OCCURENCE, DISTRIBUTION AND MANAGEMENT STRATEGIES FOR ASCOCHYTA BLIGHT (*ASCOCHYTA RABIEI PASS*.) OF CHICKPEA (*CICER ARIETINUM L.*) IN ETHIOPIA

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DECLARATION

This research dissertation is my original work and has not been submitted to any other University for a degree.

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DEDICATION

This work is fervently dedicated to my Lord and Saviour, Jesus Christ and to my beloved parents Mr. Tadesse Jirata and Mrs. Dagitu Nagaya, through whose enthusiasm and inspirations have brought me this far. This work is also dedicated to my loving brother Mesgebu, my sisters Mule, Mafte, and Gadise and to all supportive hearts and minds who assisted me throughout the process of this dissertation.

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ACRONYMS AND ABBREVIATIONS

AB	Ascochyta Blight
CSA	Central Statistical Agency
DAE	Days after emergence
DZARC	Debre Zeit Agricultural Research Center
EARI	Ethiopian Agricultural Research Institute
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
GPS	Global Positioning System
ICARDA	International Center for Agricultural Research in the Dry Areas
ICRISAT	International Crop Research Institute for Semi-Arid Tropics
LSD	Least Square Difference
MSDARDB	Minjar-Shenkora District Agriculture and Rural Development Bureau
MT	Million Tones
NMA	National metrological Agency
PRRP	Pesticide Risk Reduction Program
QTLs	Quantitative Traits Loci
RCBD	Randomized Complete Block Design
RH	Relative Humidity
ROG	Rate of Growth (annual)
RUFORUM	Regional University Forum for Capacity Building in Agriculture
SAT	Semi-Arid Tropics
SNNPR	Southern Nations, Nationalities and Peoples Region
SSA	Sub-Saharan Africa

ABSTRACT

Chickpea (*Cicer arietinum* L.) is one of the important pulse crops in Ethiopia. However, its production is affected by pest and disease. Among the diseases Ascochyta blight caused by A*scochyta rabiei*, is considered to be the most devastating. A survey was conducted during August 2015 to February 2016 to determine the status of blight disease affecting chickpea in the major growing areas of Ethiopia. More than 250 fields were visited at research centers and on farmers' field during the growing season. The result indicated that ascochyta blight was not distributed in all surveyed areas. The prevalence of the disease was low ranging from 0 to 45.6%. AB was observed in 30 of the 251 fields and incidence ranged from 0 to 25 % with mean of < 10%. The highest mean incidence was in Ensaro district of Amhara region (46.6%) followed by Lume district of Oromia region (15%). The severity varied from 1 to 7 with mean severity of 1 to 3.2 which was observed in few fields indicating that low severity of the disease on chickpea in the country. The low incidence and severity could be attributed to environmental factors. Erratic rainfalls and rise in temperature are increasingly becoming a challenge under the changing scenario of climate in Ethiopia. As a consequence of it, chickpea blight disease severity levels have declined throughout the chickpea growing regions in Ethiopia. Thirty nine advanced chickpea breeding lines were evaluated for blight resistance under field conditions during the main season of 2013/14-2014/15. The experiment was laid out in a randomized complete block design with 3 replications. Disease incidence and severity was assessed at seedling, flowering and full podding stages. There was a considerable variation between genotypes with respect to their disease reaction at three stages ($P< 0.001$). This study revealed that none of the 39 genotypes was asymptomatic, whereas 36 genotypes were resistant and two were moderately resistant on average basis. Variability in blight severity due to genetic differences among the genotypes, environment, and that due to genotype × environment interaction was highly significant ($P < 0.001$). Genotype × environment (G × E) interaction contributed only 3.33% of total variation, revealing stability of the phenotypic expression across environments. Correlation analysis of disease severities exhibited high significant association between average severity and seedling ($r = 0.65^{**}$), flowering ($r = 0.96^{**}$) and full podding ($r=0.95^{**}$) stage at $P< 0.05$. Ultimately, genotypes which showed resistance may be exploited for the development of resistant cultivars against blight disease.

Progress in chickpea breeding has been constrained by lack of good early maturity with resistance to blight disease in the short-season semi-arid environment of Ethiopia. Field experiment was conducted during 2014/2015 growing season to evaluate yield and yield components of early maturing chickpea grown under rainfed conditions. The experiment was carried out in a randomized complete block design in three replications at Debre Zeit research station. Fifteen chickpea lines obtained from ICRISAT were evaluated. Chickpea genotypes were significantly different for evaluated traits at $P < 0.05$. Days to 50% flowering ranged from 43 to 53 and plant maturity from 103 to 111 days. The earliest flowering line was DZ -2012-CK-00075 (43 days) whereas earliest maturing genotype was DZ-2012-CK-00019 (103 days). Line DZ-2012-CK-00019 produced highest grain yield(1960kg/ha) followed by DZ-2012-CK-00015(1950kg/ha). Both correlation and path analysis showed that seed weight, biomass yield and number of pod per plant could be used as a selection index for chickpea improvement.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Chickpea is one of the most important cool season legume crops and is grown in several countries worldwide as a food source (Pande et al., 2005). Among the food legumes, it is the most nutritive pulse extensively used as a source of protein (Sastri, 1950). The excellent nutritional benefits and the good economic returns have made chickpea an attractive cash crop in many parts of the world. This crop is the second most important legume after common bean in terms of cultivation followed by field pea and third in production among the legumes grains worldwide (Knights et al., 2007 and FAOSTAT, 2014). Chickpea is grown in more than 50 countries (89.7% area in Asia, 5% in Africa, 2.6% in Oceania, 2.9% in Americas and 0.4% in Europe). Globally, it is cultivated in over 14.2 million ha producing 9.7 million tons of grain (FAOSTAT, 2014). About 77% of chickpea cultivation and consumption occurs in the developing countries (FAOSTAT, 2014).

Chickpea has been grown across the tropics as a food security crop and also help to maintain soil fertility. Africa accounts for 5% of world's chickpea production, mostly from Ethiopia, Malawi, Tanzania and Kenya in eastern Africa and Morocco in North Africa. In Ethiopia, chickpea is one of the major pulse crops and second most important legume crop in terms of production after faba bean (Menale et al., 2009). Ethiopia is the largest producer of chickpea in Africa, accounting for about 46% of the continent's production during 1994-2006. It is also the seventh largest producer worldwide and contributes about 3% to the total world chickpea production (Menale et al., 2009; Abate et al., 2011). Chickpea area coverage and productivity in Ethiopia have been increasing over a period of time.

Despite its importance in Ethiopia, its productivity is very low and unstable compared to other crops. Average yield of chickpea (1.9 ha^{-1}) in Ethiopia is lower than its actual yield potential (CSA, 2015). Although many factors contribute towards low chickpea production, fungal blight disease caused by *Ascohcyta rabiei (Pass.) Lab.* is the major limiting factor. This disease has been reported in Ethiopia as well as in different chickpea growing parts of the world (Nene et al.,

1996). Due to changes in chickpea production, germplasm exchanges and changes in rainfall pattern, foliar blight disease is becoming a more serious problem in Ethiopia (Abate et al., 2011). Ascochyta blight is the most devastating foliar disease which can cause death to plants, reduces seed quality and yield losses up to 100% (Haware,1998; Nene et al., 1996; Pande et al., 2005; Pande et al., 2011; Knights and Siddique, 2002; Merzoug et al., 2009, PRRP, 2008; FAOSTAT, 2005 and Chongo et al., 2000). Blight disease can infect all above-ground plant parts. More than 35 countries across six continents have reported the occurrence of this disease (Pande et al., 2005).

Continues rainfall and cloudy weather during growing season enhance the development and spread of disease (Jhorar et al., 1998). Disease development is affected by weather conditions at all physiological stages ranging from seedling to maturity (Singh and Sharma, 1998). Climatic factors such as temperature, relative humidity, wetness duration, windy and cloudy weather are the most contributing factors to the disease favourability and hence the occurrence of disease epidemics (Weltzein and Kaak, 1984; Trapero-Casas and Kaiser, 1992; Reddy and Singh, 1990). Therefore, timely measures at all growth stages should be taken to prevent chickpea from foliar diseases and to maximize the yield in Ethiopia.

Disease management in chickpea is critical, and relies heavily on integrated management. The reports of 100% yield losses were documented (Pande et al., 2011). Therefore, the development of effective disease management strategies depend, among others, on the timely detection and precise identification of the pathogen and timely application of the control measures. Survey and identification of plant pathogens is important to understand the association of pathogens with a specific host plant and to map out their geographic distribution. A detailed understanding of the type, occurrence, incidence, severity, association with seed, and geographic distribution of major-pathogens is a prerequisite to formulate rational integrated and sustainable disease management practices in different agro-ecologies (Agrios, 1997).

In order to develop rational and economic crop disease control measures, either by breeding resistant, or use of pesticides, it is not sufficient to state that a specific disease cause losses. Ideally, the magnitude of the loss must be evaluated so that it can be related to economic gains. Only by disease loss field assessment is possible to determine the economic loss due to different amounts of diseases (Malik et al., 1991). Crop disease survey represents a basic essential step

facilitating loss determination, as the pivot to articulate and implement management schemes aimed at economic control. Improved resistance to disease could increase the yield stability of newly bred varieties. However, in order to set priorities for the development of new varieties and for disease management, quantitative data are needed on the occurrence, severity, and distribution of blight foliar disease in the different cultivation areas. Whenever possible, determination of the plant pathogens at each time of scoring is recommended. Severity of the disease varies with crop varieties, pathogen species, geographic area, environmental conditions and cultural practices (Yusuf and Sangchote, 2005).

In Ethiopia, despite the importance, the blight disease have not been extensively studied and no current quantitative information is available on the symptoms, types, occurrences, prevalence, incidence and severity of blight foliar disease on chickpea production and little knowledge is acquired for the pathogen. Variability of the pathogen must be recorded at the levels of disease severity and type of symptoms. Field assessment of disease presents the initial data critical in plant protection programs (Anonymous, 2013). Therefore, the main objective of this study was to determine occurrences, prevalence, incidence and severity of the chickpea ascochyta blight disease in the production regions of Ethiopia.

1.2 Statement of the Problem

Chickpea is one of the world's most important cool season food crops mostly grown in dry lands. The crop suffers from serious diseases that affect it in all growth stages. The pathogens that affect chickpea include fungi, bacteria, viruses, nematodes and mycoplasma, which results in severe economic losses globally. Blight fungal disease is the most devastating chickpea disease worldwide that can cause extensive yield and quality losses up to 100% in conducive environments. This disease can damage the crop at any stage thus compromising food security in many countries. Chickpea blight disease severity mainly occurs under cool, cloudy and humid weather conditions during cropping season (Singh, 1997; Gaur et al., 2007; Singh et al., 2008).

