wheat varieties

Resistant varieties are the most effective, economical, and environmentally friendly method of wheat disease control. Durability of the resistant varieties i.e., the length of time that a deployed resistant varieties remains resistant to a particular disease(s) can be relatively short, medium or long duration. After release of a variety, breakdown of durable resistance can possibly happen in short time and the variety become susceptible to diseases(s) mainly due evolution of the local pathogens, mutants, recombinants or immigrants (wind-dispersed pathogen spores can travel long distances).

Use of resistant or tolerant varieties coupled with good cultural practices can minimize yield losses. In addition to yield loss, two diseases such as ergot and scab may contaminate grain with mycotoxins, thereby affect both the yield and quality of the wheat crop.

Green Bridge Management / Volunteer Wheat Control

Volunteer wheat can be a "green bridge" that allows pests to survive the period between wheat crops. Volunteer wheat can serve as a reservoir for leaf rust, stem rust, and take-all root rot. It also harbors Russian wheat aphids, green bugs. Therefore, destruction of volunteer wheat by cultivation, heavy grazing or with herbicides is essential.

Seed Treatments

Seed treatments are excellent for control of seed borne diseases such as common bunt and loose smut. Thus, seed treatments are highly recommended for all seed production fields.

Use of Certified Wheat Seed

Ethiopian certified wheat seed has been inspected for common bunt, loose smut, and Karnal bunt. Using certified seed reduces the risk of introducing a seed borne disease into the field.

Fungicide application

Foliar fungicides are one of the few disease management tools that can be used in wheat. Fungicides that can control rusts and Septoria leaf blotch are provided in Table 3. Degree of control ranges from poor to excellent depending on the particular disease, fungicide, application timing and rate.

For the two commonly found diseases such as loose smut and take-all, the following hints are given.

Loose smut *(Ustilago tritici)*

Primary infection is by windblown spores from infected spikes and can infect healthy spikes; it can also be disseminated by contaminated seed. Extended periods of cool and moist conditions during flowering are conducive to infect open flowers of healthy plants.

Management: seed treatment with Propioconazole @ 0.1%, or a combination of vitavax with thiram; use seeds produced in loose smut free zone; remove (rogue) smutted spikes as they appear.

Take-all *(Gaeumannomyces graminis var tritici)*

Take-all favored by alkaline, compacted, poorly drained & infertile soil.

Management: Destruction of grassy weeds and volunteer wheat plants; crop rotation limit inoculum levels; balanced fertilization.

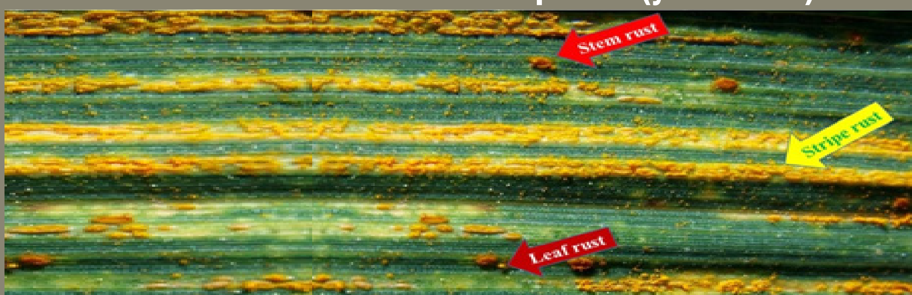
Figure 3. Foliar fungicides used for foliar disease management in wheat

Common name	Trade name	Rate	Effective for
Epoxiconazole + Thiophanate-methyl	Rex Duo	0.5 l/ha	Yellow rust
Propiconazole*	Tilt 250 EC	0.5-1 l/ha	Rusts & Septoria
Tebuconazole + Trifloxystrobin	Nativo	0.75 l/ha	Yellow & stem rusts
Propiconazole	Bumper	0.5 l/ha	Yellow rust
Flutriafol	Impact	0.5-1 l/ha	Rusts & Septoria
Triadimefon	Bayleton	0.5-1 kg/ha	Yellow & leaf rusts
Triadimefon20%EC	Prevent	0.65 l/ha	Yellow rust
Propiconazole	Topzole 250EC	0.6 l/ha	Yellow rust
Tebuconazole	Orius 250EW	0.5 l/ha	Yellow & stem rusts
Tebuconazole	Natura 250EW	0.6 l/ha	Yellow rust
Epoxiconazole	Soprano	0.75 l/ha	Yellow & stem rusts
Propiconazole	Progress 250EC	0.5 l/ha	Yellow rust
Chlorothalonil	Bravo 500	1.13 kg/ha	Septoria blotches
	Amistar xtra 280Sc	0.65 l/ha	Yellow rust
	Mancozeb	1 kg/ha	Septoria

Leaf rust

Stem rust

Stripe rust (yellow rust)



All the three rusts can be found on one leaf

Take-all

Loose smut

Septoria leaf blotch

Head scab/ Head blight

Wheat disease control by crop Rotation

Crop rotation is best management practice for wheat disease control, because it reduces the carryover of diseases, insects, and weeds between crops. One year of rotation is enough to break the cycle for most diseases.