Ethiopia is the leading chickpea producer, consumer and trader in Africa, and is among the seven most important producers in the world (Menale et al., 2009). Despite the large area under chickpea cultivation, total production and productivity is quite low in most chickpea growing areas and there is a wide gap between potential yield (5 tons ha-1) and actual yield (1.9 tons ha-1) (CSA, 2015). The cause of low yields in chickpea is its susceptibility to a number of foliar

diseases. Among foliar diseases, ascochyta blight is a widespread and most destructive disease that causes substantial crop losses to chickpea in major growing regions of Ethiopia. Historically, chickpea production has not been threatened by blight foliar disease in Ethiopia. However, due to changes in chickpea production, germplasm exchanges and changes in rainfall pattern, this disease is becoming a problem in Ethiopia (Eshete et al., 2014).

There are only few reports on chickpea blight disease are available from different areas in Ethiopia. However, very little information is available on the occurrence, prevalence, incidence and severity of chickpea blight disease in the country, which has congenial agro-climatic conditions for the disease development. There is considerable potential of augmenting the yield of chickpea by minimizing the losses caused by the disease. Therefore, there is a need to determine the status of the disease affecting chickpea in Ethiopia. Since the host plant resistance is not stable due to emergence of new pathotypes of *Ascochyta rabiei*, identification of resistant sources against the prevalent pathotypes/isolates should be considered. The present study was also conducted to identify new sources of resistance to develop blight resistant chickpea cultivars. Beside blight disease, late maturity is another major constraints to chickpea production in Ethiopia as chickpea growing season is short. Thus, the current study also designed to evaluate early maturing cultivars which can be produced in short growing periods to escape ascochyta blight under rainfed environments of Ethiopia.

1.3 Research Objectives

1.3.1 General Objective

To study the occurence, distribution and management strategies for ascochyta blight (A*scochyta rabiei pass.*) of chickpea (*Cicer arietinum L.*) in Ethiopia

1.3.2 Specific Objectives

1. To determine chickpea ascochyta blight disease occurence and distribution in production regions in Ethiopia
2. To screen chickpea genotypes for resistance to ascochyta blight under hotspot field conditions
3. To evaluate and identify high yielding and early maturing chickpea lines with potential for production in ascochyta blight-free post-rainy season

1.4 Research Questions

The research questions of this studies are;

1. What is the occurence and distribution of chickpea ascochyta blight disease in production regions of Ethiopia ?
2. What are the ascochyta blight disease resistant chickpea varieties/breeding lines?
3. What are the early and extra early maturing chickpea lines which can escape ascochyta blight and drought conditions?

1.5 Justification of the Study

Chickpea represents an important component of agricultural food crops consumed in developing countries and are considered a vital crop for achieving food and nutritional security for poor people around the world. However, this crop suffers from serious diseases (Nene et al., 2012). Control measures and effective disease management depend on the proper identification of diseases and causal agents and on a sound understanding of the status of the disease, and patterns of regional spread. Knowing which regions are worst affected, and which are currently threatened is vital for the effective formulation of control interventions (James, 1968).

As part of the efforts to mitigate the effects of this disease and guide control interventions, a disease diagnostic survey was conducted to monitor changes in disease and therefore give an update on the chickpea diseases status in the region, with a view to provide data that would be useful in development of control strategy of the disease. Agricultural disease surveys are an important component of integrated disease management plans and making estimates of disease losses. The disease surveys give producers advanced notice of potential disease problems and provide an incentive to take the necessary monitoring, preventative and control measures. Failure to properly identify the disease in the field may lead to further crop losses.

There is a need to get knowledge on the current status of the diseases to formulate effective control interventions and to have and sustain sound management of the chickpea pathology which can enhance seed production and reduce yield loss to ensure food security in the country. Therefore, this study provide a comprehensive stepwise information and understanding on chickpea diseases, and useful to all growers, extension workers, students, researchers and scientists involved in chickpea disease management and control measures. Further, this study will open chance for future research on related diseases.

1.6 Scope of the Study

In order to have more comprehensive information about blight disease, the study included major chickpea growing regions of Ethiopia. Due to time, financial and related constraints this study was confined to major chickpea growing regions of Ethiopia. This study also focused only on field diagnosis survey of blight foliar disease of chickpea in major growing areas of Ethiopia during the growing season which was from mid-August 2015 to February 2016 due to the above stated constraints and relative economic importance of the disease.

CHAPTER TWO

LITERATURE REVIEW

2.1 Chickpea Production Worldwide

World chickpea area and production have not shown dramatic increases. The area, yield, and production grew at annual rates of 0.4%, 0.0%, and 1.2%, respectively, during the period from 1985-87 to 2005-07. The 2005-07 average world area planted to chickpea stands at nearly 11 million ha with the corresponding production of close to 9 million MT; average yields are just over 800 kg per ha (Gurjar et al., 2010). This crop is grown in nearly 60 countries around the world. India accounts about 65% of the world's total production. Pakistan is a distant second with about 8%. Other countries that grow chickpea on more than 100,000 ha are Turkey, Iran, Ethiopia, Myanmar, Australia, Canada, Mexico and Iraq. Myanmar, Ethiopia, Australia, Canada and Iraq have shown the fastest growth in chickpea production over the two decades. India is also the largest importer of chickpea (Abate et al., 2011). Turkey is the largest exporter of chickpea followed by Australia. The average yield of chickpea worldwide is 1.31 t/ha (FAOSATA, 2014). By contrast, area, yield and production have declined in some traditionally major producing countries such as Turkey over the last two decades (Abate et al., 2011).

2.2 Chickpea Production in sub-Saharan Africa

Chickpea in sub-Saharan Africa play a vital role by being a source of livelihood for millions of people; and offer tremendous potential to contribute to the alleviation of malnutrition among resource-poor farmers. The SSA region accounts for about 3.5% (398,000 ha) of the world's total area (and production). Ethiopia, followed by Malawi and Tanzania, is the major producer of chickpea in SSA (FAOSTAT, 2014). The annual area planted to chickpea in Ethiopia is estimated at about 239,755 ha with a production total of 458,682 MT. Sudan, Kenya, Eritrea, and Uganda have more than 1,000 ha; Zimbabwe and Niger plant less than 500 ha each year. More than 2 million rural households grow chickpea in the SSA region (FAOSTAT, 2014).

The average yield for SSA is about 769 kg per ha; only Ethiopia and Sudan get yields over 1 MT per ha. The average area for the region grew by about 2.4% per year whereas the Rate of Growth (ROG) for yield was 1.4%. In Eastern Africa, chickpea acreage has doubled during the past 30 years (from 210,000 hectares in 1979–1981 to 420,000 hectares in 2006–2008). By contrast,

Ethiopia registered ROGs of 2.3% in yield, 2.5% in area, and 4.8% in production. This improvement in chickpea yield is brought about by a value chain approach introduced over the last few years (Abate et al. 2011).

2.3 Chickpea Production in Ethiopia

In Ethiopia, the earliest finding of chickpea is reported in 1520 BC (Joshi et al., 2001). Ethiopia is the largest producer of chickpea in Africa accounting for about 46% of the continent's production during 1994-2006. It is also the fifth largest producer worldwide and contributes about 3.2% to the total world chickpea production (FAOSTAT, 2014).

Chickpea, locally known as *shimbra*, is one of the major pulse crops (including faba bean, field pea, haricot bean, lentil and grass pea) in Ethiopia and in terms of production it is the second most important legume crop after faba beans. It contributed about 17.6% of the total pulse production during 2014. The total annual average (1999-2014) chickpea production is estimated at about 260 thousand tones. Chickpea production and cultivated area are steadily increasing over the years 1999-2014 (FAOSTAT, 2014).

The average annual growth rate in area and production showed that cultivated area under chickpea and production of chickpea increased by 2.1% and 7.6%, respectively during the same period. The production growth rate is relatively higher compared to faba beans (5.7%). Grain yield of chickpea has also showed upward trends, particularly starting from the year 2004 and onwards, with an average annual growth rate of 5.9%. Most of the chickpea is cultivated under rain fed conditions (Menale et al., 2009).

2.4 Major Constraints to Chickpea Production

Despite the high total production, the average yield of chickpeas worldwide is about 1.31 t/ha which is much below its potential (FAOSTAT, 2014). Chickpea production is limited by various biotic and abiotic stresses worldwide. Nearly 172 pathogens (About 67 fungi, 22 viruses, 3 bacteria and 80 nematodes) have been reported so far that infect chickpea in different parts of the world (Nene et al., 1996; Gurjar et al., 2010), but only few of these cause economically important diseases (Haware, 1998). Among the diseases, which lead to an overall reduction in chickpea annual production, fungal diseases are of prime importance followed by viral and bacterial diseases which affecting all parts of the plant at all stages of growth. Ascochyta blight and fusarium wilt are the most devastating diseases affecting chickpea in temperate and tropical

regions, respectively; while in the Mediterranean countries, ascochyta blight, fusarium wilt, grey mold, stem rot, stunt and root rot are the most commonly occurring diseases (Gurjar et al., 2010).

2.4.1 Cause of the Disease

Ascochyta blight is caused by the fungus Ascochyta rabiei. There are no other crop or weed hosts. Ascochyta blight of pea (Ascochyta pisi) and lentil (Ascochyta lentis) are caused by different species, and do not cause Ascochyta blight on chickpea (Nene, 1982). This disease can causes extensive grain yield and quality losses up to 100% under favourable conditions (Chongo et al., 2000).

2.4.2 Disease Symptoms

Symptoms of Ascochyta blight that develop on all aerial parts of plant include wilting leaf tips, leaf lesion, stem lesion causing stem breakage and on pod resulting in seed infection (Sally, 2005).The symptoms consist of necrotic lesions with clear border, in the center of which numerous pycnidia are formed (Pande et al., 2005). On the stems, the fungus causes deep necrotic lesions, which lead to stem breakage and the death of the plant tissue above the affected zone. Stem lesions are initiated at the base of dead leaves. Leaves with many lesions wither before the lesions become large, especially those on the lower portion of plants. On leaflets the lesions are round or elongated, bearing irregularly depressed brown dots, and are surrounded by a brownish red margin (Pande et al., 2005). On the green pods the lesions are usually circular with dark margins and have pycnidia arranged in concentric circles. Often the infected seeds carry lesions. As the disease advances, patches of diseased plants become prominent in the field and slowly spread, involving the entire field (Ali and Ozkan, 2015).

2.4.3 Distribution and Spread of the Disease

The occurrence of AB of chickpea has been reported from 35 countries across six continents – Asia (Bangladesh, China, India, Iran, Iraq, Israel, Jordan, Lebanon, Pakistan, Syria and Turkey); Africa (Algeria, Cyprus, Egypt, Ethiopia, Kenya, Libya, Morocco, Sudan, Tanzania and Tunisia); Europe (Bulgaria, France, Greece, Hungary, Italy, Portugal, Romania, Spain and Ukraine); North America (Canada and USA); South America (Columbia and Mexico); and Australia (Nene et al. 1996, Pande et al. 2005, Knights and Siddique 2002). More than 20 epidemics have been reported and most of these epidemics have occurred in Pakistan, India and

European countries. Severe epidemics of AB have also caused substantial yield loss in the Mediterranean region (Singh, 1984).

Because trace quantities of *A. rabiei* in and on seed are difficult to detect, the blight fungus is readily dispersed in and on chickpea seed. In addition to seed, windblown windblown ascopsores are another major source of primary inoculum that can initiate blight infection. Ascospores are produced abundantly on infested crop residues that persist overwinter on the soil surface (Kaiser, 1989). Released in the spring and early summer under fluctuating moisture conditions, the ascopsores may be carried by wind for several miles. Once infections are established, numerous asexual spores (conidia) produced on blighted plants then cause secondary spread of the disease within the field. Produced even when minimal moisture is available, these asexual spores are spread by rain splash and somewhat by wind. They may also be dispersed with infested living plant parts, within crop residues, on contaminated machinery, on seed, and within seed. Infested crop residues and seed are primarily responsible for season to season survival of the fungus. Growers need to remember that apparently symptomless seed may still carry the fungus (Weltein and Kaak, 1984).

2.4.4 Disease Management

Successful disease management requires planning well in advance. This disease is most effectively managed with the integration of several different strategies. Since only chickpeas are susceptible to several cultural practices such as rotation with non-host crops, not growing chickpeas more frequently than every 3-4 years, and not planting new crops near previous blighted fields, the use of disease free seeds and destruction of plant diseased debris, will all help to reduce inoculums level and inhibit severe epidemics. Tillage practices like burial of infected residue and controlling volunteer chickpeas will also be beneficial (Ali et al., 2010).

2.4.4.1 Fungicide Application

Producers should pay particular attention to protecting young green foliage during pod fill. Several fungicides are labeled for this disease, including Bravo (Chlorothalanil), Quadris (Azoxystrobin), and Headline (Pyraclostrobin). All fungicides have been demonstrated to increase yields and reduce losses from the pathogen, but their use will not be economically

feasible unless disease pressure is high. Watching weather reports and monitoring environmental conditions for disease development are useful methods for estimating need and timing for fungicide applications. Scouting fields early for the presence of isolated, infected plants is also an important part in this process (Ali et al., 2010; Amin and Fufa, 2014).

Using fungicide with these products has been shown to completely shut down disease activity of A. rabiei and allow for additional regrowth and flowering of infected plants. Several seed treatments are available for early season disease protection. However, this will only protect against seedling damping-off from certain soilborne pathogens such as *Pythium* and *Fusarium*. They will not protect plants from seedborne infections. Research has indicated that foliar fungicide applications are not cost effective when *Ascochyta* blight severity is very low. One or more applications of a foliar fungicide during flowering, or even early podding, can increase seed yield and quality. Timely application of fungicide is especially important if the forecast calls for rain (Ali et al., 2010).

2.4.4.2 Plant Antifungal Proteins

Plants develop a complex variety of defense responses when infected by pathogens. Pathogenesis Related (PR) proteins, for example, are a group of diverse proteins whose accumulation is triggered by pathogen attack or abiotic stress. PR proteins have been classified into 12 major groups or families. Some of them show antifungal activity. The functions of most PR proteins remain a mystery but some of them are known to be β-1,3-glucanases (PR-2), chitinases (PR-3) or fungal membrane permeabilizers (PR-5). In theory, the constitutive expression of PR proteins, either singly or combined, might confer decreased susceptibility to a specific group of pathogens (Coram and Pang, 2006;Ali et al., 2010).

2.4.4.3 Genetic Control

The yield losses of chickpea due to blight range from 10 to 100 per cent under severe natural epidemics (Pande et al., 2011). Most of the resistances to blight identified so far is under multigenic control52. The chickpea lines exhibiting resistance to 3-5 races of *Ascochyta rebiei* were identified after evaluation of 1,069 germplasm lines (Singh et al., 1996). Reddy and Singh (19984) observed resistance to ascochyta blight in 0.29 and 0.06% of *kabuli* and desi accessions, respectively. Total 19,343 *Cicer* germplasm accessions which includes both *kabuli* and *desi*

types were screened for resistance to six races of A. rabiei and 14 lines (9 *kabuli* and 5 *desi* accessions) of durable resistance at both vegetative and podding stage were identified by ICARDA, Syria (Singh and Reddy, 1994). More concerted efforts at ICARDA, Syria led to the development of 92 lines resistant to all the six physiological races of *A. rabiei*, which have registered 33% more seed yield than the original resistant sources. Planting of these highly resistant lines in winter season increases the prospects of achieving higher yields in the Mediterranean region (Singh and Sharm, 1995).

Rainfall and cloudy weather during the growing season favour the development and spread of disease (Jhorar et al., 1998). The disease development is affected by weather conditions at all physiological stages ranging from seedling to maturity (Singh and Sharma, 1998). Climatic factors such as temperature, relative humidity, and wetness period, windy and cloudy weather are the most favourable factors for the occurrence of epidemics (Weltzien and Kaak, 1984; Trapero-Casas and Kaiser, 1992; Reddy and Singh, 1990).

The average chickpea yield in Ethiopia on farmers' fields is usually below 2 t/ha although its potential yield is more than 5 t/ha (Geletu and Yadeta, 1994; Jagdish et al., 1995; Melese, 2005 and CSA, 2015). A number of biotic and abiotic factors are responsible for high yield gaps. One of the greatest biotic stresses reducing potential yields in chickpea is Ascochyta blight caused by *Ascochyta rabiei* (Pass) *Labr* (Iqbal et al., 2003; Ibrahim et al., 2012). Severe epidemics of the disease have been reported from many chickpea growing countries including Ethiopia (Nene and Reddy, 1987).

Chickpea blight disease may cause yield losses of up to 100% depending on time of infection (Pande, 2010). The recommended method of managing the diseases is to use resistant varieties (Raju et al., 2013). A number of improved chickpea disease resistant varieties have been multiplied and disseminated to farmers in many districts of Ethiopia. However, their current prevalence in farmers' fields and the severity of the plant has not been documented. Therefore, timely measures at all growth stages should be taken to prevent chickpea from blight foliar fungal disease and to maximize the yield in Ethiopia.

In order to develop rational and economical crop disease control measures, either by breeding resistant cultivars, or application of fungicides, it is not sufficient to state that a specific disease cause losses. Ideally, the magnitude of the loss must be evaluated so that it can be related to

economic gains. By field assessment is it possible to determine the economic loss due to different amounts of disease. Crop disease survey represents a basic essential step facilitating loss determination, as the pivot to articulate and implement management schemes aimed at economic control. Field disease assessment is the only way of determining the amounts and variation in distribution of diseases and pathogens in crops and the significance of the results and conclusions have far reaching effects (James, 1968). There are no standard protocol for disease assessment reporting, although many forums have been set to look for practical efficient and accurate assessment of disease severity.

A globally accepted standard method would encourage data comparison through exchanges, improvement of communication and interpretations of results between professionals and ultimately to the consumer the farmer (Watson et al., 1990). The lack of reliable data to define the importance of diseases in World agriculture may well have retarded the progress of plant pathology as much as any other single factor. Losses due to disease are substantially higher in developing countries and unfortunately more severe in countries that can least afford them. Assessment of disease presents the initial data critical in plant protection programs. In order to have and sustain sound planning or management of plant pathology investment, we need precise identification of the disease. Priorities in resource allocations must be established during planning stages. Field disease assessment generates a large data base which is expensive to collect and therefore should be fully interpreted and feedback given to the farming community (James, 1968).

Field diagnosis of disease is fundamental to control and this has been facilitated by advances in pathogen identification. Accordingly, the existing information on blight foliar diseases of chickpea in Ethiopia is rather limited, and no meaningful conclusions can yet be drawn about their significance and economic impact on production. It should be noted that effective disease management depends on a sound understanding of the status of the blight disease, and patterns of regional spread (Malik et al., 1991). As part of the efforts to mitigate the effects of this disease and guide control interventions, a disease diagnostic survey will be conducted to monitor changes in disease incidence, severity and spread in Ethiopia and therefore give an update on the blight disease status in region, with a view to provide data that would be useful in development of control strategy of the disease.

In Ethiopia, despite of its importance, blight disease of chickpea have not been extensively studied and little information is available on the status of the diseases. Precise information of the pathogen is a prerequisite to formulate rational integrated and sustainable disease management practices in different agro-ecologies. Disease surveys are an important component of integrated disease management plans. Therefore, the main objective of this study was to determine chickpea ascochyta blight disease status in chickpea production regions of Ethiopia.

CHAPTER THREE

DETERMINATION OF ASCOCHYTA BLIGHT DISEASE OCCURENCE AND DISTRIBUTION IN MAJOR CHICKPEA PRODUCTION REGIONS OF ETHIOPIA

3.1 Abstract

Chickpea (*Cicer arietinum* L.) is one of the important pulse crop in Ethiopia. Ascochyta blight which is caused by *Ascochyta rabiei* is considered the most devastating disease of this crop. A survey was conducted during August 2015 to February 2016 to determine the status of blight disease affecting chickpea in the major growing areas of Ethiopia. More than 250 fields located at research centers and on farmers' field from various chickpea growing regions were visited. The results indicated that ascochyta blight (AB) was sporadically distributed in all surveyed areas. The prevalence of the disease was low ranging from 0 to 25%. The incidence and severity of the disease were low in all regions. AB was observed in 30 of the 251 fields and incidence ranged from 0 to 45.6 % with mean of < 10%. The highest mean incidence was in Ensaro district of Amhara region (46.6%) followed by Lume district of Oromia region (15%). The severity varied from 1 to 7 with mean severity of 1 to 3.2 which was recorded in few fields indicating low severity of the disease on chickpea in the country. The geographic distribution of blight was mapped. The overall results of the present survey showed low prevalence, incidence and severity of ascochyta blight in different regions of Ethiopia. This could be attributed to many environmental factors such as low rainfall and rise in temperature. The season 2015/2016 was particularly a dry and the conditions did not favor chickpea blight occurrence. There is likelihood that the status of blight disease can change with climate change. The study demonstrates that climatic variabilities such as temperature, relative humidity and rainfall are important factors in influencing blight infection and development in chickpea. Detailed surveys to monitor changes in ascochyta blight incidence from one year to another should be continued. Meteorological data should o be recorded to determine its relationship to the epidemic occurrence of ascochyta and disease forecasting for more refined analysis.

3.2 Introduction

Chickpea has big importance in the world economy and as a legume crop it plays a significant role in reducing poverty and hunger, improving human health and nutrition and enhancing ecosystem balance. Chickpea is grown in more than 50 countries of the world, and it occupies third position in terms of pulse production after dry bean and field pea. Currently, it is one of the widely cultivated crop at the global level on over 14 million hectares of land from which 11.6 million tons of grain is produced every year with the productivity of 1.3 ton per hectare (FAOSTAT, 2014).

Chickpea is an important grain legume grown under rainfed conditions in Ethiopia. The country is among the top ten countries in production of chickpea in the world (FAO, 2012). Despite the large area under chickpea cultivation, total production and productivity is quite low in most chickpea growing countries and there is a wide gap between potential yield (5 tons ha^{-1}) and actual yield (1.9 tons ha^{-1}). Many factors limit chickpea production, of which fungal diseases are among the most serious. Ascochyta blight has been reported in Ethiopia as well as in different chickpea growing parts of the world (Nene et al., 1996). It is usually associated with severe reduction in chickpea yield quantity and quality, especially under cool and wet conditions (Kaiser, 1997).