Scouting

Frequent scouting (monitoring of crop fields) for the presence of diseases is a critical step in wheat diseases management i.e., identifying the diseases in the early stages before they become severe. Correct diagnosis is crucial because control measures are different for the different diseases. Color pictures of common wheat diseases are available in PPT slides provided during the trainings or contact the nearest Research Center or Extension Agent for assistance in diagnosing wheat diseases.

4.11.2. Insect pest management

The most common irrigated wheat insect pests in Ethiopia are Russian wheat aphid *(Diuraphis noxius)* and termite *(Macrotermes subhyalinus Rambur).*

Russian wheat aphid: the aphid is a pest and vector of plant diseases (virus diseases).

Management: use host plant resistance (varietal resistance); spray chemicals like dimethoate, thiamethoxam, and imidacloprid; or biological control by predators (lady beetles, suriphid fly), effective in keeping the aphids below damaging levels.

Termites: termites are very serious pests in several parts of Ethiopia, particularly in the western parts of the country. Termites also pose a serious problem on irrigated wheat.

Management: integration of cultural, botanical, and chemical methods of mound treatment for termite control.

Cultural: flooding of mounds; digging mounds and removal of the queens; excavating the top parts of the mounds and burning straw to suffocate and kill the colony. Queen removal is effective and eco-friendly method of termite control.

Chemical: Mound poisoning with chemicals is the most widely used method of termite management. (Diazinon 60% EC and Chlorpyrifos 48% EC may be used).

4.11.3. Weed Management

Weeds reduce wheat yields and profits by competing with the crop for moisture, light, space, and nutrients. Weeds also interfere with harvest and lower grain quality. Yield losses and harvest problems caused by weeds in wheat varies depending on the weed species, weed population, time of weed emergence, growing conditions, and status of the wheat crop.

Wheat crop can be infested with both grassy and broadleaf weeds. Time of weed emergence relative to crop emergence has a tremendous influence on competition and yield reduction caused by weeds. Weeds that emerge with the wheat crop or early in the season are more competitive with wheat than weeds that emerge later in the season.

An effective weed control in wheat considers all aspects of the cropping system, including tillage practices, crop rotation and herbicide application. Physical methods of weed control have been found laborious, tiresome and expensive due to increasing cost of labor, draft animals and implements. Further, weeds cannot be effectively controlled by physical methods merely due to crop mimicry. Therefore, herbicidal weed control in irrigated wheat is a must.The choice of most appropriate and effective herbicide, proper time of application and proper dose is an important consideration for lucrative returns. Timely herbicide applications are important for weed control in irrigated wheat.

Herbicidal weed control in irrigated wheat

Herbicides, if used properly, are a safe and effective option for control of weeds in wheat. However, herbicides will not solve all weed problems and should be used only as needed in an integrated weed management program. Several herbicides are approved for use in wheat to control different weed species are provided in Table 4.

Table 4. List of herbicides used to control weeds in wheat

No.	Trade name	Common name	Rate (L/ha)	Effective for
1	Agro-Amine	2,4-D	1	Broadleaf
2	Derby 175 SC	Flurasulam 75 G/L+flumetsulam 100 G/L SC	0.06	Good for grass but also used for broadleaf
3	Pallas 45 OD	Pyroxsulam	0.5	Excellent for grass but also used for broadleaf
4	Atlantis 37.5 OD	Mesosulfuron methyl + Iodosulfuron methyl sodium	1	Excellent for grass
5	Topik		1	Good for grass
6	Pendamethalin	Stomp	2.5	Pre-emergence
7	Glyphosate	Round-up	2	Pre-plant

Bird *(Quelea quelea)* damage

Birds can cause an extensive damage to wheat crop, particularly when the crop is at milk to dough stage, crushing the juice out of wheat grains. The bird damage is usually severe during crop maturation stage. Wheat fields near to the breeding or roosting sites of the birds are more susceptible to damage. Trees, bushes or reeds around the wheat fields provides nesting place for birds, and the birds will continuously feed on the crops close by. Wheat fields next to streams or dams are vulnerability to bird damage as they attract birds as source of water supply. Late sowing of wheat predisposes the crop to damage by migrating birds, when the crop reaches grain filling stages, birds are arriving.

Various strategies can be used to control birds including use of repellents, cultivars with awns, and chemical control. Aerial spray of the nesting or roosting sites with avicides are widely used to combat quelea birds. Spraying of avicides should be done in the evening when all quelea are in the nesting sites and die during the night.