It affects and parasitize all the aboveground parts of plants. It also attacks the plant at any growth stage and can cause total crop loss (Bertag, 1982; Singh and Reddy, 1996; Annonymous, 2013). Symptoms of Ascochyta blight that develop on all aerial parts of plant include wilting leaf tips, leaf lesion, stem lesion causing stem breakage and on pod resulting in seed infection (Sally, 2005).The symptoms consist of necrotic lesions with clear border, in the center of which numerous pycnidia are formed (Pande et al., 2005).

Ascochyta blight has been reported to cause up to 100% crop loss under favorable environmental conditions where the relative humidity is greater than 60% and temperature range of 10-20 ^{o}C (Malik et al., 1991; Nasir et al., 2000; Taleei et al., 2010). Disease epidemics have been reported in Ethiopia and in other parts of the world (Nene, 1982,1984; Kaiser, 1992). Blight diseases of chickpea have not been extensively studied and no information is available on their incidence. The main objective of this study was to determine ascochyta blight distribution in the major chickpea production areas of Ethiopia.

3.3 Materials and Methods

3.3.1 Field Observations

Survey was conducted between August 2015 to February 2016 during the chickpea growing season in four major regions of Ethiopia (Table 3.1) for the determination of the prevalence, incidence, and severity of chickpea blight disease. Suspected districts and locations from each region visited based on occurrence of the disease. The number of fields visited within each selected location was based on predetermined distance criterion and occurrence of the disease as well. A convenient approach was to stop at regular predetermined intervals along motorable roads traversing each sample area. The intervals between stops depended on the size of the sample area and the availability of suitable chickpea fields.

3.3.2 Selection of Survey Area

The area surveyed was selected to meet the overall objectives of the study. In surveying chickpea diseases, emphasis was put on areas where chickpea is an important crop, or where the disease has caused serious problems. Administrative boundaries and agro-ecology were used to define sampling domains. In countrywide surveys, the chickpea growing zones were selected for study.

3.3.3 Sampling Methods

Discussions were held with teams of scientists and different stakeholders who were directly working with farmers for a broader understanding of the production and access to the survey districts, locations and fields. From the discussion, study objectives, sampling method, sample size and sample instrument were refined. A formal survey questionnaire was prepared to gather information from the farmers via personal interviews. Purposive sampling method were used to select districts, locations and fields were selected randomly.

3.3.3.1 Sample Size Determination and Sample Selection

A number of zones, districts, locations, fields and plants was surveyed from chickpea growing regions of Ethiopia (Table 3.1). Suspected zones, districts and locations in each region were surveyed based on occurrence of the blight disease. Fields suspected of blight infection were surveyed on the basis of predetermined distances between fields, where distance between the fields ranged from 5 to 10 km; each field was evaluated using a standard methodology. Plant samples exhibiting symptoms of disease were randomly selected from the fields. A total of 251

fields covering 83 districts were surveyed. Chickpea growing areas were selected, based on reports received from farmers, local extension workers, district agricultural offices and research institutions. Also, the willingness of the farmer to cooperate after explaining the purpose of the study was considered in selecting the fields. The number of fields visited were based on the relative abundance of the farm and occurence of blight disease. In each field 10 to 20 plants were selected at random while walking in a diagonal path.

The blight disease was identified in the field on the basis of visual symptoms. Infected chickpea plant samples (leaves, stems, flower and pods) was collected for disease determinations. Chickpea plants showing typical blight symptoms were collected in separate paper bags and was taken to the EIAR laboratory for isolation and further analysis. Samples were collected following hierarchical sampling strategy comprising 10 plants from five random places across a diagonal in each of the selected field (McDonald and Martinez, 1990).

Table 3.1: Chickpea growing areas surveyed during the 2015 cropping season in Ethiopia

Region	Zone	District
Oromia	East Shewa	Adea,Alem Tena, Lume, Gimbichu, Dodota, Gelan, Liban
	South West Shewa	Sebeta, Lemen/K/malima, Kersa malima, Lemen, Sodo Dachie, Goro/woiliso, Woiliso, Seden Sodo, Becho,
	North Shewa	Sheno
	East Hararge	Haromaya, Jarso, Kersa, Meta
	West Hararge	Odabultuma,Tullo,Habro
	Arsi	Xiyo, Shirka
	Bale	Adaba, Sinana, Goro
Ahmara	North Shewa	Minjar Shenkora, Enewar, Moretina Jiru, Siya Debir, Deneba
	North Wollo	Raya Kobo,Mersa, Gubalafto, Wolideya, Qobo, Sirinka, Dahana, Sekota
	South Gondar	Tachgaynt/D Tabor, D/Tabor, D/Tabor/fogera,Fogera, Libokemkem
	North Gondar	Gondar Zuria, Denbia,Takusa, Chilga
	West Gondar	N/Achefer, Jabi tena
	East Gojjam	Guazamen, Awobel
	Debre Brihan	Ensaro, Marabete
SNNP	Wolaita	Damot Gale, Bolloso Sore
	Gurage	Sodo, Meskan/sodo, Kebena
	Siltie	Hurbaray
	Hadiya	Badewchi
Tigray	West Tigray	Enderta, Dega Tenbel, Meserit
	Central Axum	Abiyadi, Laymachew, Tachmachew
	N/W/Tigray	Shire, Tahtay Qoraro, Asgetsibila, Tachmeachew, Medebay Zena
	North Tigray	Tahtew machew
	East Tigray	Tsedeaba, Gemad, Wuqero
	South Tigray	Quha, Enderta, Lay Mahcew

3.3.4 Geographical Data Collection

During the survey, a Global Positioning System (GPS) instrument was used-to determine the coordinates precisely for each field visited, in terms of altitude, longitude and latitude. GPS based survey sheet were prepared to collect information on disease status. The name of variety of each chickpea plant sampled, whether it was local or improved, was identified from the farmer.

3.3.5 Determination of Disease Parameters

3.3.5.1 Disease Scoring

Visual identification of the disease was used on all visited fields. Beginning at 14 days after planting, assessment for blight foliar disease prevalence, incidence and severity was conducted for the reported locations. The level of disease severity for each field was determined by using visual 1-9 disease rating scale as given by Jan and Wiese (1991), Chen and Muehlbauer (2003), Chen et al. (2004), Sharma et al. (2005) and Pande et al. (2011).

Table 3.2. Disease rating scale for blight foliar diseases in chickpea

Scale	Disease symptoms
1	No visible symptoms
2	minute lesions prominent on the apical stems
3	lesions up to 5–10 mm in size and slight drooping of apical stems
4	lesions obvious on all plant parts and clear drooping of apical stems
5	lesions on all plants parts, defoliation initiated, breaking and drying of branches slight to moderate
6	lesions as in 5, defoliation, broken, dry branches common, some plants killed
7	Lesions as in 5, defoliation, broken, dry branches very common, up to 25% of plants killed
8	symptoms as in 7 but up to 50% of the plants killed
9	Symptoms as in 7 but up to 100% of the plants killed.

3.3.5.2 Disease Prevalence

Refers to the proportion or percentage of sampling *areas* in which a disease is present. The formula for determination of prevalence is;

$$\text{Disease Prevalence } (\%) = \frac{\text{Number of locations showing chickpea disease}}{\text{Total number of locations/fields}} \times 100$$

3.3.5.3 Disease Incidence

Disease incidence was determined in each field on the basis of visual symptoms and by counting the number of symptomatic or infected plants in a sample of total plants in randomly selected in

the fields. An overall disease incidence value was obtained by averaging the incidence among all the fields (including the fields which has no disease).

The formula for determination of incidence is;

$$\text{Disease Incidence (\%)} = \frac{\text{Number of diseased chickpea plants in a field}}{\text{Total number of plants in a field}} \times 100$$

3.3.5.4 Disease Severity

The proportion of the area of a plant or plant organ (e.g. leaf, stem, branch and pods area) that is affected. It measures percentage of disease damage and yield loss on the chickpea plant which given by;

$$\text{Disease Severity (\%)} = \frac{\text{Area of plant tissue affected}}{\text{Total number of plants area}} \times 100$$

Climatological data for monthly rainfall, relative humidity, monthly maximum temperature and minimum temperature were collected from a total of 23 standard stations in the chickpea growing areas for both 2014/2015 and 2015/2016 growing season. Monthly averages of rainfall, relative humidity, monthly maximum and minimum temperature were calculated from August - February for both years. This period covered the chickpea growing season in the country.

3.3.6 Statistical Data Analysis

The data collected from the survey was checked completeness and analyzed using R statistical procedures. Descriptive statistics used to summarize the data. Analysis was conducted by disaggregating important relevant information by district and region so that comparison could be made.

3.4 Results and Discussions

3.4.1 Results

This chapter presents the results of the data collected from a field survey conducted to determine chickpea ascochyta blight disease status in Ethiopia. The map of Ethiopia is presented indicating the districts which were surveyed within the country (Figure 3.3). These districts consist the important chickpea growing areas of Ethiopia. It is important to note that these areas are well served with all-weather roads but access roads are very poor being either bare earth or gravel surfaces which tended to limit how far one can penetrate into the farm lands. The results indicated low distribution of blight disease in Ethiopia. From 251 fields surveyed, only 30 field showed A*scochyta rabiei* symptoms during survey. Table 3.3 presents disease prevalence, incidence and severity as observed per site visited. Levels of ascochyta varied among districts, but sample sizes were too small in many districts to interpret these differences. The data collected during this survey was also insufficient to perform statistical analysis. The 2015/16 growing season was characterized by low average rainfall in major chickpea growing districts.

3.4.1.1 Disease Symptoms in the Field

Several symptoms were found affecting chickpea during surveys, which designated as lesions, wilt, foliar yellowing and yellow stunt. Those different complexes (wilt, foliar yellowing and yellow stunt) were discernible in the early stages of development but later they became difficult to distinguish. Lesions started occurring in the stages of vegetative but later it became difficult to distinguish from moisture stress. *Ascochyta rabiei* attacks the aerial parts of chickpea plant; on leaflets the lesions are either round or elongated, bearing irregularly depressed brown dots surrounded by a brownish red margin (Fig. 3.1C). On the green pods, the lesions were circular with dark margins with pycnidia arranged in concentric circles (Fig. 3.1A). Often the infected seeds carry the lesions. Elongated, brown lesions were observed on the stem and petiole, which bear black dots and girdle the affected portion (Fig. 3.1B). When lesions girdle the stem, the portion above the point of attack rapidly dies. If the main stem is girdled at the collar region, the whole plant dies. As the disease advances, patches of diseased plants become prominent in the field and slowly spread, involving the entire field (Fig. 3.2A-C). In the wilt complex, individual leaves showed flaccidity followed by a dull-green discoloration and desiccation. Shortly after,

symptoms developed on all the foliage and the plants died; necrotic leaflets remained attached to the petiole. Vascular and pith tissues were colored dark-brown. Foliar yellowing was most conspicuous from onset of flowering. Yellowing gradually progressed upwards on the plant and necrotic leaflets fell off. Plants with foliar yellowing had either dark-brown vascular and pith tissues, a cortical necrosis of collar and root, or a severe back collar and root rot. Some plants affected by foliar yellowing also showed wilt symptoms. Plants affected by yellow stunt had shortened internodes and a bunchy appearance due to expensive branching. A golden yellow discoloration of leaflets developed basipetally on an affected plant, followed by necrosis of the stem apex. In some instances, stems grew in a zigzag pattern and had longitudinal grooves. Lower stems were purplish-white with brown phloem tissue. Such a discoloration was diagnostic and could be easily observed on transverse sections or by stripping the epidermis from stems. Most affected plants died before producing any seed. Frequently, plants affected by yellow stunt also showed symptoms of vascular wilt or foliar yellowing.

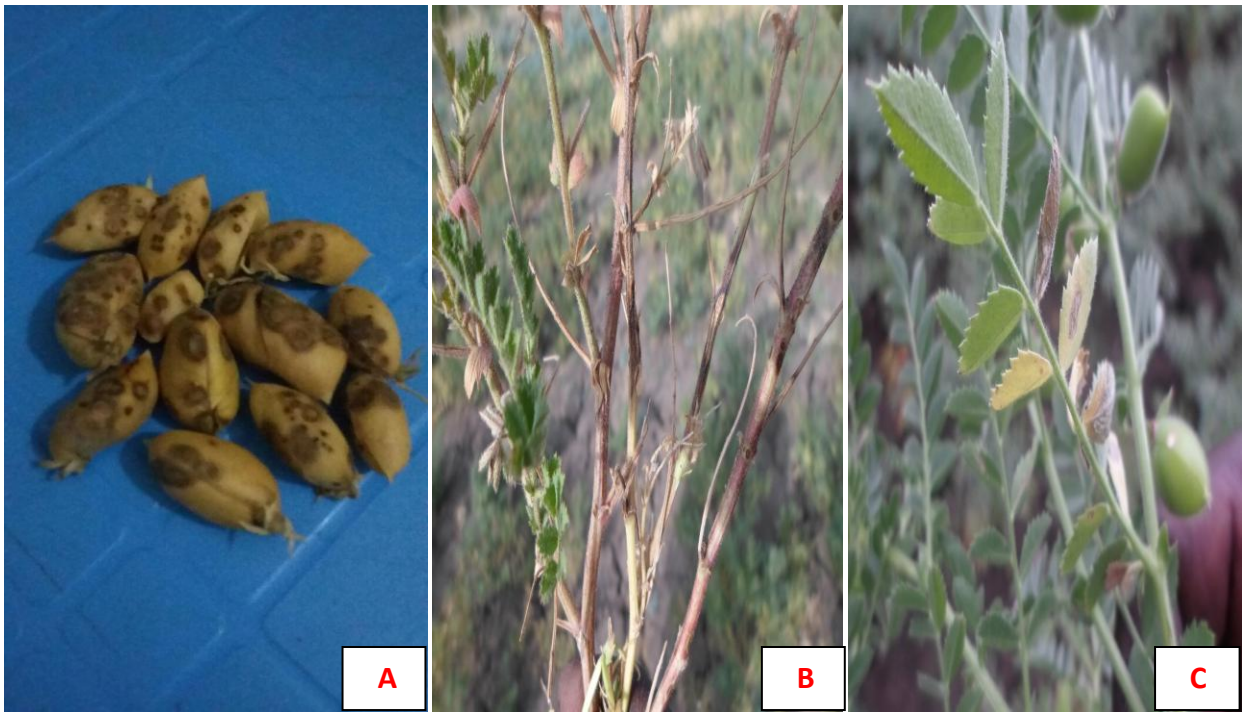

Figure 3.1. Chickpea showing ascochyta blight symptoms - circular lesion on the pods (A), necrotic lesion on the stems (B) and round lesion on the leaves (C).

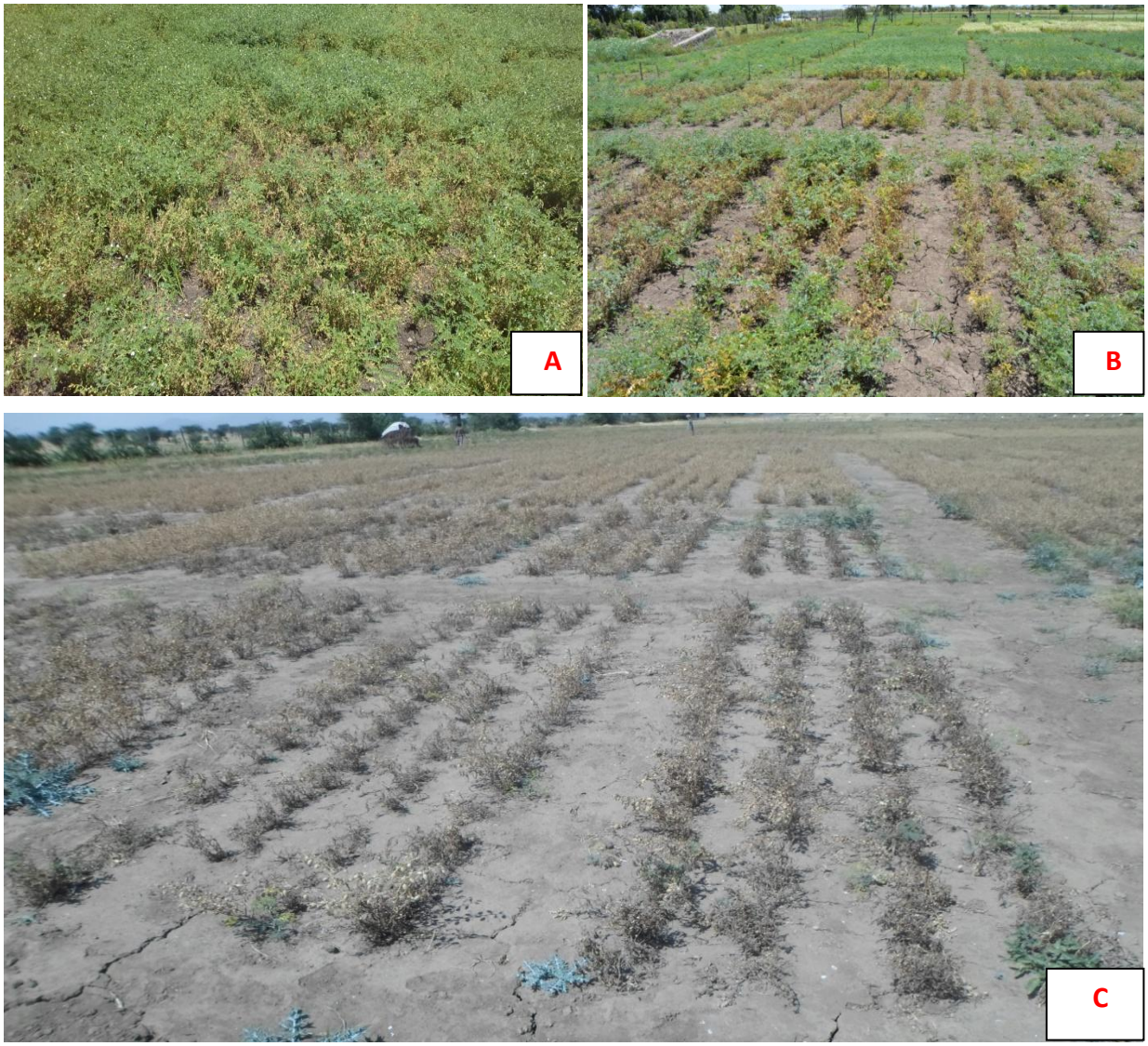

Figure 3.2. Ascochyta blight infection at Lume farmers field (A), Minjar (B) and Alem Tena (C) research sites**.**

3.4.1.2 Survey and Sampling for Assessment of Chickpea Ascochyta Blight

3.4.1. 2.1 Prevalence

The survey and sampling of ascochyta blight infected plants was made in the month of August 2015 to February 2016 on the basis of disease prevalence, incidence and severity from regions of Oromia, Ahmara, SNNPR and Tigray. The prevalence of chickpea ascochyta blight in different areas are given in Table 3.3 and Figure 3.3. It is evident from the table that highest prevalence (25%) was recorded in Debre Brihan area followed by East Shewa(15%). The prevalence of other surveyed areas varied from 0 to 10%. In Debre Brihan zone, particularly in Ensaro districts

blight diseases were moderately prevalent (25%) of all fields having visible infections, and reached 30% in one of these fields. Most of the chickpea growing areas have not shown disease prevalence and this indicate that the weather condition of the period of the study was not conducive for ascochyta blight development. No ascochyta blight was observed at Tigray region during the growing season of 2015/16, due to extremely dry conditions. In the SNNP region, ascochyta blight symptoms were recorded only in one field around November, but the distribution was low. Ascochyta blight disease was more prevalent during flowering/pod setting stage in visited fields (Figure 3.1).

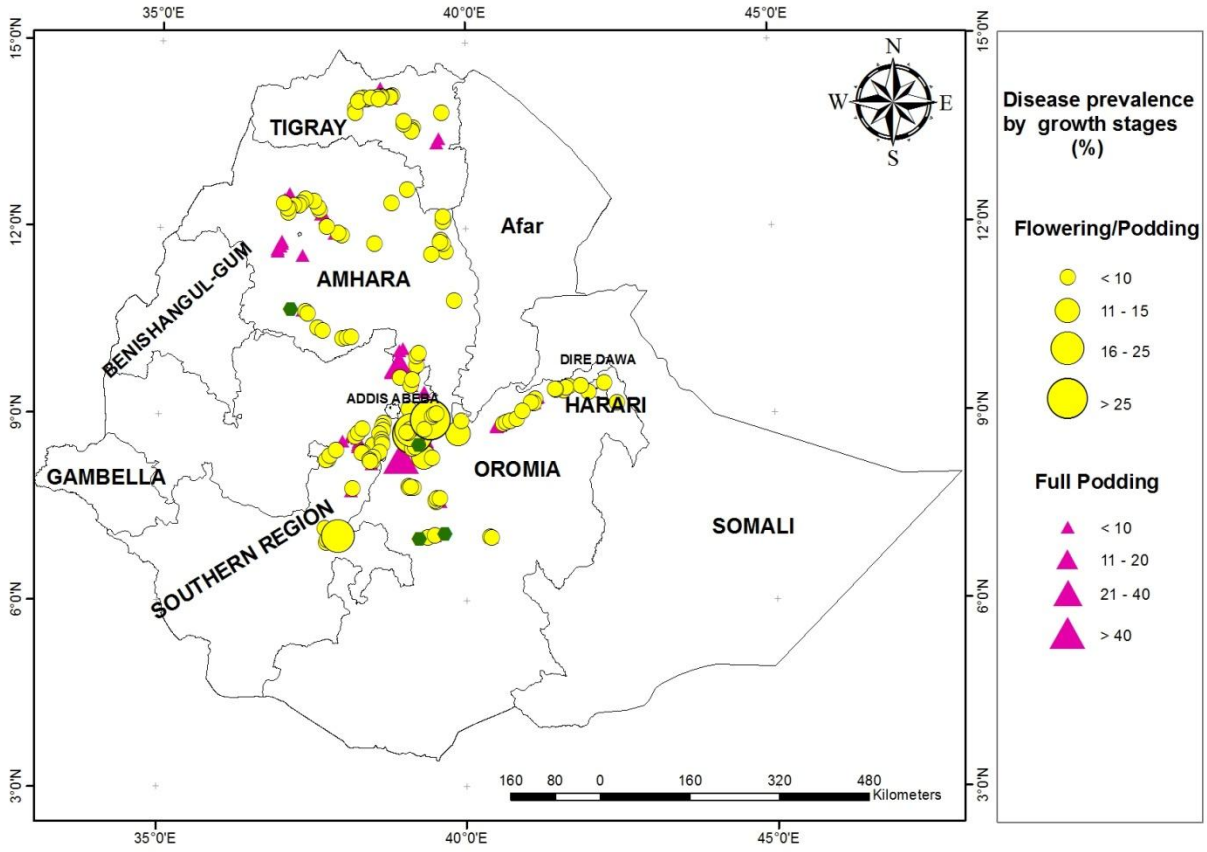

Figure 3.3. Prevalence of chickpea ascochyta blight disease by growth stages in major chickpea growing regions of Ethiopia (2015)

Most of blight disease prevalence at flowering/pod setting was recorded in Amhara region followed by Oromia region with < 10% (Figure 3.1). Low disease prevalence was also recorded during full podding (<10%) (Figure 3.1).