4.12. Harvesting

Based on scale of production, traditional and modern methods of wheat harvesting can be used. Reaping by hand using sickle, tie in sheaves and stacking followed by threshing either by mechanical threshers or on oxen-trodden on mud-packed threshing floors is common practice by small-scale wheat farmers in Ethiopia. Large scale commercial farmers and well to do farmers in wheat belt areas of the country use combine harvesters.

In all cases, wheat crop must be harvested on time after physiological maturity, when golden color of ears and straw observed, grain become firm and harden, i.e., before shattering, pre-harvest sprouting, bird damage or weathering. There are different ways to determine the correct harvest time including grain moisture content (18-20%), straw becomes dry and brittle, number of days after sowing that lies between 100 days after sowing for early, 110 days for medium, and 120 days for late maturing varieties. Therefore, wheat should be harvested as soon as it is ready to harvest to avoid buildup of insects in the field and should be dried thoroughly before storage.

Hand Held Harvester


Thresher


Combine Harvester

4.13. Storage Management

Wheat grain in storage must be kept free of insects, fungi, rodents or other pests to ensure acceptance by buyers. Good storage practice minimizes the risk throughout the supply chain and safeguards food safety for consumers. Note that low levels of insect infestations can develop into damaging populations before the grain reaches its final destination. Therefore, an effective storage pest control system should be adopted in a sequential and integrated manner as follows: (i) harvesting at 18-20% moisture, drying to 13% moisture and storage of clean dry grain, (ii) disinfecting the storage systems, and (iii) controlling or preventing pest infestation during the storage period.

The storage should be protected from moisture and high relative humidity because fungi *(Aspergillus* and *Penicillium)* cause damage to stored grain if grain moisture content is high. High storage temperature creates favorable condition for weevil and other insect pest development. Hence, stores should be designed to maintain low temperature. Small-scale farmers can use air tight storage facilities like metal silos or hermetic bags.

The use of metal silos can prevent or kill the insect pests that damage the grain. The capacity of the silos varies from 100 - 1000 kg, very suitable at household level. After filling the silo with stored grain, a candle is placed inside the silo on a small tray, to avoid wax from getting on the grain.

Then the candle is lit to use up all of the air (oxygen) in the silo. The burning candle inside the silo will go out as soon as all of the air is used up by the candle. Insects will die due to the lack of air available for them to breathe. Thus, metal silos allow grains to be kept for long periods and prevents attack from pests such as rodents, insects and birds. The metal silos are cheap, safe and environmentally friendly, no use of insecticides.

Another air tight storage option is use of hermetic bags. Hermetic storage is the process by which oxygen is depleted and replaced by carbon dioxide, thus controlling grain storage pests without insecticide.

Hermetic bag **Metal silo**

4.14. Marketing

Small-scale wheat farmers in Ethiopia want to sale their wheat in small amount at a time, while millers and processors want to buy in bulk tonnage. At individual farmer level it is difficult to meet the minimum marketing threshold required by processors. The likely way through which this could be done is by encouraging small-holder farmers to increase their productivity and production through cluster production, contractual farming, product aggregation and community marketing.

Community marketing could enhance market bargain capacity of small-scale farmers to secure better prices and increase their income generation from wheat sale.

4.15. Grain, Flour and Baking Qualities

Grain protein content is widely used as the main parameter in evaluating baking quality of wheat and a higher price is usually achieved with high-protein wheat. The gluten proteins (gliadins and glutenins) play important roles in determining baking quality of wheat flour as gliadins mainly contribute to dough viscosity and extensibility, while glutenins to dough strength and elasticity (Wieser, 2007).

Wheat also contains high quality fats (polyunsaturated and cholesterol-free) which supply energy to our bodies. Whole wheat contains 12.5% fiber necessary for proper digestion. Wheat is a good source of vitamins and minerals. The whole wheat flour (brown) has more of these nutrients than highly milled or white flour. However, the white flour is highly valued because of its better baking and keeping quality than brown flour. The proximate composition of irrigated wheat in Ethiopia is given in Table 4.

Table 4. Grain, flour and baking qualities of irrigated wheat

Parameter	Range
Grain quality characteristics	
Thousand kernel weight (TKW)	36 - 40 g
Hectoliter weight (HLW)	81 - 83 kg/hl
Falling number	270 – 380 sec
Kernel Length	6.8 - 7.5
Kernel Thickness	2.8 - 3.3
Physico-chemical characteristics	
Moisture	11.1 - 11.8 %
Ash	0.77 - 1.8 %
Crude Protein	14.5 - 16.8 %
Crude fat	0.8 - 1.8 %
Carbohydrate	62.8 - 76.9 %
Wet gluten (%)	40 – 45 %
Zelany index	75 – 85 ml
Bread parameters	
Loaf weight	235 – 270 g
Loaf volume	284.3 – 368.6 cm3


Ethiopian Institute of Agricultural Research(EIAR)
Training on Bread Making and Wheat Value Addition

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