3.4.1.2.2 Disease Incidence and Severity

The disease incidence and severity of chickpea was recorded in 83 districts (Table 3.3). AB was recorded only in 30 of the 251 fields, and average incidence values ranged from 0 to 45.6%. Mean incidence was highest in the Debre Brihan zone (Table 3.3). Of the fields that were surveyed, the average incidence of AB in the two districts was more than 50%. However, there was a small variation in blight occurrence and incidence in different areas across the country. Regions with blight incidence was Amhara followed by Oromia and SNNP, but no blight disease was recorded in Tigray region. Present study revealed that, moderate average disease incidence was noticed in Debre Brihan (45.6%) and low disease incidence recorded in East Shewa (15.5%) followed by Woliata (9.3%), North Shewa (5%), North Wollo (2.5%) and South Wollo (2.1%). Particularly, in Minjar district of north shewa area blight disease was recorded on research station with high incidence (82%). In all other areas, disease incidence was not recorded. In this survey, it was recorded that ascochyta blight was prevalent in Debre Brihan zone with moderate incidence.

Ascochyta blight severity was generally low in these fields, ranging from 1 to 7 with mean value between 1 and 3.2 (Table 3.3). Two fields in East Shewa research sites had disease severities up to 9 in the scale used. The majority of fields had no disease. The maximum average blight severity (3.2) was found in East Shewa area followed by Debre Brihan Shewa (2.3). On the other hand, although several areas inspected in the regions was surveyed, disease was not observed in most of them. This shows that disease incidence and severity was low throughout the country. Variability in blight incidence and severity among the surveyed areas was minimal. The data obtained from the survey was not sufficient for analysis due to blight disease absence which was related to weather condition. This change of weather conditions brought by *El Nino* drought of 2015 caused low incidence of ascochyta blight disease in the chickpea growing areas. The individual mean prevalence, incidence and severities of chickpea blight in each areas are given in Table 3.3.

Table 3.3: Prevalence, incidence, and severity of Ascochyta blight in major chickpea growing areas of Ethiopia (2015)

Region	Area	No. of districts covered	No. of fields surveyed	Disease Prevalence (%)	Disease Incidence (%)		Disease Severity (1-9 rating)	
					Range	Mean	Range	Mean
Oromia	East Hararge	4	13	0	0	0	1	1
	West Hararge	3	15	0	0	0	1	1
	South West Shewa	9	28	0	0	0	1	1
	North Shewa	1	3	0	0	0	1	1
	Arsi	2	12	0	0	0	1	1
	Bale	3	8	0	0	0	1	1
	East Shewa	7	39	15	0-84	15.5	1-7	3.2
Amhara	South Gondar	5	5	0	0	0	1	1
	North Gondar	4	15	0	0	0	1	1
	West Gondar	2	9	0	0	0	1	1
	East Gondar	2	6	0	0	0	1	1
	North Shewa	5	31	10	0-82	5	1-4	1.8
	North Wollo	7	9	8	0-15	2.5	1-3	1.6
	South Wollo	1	1	5	5-40	2.1	1-3	1.4
	Debre Brihan	2	6	25	5-86	45.6	2-5	2.3
SNNP	Gurage	3	6	0	0	0	1	1
	Silte	1	2	0	0	0	1	1
	Hadiye	1	2	0	0	0	1	1
	Waliata	2	8	5	56	9.3	1-6	2.0
Tigray	West Tigray	3	4	0	0	0	1	1
	Central Axum	3	10	0	0	0	1	1
	North West Tigray	5	12	0	0	0	1	1
	North Tigray	1	1	0	0	0	1	1
	East Tigray	3	3	0	0	0	1	1
	South Tigray	3	3	0	0	0	1	1

3.4.1.3 Weather conditions

Climate data on temperature (°C), rainfall (mm) and relative humidity were compiled monthly for 23 metrological stations of major chickpea growing zones for 2014/15 and 2015/16(Table 3.4 and Table 3.5) growing season. Weather conditions during the growing seasons of 2014/15 to 2015/2016 differed substantially, mainly from the time of seedling to plants maturity. Mean temperatures of growing seasons was highest in 2015. Similarly, rainfall distribution was quite

different in both years. In 2015/16 temperature from the months of August to February was also higher compared to previous data and this period was very dry, causing growing conditions that were unfavorable for the ascochyta blight disease development.

Table 3.4. Weather characteristics of metrological stations located in major chickpea producing in areas Ethiopia (average of the months from August to February for the year 2014/15).

Region / Station	Zone	Elevation (m)	Average Rainfall (mm)	Average Relative Humidity	Maximum Temp. (^{0}C)	Minimum Temp. (^{0}C)
Oromia						
Alemaya	East Hararge	2020	98.73	77.71	24.70	4.20
Ambo Agriculture	West Shewa	2068	41.14	62.33	28.00	11.00
Fiche	North Shewa	2784	72.74	82.03	21.20	6.20
Kulumsa	Arsi	2211	76.44	66.39	29.90	11.30
Mojo	East Shewa	1763	74.94	57.37	31.30	6.50
Robe	Bale	2480	63.64	69.49	23.80	5.90
Woliso Giyon	West Shewa	2058	65.19	59.86	29.50	12.70
Amhara						
Aykel	North Gondar	2254	84.56	54.21	25.50	12.30
Debre Berhan	North Shewa	2750	67.56	65.91	20.90	2.40
Debre Tabor	North Gondar	2612	117.49	67.59	25.20	7.90
Debre Work	East Gojjam	2508	37.80	60.13	25.50	6.50
Finoteselam	West Gojjam	1840	80.44	68.07	29.10	11.00
Gondar A.P.	North Gondar	1973	81.14	59.69	29.10	12.30
Sirinka	North Wollo	1861	88.49	59.74	19.70	4.10
Wegidi	South Wollo	2405	55.84	71.97	27.00	9.40
Wereilu	South Wollo	2708	73.09	58.56	27.20	9.80
Wereta (Add)	South Gondar	1819	109.44	73.23	21.40	7.40
Woldia	North Wollo	1897	113.60	61.54	26.70	11.70
Mehal Meda	North Shewa	3084	67.57	57.74	28.40	10.10
SNNP						
Wolaita	North Omo	1854	131.39	65.39	29.30	8.90
Hosana	Hadiya	2307	144.06	58.89	28.00	13.60
Tigray						
Adigrat	East Tigray	2497	44.46	55.67	23.20	0.10
Mekelle (Obs)	South Tigray	2000	62.86	63.89	28.40	8.30

Source: National Metrological Agency of Ethiopia, 2015

Table 3.5**.** Weather characteristics in the chief metrological stations located in major chickpea producing in areas of Ethiopia (average of the months from August to February for the year 2015/16).

Region / Station	Zone	Elevation (m)	Average Rainfall (mm)	Average Relative Humidity	Maximum Temp. (^{0}C)	Minimum Temp. (^{0}C)
OROMIA						
Alemaya	East Hararge	2020	90.83	70.36	26.70	2.90
Ambo Agriculture	West Shewa	2068	41.56	56.93	29.40	10.60
Fiche	North Shewa	2784	63.51	64.26	23.20	5.90
Kulumsa	Arsi	2211	38.84	60.74	31.00	9.80
Mojo	East Shewa	1763	56.94	56.54	31.60	5.50
Robe	Bale	2480	52.26	64.29	25.00	4.70
Woliso Giyon	West Shewa	2058	49.71	56.67	30.60	12.40
AMHARA						0.00
Aykel	North Gondar	2254	69.33	46.70	31.00	12.80
Debre Berhan	North Shewa	2750	55.41	56.71	22.00	1.70
Debre Tabor	North Gondar	2612	91.19	62.39	28.70	7.60
Debre Work	East Gojjam	2508	15.14	55.93	26.20	6.40
Finoteselam	West Gojjam	1840	76.67	55.67	31.50	11.30
Gondar A.P.	North Gondar	1973	73.97	53.79	32.00	11.60
Mehal Meda(RS)	North Shewa	3084	44.84	62.96	20.90	3.40
Sirinka	North Wollo	1861	85.81	65.36	28.30	10.30
Wegidi	South Wollo	2405	51.33	54.44	28.50	9.80
Wereilu	South Wollo	2708	43.50	63.61	25.60	7.30
Wereta (Add)	South Gondar	1819	182.47	58.96	30.80	12.30
Woldia	North Wollo	1897	68.56	56.46	30.00	8.40
SNNP						0.00
Hosana	Hadiya	2307	99.33	61.37	28.90	7.70
Wolaita	North Omo	1854	93.46	55.70	29.70	13.40
TIGRAY						0.00
Adigrat	East Tigray	2497	30.87	49.76	25.50	-0.20
Mekelle (obs)	South Tigray	2000	33.00	60.74	29.30	6.30

Mean monthly rainfall, relative humidity, monthly maximum and minimum temperature of the 2014/15 and 2015/16 chickpea growing seasons were summarized in Table 3.6, Figure 3.1 and 3.2. Average rainfall for growing season (August-February) in 2015/16 was 80.55 mm, which was 18.02 mm greater than that of 2014/15. A sharp change in the pattern of rainfall was evident in all locations, which showed a shift in rainfall for some areas. Mean relative humidity for the growing season (August-February) in 2014/15 was 58.71%, which was 5.52% less than that of

2015/16. Mean maximum and minimum temperatures of growing seasons was highest in 2015/16. The current climate compared to the last year climate showed an average increase in air temperature. The average maximum temperature for 2014/15 was 29.3 °C and 31.5 °C for 2015/16. Average minimum temperature during the growing season in 2014/15 was 2.3°C, which was 1.0 °C less than in 2015/16. Therefore, microclimatic factors such as rainfall, temperature and relative humidity may affect the sporulation of blight fungi. When the temperature is not favourable and the moisture requirements of a pathogen on a susceptible host are not fully met, an epidemic is not likely to develop which was observed during this survey.

Table 3.6 Monthly mean rainfall, mean relative humidity, monthly maximum temperature and minimum temperature during the chickpea growing seasons of 2014/15 and 2015/16 for major growing areas in Ethiopia.

Year	Parameter	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mean
2014/15	Average Rainfall **(mm)**	257.10	140.52	89.95	36.76	12.88	6.46	20.17	85.6
	Average Relative Humidity(%)	73.56	72.63	66.03	63.28	57.44	57.40	59.29	64.2
	Maximum Temperature **(^{0}C)**	28.30	28.40	28.40	29.40	29.30	29.90	31.30	29.2
	Minimum Temperature **(^{0}C)**	2.10	3.20	2.20	2.10	0.10	2.40	4.10	2.3
2015/16	Average Rainfall **(mm)**	200.34	119.06	67.64	30.67	13.87	1.96	4.18	62.5
	Average Relative Humidity(%)	67.90	67.89	59.35	59.67	55.05	51.75	49.35	58.7
	Maximum Temperature **(^{0}C)**	31.00	29.50	30.70	30.00	29.70	31.00	32.00	31.5
	Minimum Temperature **(^{0}C)**	2.90	5.80	5.30	3.30	1.00	-0.20	5.20	3.3

Low rain and high temperatures in 2015/16 growing season (Table 3.6) resulted in hot, dry weather conditions, which don't favor Ascochyta blight occurence.

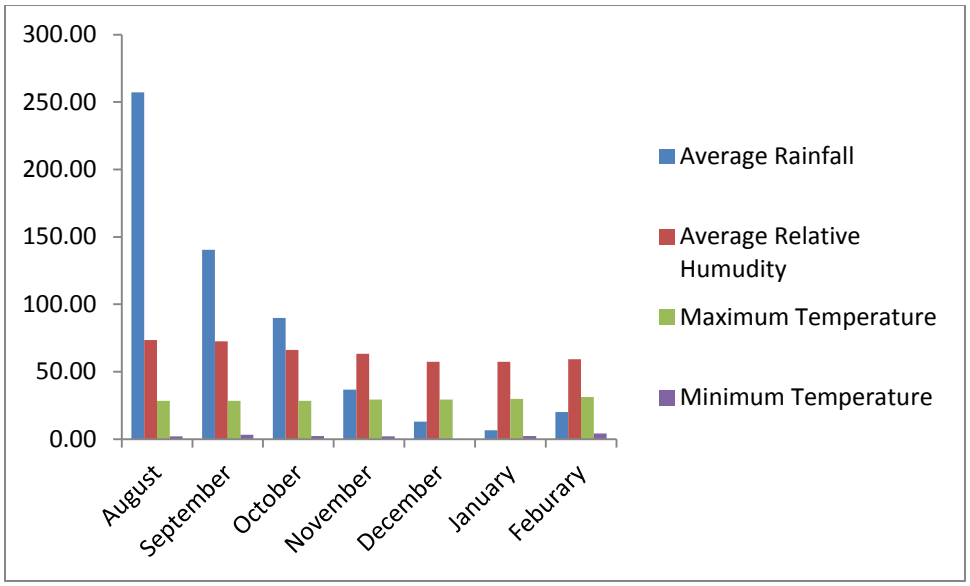

Fig. 3.4 Average monthly rainfall, relative humidity, minimum and maximum temperatures of chickpea growing season of Ethiopia, 2014/15.

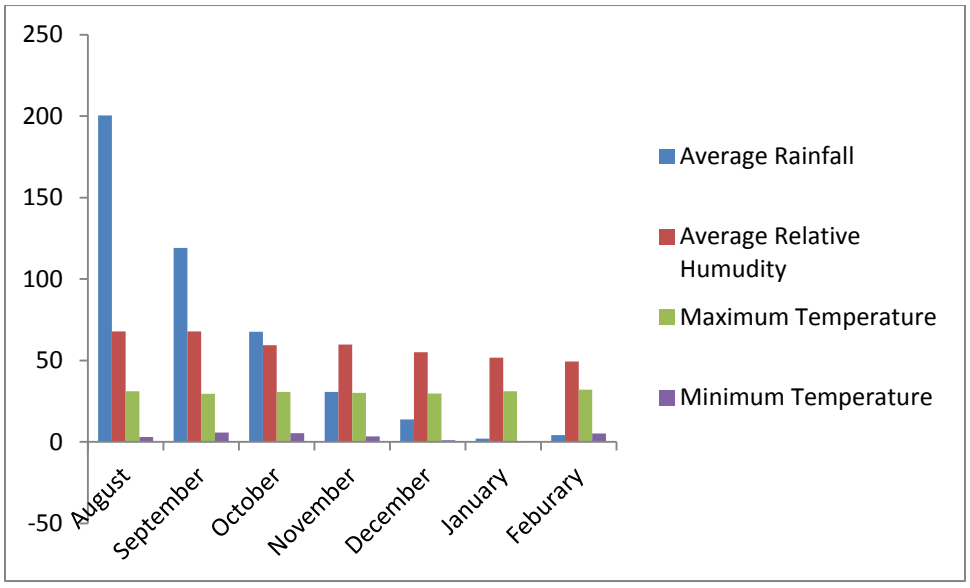

Fig. 3.5 Average monthly rainfall, relative humidity, minimum and maximum temperatures of chickpea growing season of Ethiopia, 2015/16.

3.4.2 Discussions

Field surveys generate knowledge on the current status of Ascochyta blight disease prevalence, incidence and severity, which forms the basis of priority setting in the integrated disease management. Such knowledge is currently lacking or outdated for the chickpea Ascochyta blight pathosystem in Ethiopia. The survey of ascochyta blight in 2015/16 cropping seasons on chickpea in Ethiopia, indicate that the disease information is still not available to chickpea as conditions were not favourable for disease development. Chickpea blight is serious disease, which is mostly prevalent in relative humid weather conditions. It causes significant yield losses in different chickpea areas depending on its prevalence and intensity. The survey was systematically conducted to assess prevalence, incidence and severity of Ascochyta blight disease.

3.4.2.1 Surveys for Assessment of Chickpea Blight

In the present survey to estimate disease status of four regions were made according to disease prevalence, incidence and severity of chickpea blight. These four regions showed small variation due to limited data occasioned by luck of disease occurence. Chickpea is generally planted in rainfed areas of Ethiopia and its area is divided into two ecological zones on the basis of rainfall and crop duration, that is main season which has long duration and high rainfall and off season which has low rainfall. These ecological zones have different characteristics which have different impacts on chickpea production.

Disease symptoms were recorded in early October in few fields. Hot, dry weather arrested disease progress in all regions. Similar results have been reported (Ahmed et al, 2008). Ascochyta blight is endemic (Ahmed et al., 2005; Chang et al., 2000, 2002, 2003) in the surveyed area, and disease prevalence and severity depend on the occurrence of favourable weather, particularly precipitation (Chang et al., 2000, 2002, 2003). Similarly, Trapero-Casas and Kaiser (1997) reported that blight disease severity increases with the increase relative humidity. Cloudiness and prolonged wet weather favour rapid development and spread of the disease.

The results of this study demonstrate very low distribution of the disease in almost all chickpea growing areas limited by blight-unfavoured weather conditions of this season as compared to observations in earlier seasons.

The results obtained in this study are in agreement with the report of Chongo et al. (2002). Symptoms started occurring at vegetative stage and the spread was high at flowering and pod setting stages, varying among few observed fields. The symptoms observed in this survey were exactly identical to those described earlier by Gurjar et al. (2010), Pande et al. (2012), Nene et al. (2012) and Ali and Ozkan (2015).

The mean disease prevalence for the area surveyed ranged from 0 to 30 %. The mean disease incidence for area surveyed ranged from 0 to 45.6 % and that of average severity was varied from 1 to 3.2. The maximum disease prevalence (25%) and incidence (45.6%) was observed in Debre Brihan area of Amhara region and maximum severity (3.2) was observed in East Shewa zone. No ascochyta blight was observed in surveyed areas of Oromia region except East Shewa area. Most of surveyed fields showed very low levels Ascochyta blight severity (mean < 2) (Table 3.1), likely due to the hot, dry weather condition. The same situation was reported in Canada (Chongo et al., 2002). Besides the scanty rainfall, the temperature in all areas rose sharply during survey period, thereby limiting the chances of blight occurrence in these areas were generally low due to drought conditions. The average annual rainfall in these districts varied from 15.14 to 182.47mm (Table 4.3).

The rainfall in Ahmara region was recorded from 15.14 to 18.47 mm during cropping period. Similar study by Ahmed et al. (2008) found that ascochyta blight occurred in all areas sampled and was more severe in wet areas than in dry areas of Canada. Chongo et al. (2002) also reported widespread of blight disease but the severity was generally low in many fields of surveyed areas due to extreme drought.

Although infection started in some fields in some provinces, further disease development was arrested due to drought conditions in 2015⁄2016 cropping season. In some districts of Debre Brihan area, moderate disease incidence and severity were observed. This is probably due to cool temperature and relatively high humidity conditions that are suitable for disease development (Pande et al., 2005) and conducive to the development of the sexual stage (Raheem et al., 2008). No Ascochyta blight infection was detected in 19 of 25 counties/areas in 2015⁄2016, due to

drought conditions during the season. Most of the chickpea were planted very late and that also contributed for the failure of disease development. Late planting is a deliberate effort by farmers to escape the disease. Similar results were reported by Atik et al. (2010); Chongo et al. (2002) and Ahmed et al. (2008) who found low severity in many fields due to drought conditions. Although farmers could not differentiate most of the chickpea varieties during the survey, many Ethiopia farmers grow improved varieties of chickpea.

The survey revealed that disease incidence and severity were varied but low from locality to locality due to cultivation of different varieties in different geographical and environmental conditions prevailing in each locality. The observed incidence and severity of the disease in surveyed areas may be associated with the presence of favorable environmental condition. These conditions increase in humidity that favors the distribution of the pathogen. Similarly, Atik et al. (2010) has reported low disease prevalence and severity of chickpea blight in nine major growing provinces of Syria which was associated to dry condition. The survey results showed that disease severity was different among provinces. Ahmed et al. (2008) also reported existence of blight disease variation among surveyed areas of Alberta.

Unlike in 2015/16, the cropping season in 2014⁄2015 was more favourable for disease development, and infections were observed on several locations on both cultivated chickpea varieties and wild relatives. Symptoms on chickpea seedlings were reported around mid of September in 2014⁄2015 in central parts of Ethiopia, which was much earlier than in this 2015/16. The widespread occurrence and early appearance of ascochyta blight symptoms was attributed to cool, wet weather conditions favourable for pathogen spread and infection, to high levels of inoculum in chickpea- production areas, and to planting of infected seed. This finding is in agreement with that of Chang et al. (2003) who found widespread Ascochyta blight on chickpea in Saskatchewan.

Ascochyta blight epidemics are a recurrent phenomenon in Ethiopia (Asrat et al., 2015), indicating that no cultivars are immune to *A. rabiei* as the pathogen continues to evolve the ability to overcome resistant varieties (Chen et al., 2004). More effort is needed to identify new sources of resistance. Knowledge of genetic variation of pathogen populations is required for successful resistance breeding (Peever et al., 2004). However, recent observations indicate that the disease occurrence is becoming variable over seasons due to changes in rainfall that favour

disease development and severe pod infection (Abang and Malhotra, 2008). Considering that even resistant chickpea varieties are susceptible to Ascochyta blight during the reproductive phase, concerted effort is needed to ensure the development of lines that are resistant at all developmental stages of the crop (Abang and Malhotra, 2008).

3.4.2.2 Climate Change and Changing Scenario of Chickpea Ascochyta Blight in Ethiopia

Increasing climate variability with the change in climate is recognized unequivocally. With the changing climate patterns and cropping systems, host, pathogen and favourable environment interactions are leading to diseases epidemics in a range of crops. Three essential components are required simultaneously for a disease to occur: a virulent pathogen, a susceptible host and favourable environment and the effect over time of the evolutionary forces on living populations leading to new disease epidemics. Climate variability is adding a new dimension to managing plant diseases by altering the equilibrium of host-pathogen interactions resulting in either increased epidemic outbreaks or new pathogens surfacing as threats or less known pathogens causing severe yield losses (Aggarwal, 2003).

3.4.2.3 Changing Scenario of Ascochyta Blight and Pathogens in Ethiopia

Climate change may affect plant pathosystem at various levels viz. from genes to populations, from ecosystem to distributional ranges; from environmental conditions to host vigour/susceptibility; and from pathogen virulence to infection rates. In general, climate variability has shown positive and negative impacts on host-pathogen interactions. However, in general climatic changes could result changes in diseases/pathogens (Pande and Sharma, 2010).

Broad weather patterns have been associated with climate change and may affect disease. Associations of disease with *El-Nino* have been made and indicate the potential for future epidemics if weather patterns become more variable (Checkley et al., 2000; Rodó et al., 2002). Plant pathogens have varying ranges of temperature requirements that affect the various steps in disease infection cycles such as penetration, pathogen survival, dispersal, epidemic development, survival and sexual reproduction. A few studies have shown that wheat and oats become more susceptible to rust diseases with increased temperature (Coakley et al., 1999). On the contrary, cooler temperature and wetter conditions are associated with increased incidence on blights (*Ascochyta spp.)* in chickpea, lentil, and pea (Pande et al., 2010, Panagga et al., 2004).

This study also assessed the impact of climate change on ascochyta blight disease on chickpea in Ethiopia for 2015/16 growing season, are highlighted as follows. Compared to previous climatic conditions, the current climate scenario exhibits (i) a higher temperature across the months, (ii) a relatively warmer growing season, (iii) major change in annual total rainfall, (iv) a distinct shift in rainfall pattern and (v) an overall decrease in the number of rainy days. Extensive climate change studies conducted in southwestern region of Western Australia largely agree with the expected shifts of weather pattern summarized in this study (Bates et al., 2008).

Chickpea is largely grown in rainfed environments worldwide. Microclimatic factors such as air/plant temperature, relative humidity and light interception can affect the sporulation of fungi. The temperature and rainfall variability within the rainfed ecologies is very high, leading to varying intensities of moisture deficit. Weather conditions, including growing season rainfall and mean air temperature, influence the development of disease epidemics (Shtienberg et al., 2000; Trapero- Casas and Kaiser, 1992). Present finding supported these findings, in that ascochyta blight prevalence and incidence in 2014/15 was relatively higher than in 2015/16, associated with wetter, cooler conditions in 2014/15 (Table 3.6). Mean air temperature for the growing season (August - February) in 2014/15 was 29.3°C and 2015/16 was 31.5 °C. When the temperature is favourable and the moisture requirements of a pathogen on a susceptible host are fully met, an epidemic is likely to develop (Jhorar et al., 1998). Relative humidity (RH) directly affects sporulation of many fungi and germination of *A. rabiei* conidia occurs at 98-100% RH (Hassani, 1981). A change in the crop canopy micro-environment may affect disease development. A crop canopy that is open could allow the foliage and topsoil to dry, which is unfavorable for pathogen development.

3.4.2.4 Effect of Environmental Conditions on Ascochyta Blight

The combination of a sufficiently large population of a susceptible host, a virulent pathogen and an adequate duration of favourable environment is required for AB disease epidemics. Ascochyta blight is thought to be largely influenced by microclimate of the crop which in turn is influenced by prevailing weather conditions. The pathogen was affected by the weather at all crop growth and development stages up to maturity. Therefore crop losses due to this could vary from 0 to l00 percent, depending on the weather conditions, which emphasizes the scope of using the degree of crop loss as an important tool to identify both the favourable as well as unfavorable weather

conditions for the disease (Singh and Sharma, 1995). Quantitative information on crop microclimate and the response of the pathogen is a prerequisite to assess the importance of the microclimate on disease (Butler, 1993).

AB is favoured by cool and moist conditions. Under favorable conditions such as cool and moist weather (>350 mm annual rainfall and 23–25 °C) the disease may cause 100% yield loss (Nene and Reddy, 1987). The microclimatic factors such as plant temperature, relative humidity, rainfall, moisture, surface wetness and light interception are likely to affect the sporulation of *A. rabiei*. Any alteration in these factors would retard AB development. Rainfall and high relative humidity (RH) are critical for most epiphytotics, with temperature also playing an important role in development. During the early stages of infection, fungal diseases need favourable environmental conditions such as surface moisture, high RH and suitable temperature, for germination of spores and mycelial growth.

3.4.2.4.1 Effect of Relative Humidity on Blight in Ethiopia

Mean relative humidity for the growing season (August-February) in 2014/15 was 58.71 which was 5.52 less than that of 2015/16. A stronger influence of relative humidity was found on Ascochyta blight epidemic development in the country. In the early part of crop growth, though the disease started occurring on some parts of the country, the crop was affected by drought condition later on. Therefore low relative humidity resulting from drought found in the country limit blight epidemics. Many researchers have reported the importance of humidity in the development of blight disease. It directly influences sporulation by many fungi and has implication for the persistence of wetness. Reddy and Singh (1990) reported that Ascochyta blight is influenced by high humidity in association with favourable temperature. High relative humidity and a favourable temperature can increase ascochyta blight severity on chickpea (Jettner et al., 1999, Siddique et al., 1998). Disease infection occurs at relative humidity of > 95% (Jhorar et al., 1997). Using long term weather data, Jhorar et al. (1997) correlated disease severity with maximum temperature and afternoon relative humidity. The relationship between the disease and temperature was linear, and with relative humidity was an exponential asymptote.

3.4.2.4.2 Effect of Rainfall on the Blight in Ethiopia

Movement of water in canopies is most commonly associated with rain. Of the diverse attributes of rain, time, frequency and duration are critical in determining plant surface wetness and pathogen dispersal in plant communities through trickling and splashing. The intensity of rain as a function of the number, size and velocity of droplets affects disease in different ways. The cumulative effect of these factors may affect plant disease epidemic outbreaks (Royle and Butler, 1986). A similar study during the chickpea growing season by Kauser (1965) on the influence of winter rainfall on epiphytotic and revealed that high rainfall resulted in high chickpea blight incidence.

In this survey, differences were observed between the two years (2014/15 and 2015/16) with respect to reaction to Ascochyta blight. The mean growing season rainfall in 2014/15 (80.55mm) was higher than this year. The mean growing season rainfall in 2014/15 was 25% more than in 2015/16 (62.53mm), therefore, ascochyta blight growth would have been adversely affected during 2015/16 growing season. The growing season average rainfall for chickpea growing areas at Amhara-2014/15 (81.4 mm) was more than Amhara-2015/16 (71.5 mm). Ketelaer et al. (1988) reported monthly rainfall of 40 mm were needed before an epidemic of AB occurred. Rain splashing may accelerate the disease spread and keep the leaf surface wet. Increasing leaf wetness periods increase the disease severity (Armstrong et al., 2004).

3.4.2.4.3 Effect of Temperature on the Disease Severity

Temperature has important effects on the lifecycle of *Ascochyta rabiei*, the infection process, and disease development. Temperature as well as relative humidity during this survey period remained unfavorable for the growth of the pathogen and the pathogen - host interaction. The most favourable period for the development of Ascochyta blight was from 15-25 °C, however, the temperature of this year remained between -0.2 and 32.0°C with a mean value of 15.9°C. This would have been out of the optimum range of temperature most of the time, since 15-25 °C range was most favourable for fungal growth (Bedi and Aujla, 1970; Singh, 1984), thus, blight fungal growth would have been adversely affected this year. Ascochyta blight infection and disease development occur in the temperature range of 5 - 30 °C, with an ideal temperature of 20 °C (Trapero-Casas and Kaiser, 1992; Trapero-Casas and Kaiser, 2007). Disease severity increased with increasing temperatures to a maximum of 20 °C, then declined sharply at

temperatures above 25-30 °C. Colhun (1973) suggested that in general, disease development continues as long as healthy plant tissue is available under the favourable weather conditions. Temperature influences various fungal diseases and if it is too low or too high, the disease development stops. *A. rabiei* therefore, is infective in areas with cool, cloudy and humid weather (Pande et al., 2005).

A range of temperature from 5 to 30°C for infection and disease development has been defined by various researchers, and this was not prevailed during this period as temperature ranged from -0.2 to 32°C. The study clearly demonstrates that climate variabilities are important in influencing the Ascochyta blight infection.

This gave a strong indication that the combined effect of climatic variabilities may further be explored for a more refined analysis. As evident from the survey, temperature, relative humidity and rainfall are important factors which influences Ascochyta blight. This study will substantially accelerate the on-going efforts to understand the host × pathogen × environment interactions in chickpea under the changing scenario of climate.

3.5 Conclusions

Ascochyta blight disease is a major threat to chickpea production in several regions of Ethiopia. A countrywide survey was conducted in 2015/16 growing season to determine occurrence, prevalence, incidence and severity of the chickpea ascochyta blight disease in chickpea growing regions of Ethiopia. The study revealed that, ascochyta blight disease was not widely distributed and had low incidence and severity in the survey. This disease should however not be ignored as its status may change with changes in climatic conditions. The result indicated that AB is currently less prevalent in all surveyed areas. Only around 23% of surveyed districts showed disease symptoms. The disease incidence ranged from 0 to 45.6% with the mean of less than 10%. Debre Brihan and East shewa areas had high incidence relative to other surveyed areas. High mean severity score (7) was observed in few farmer's fields in East Shewa (Lume district) followed by Debre Brihan, Woliata, North Shewa, North and South Wollo but all the other areas showed no blight symptoms. Low disease development was attributed to extreme unusual drought conditions. Detailed surveys to monitor changes in ascochyta blight incidence from one year to another should be continued. There is likelihood that the status of blight disease can change with climate change.

CHAPTER FOUR

SCREENING OF CHICKPEA GENOTYPES FOR HOST PLANT RESISTANCE TO ASCOCHYTA BLIGHT UNDER HOTSPOT FIELD CONDITIONS

4.1 Abstract

Ascochyta blight caused by *Ascochyta rabiei* is a devastating and widely distributed disease of chickpea in Ethiopia and causes severe losses in yield. In the present study 39 chickpea genotypes from different sources were evaluated under field conditions in two different environments to identify sources of resistance against this disease. The experiment was planted in a randomized complete block design with 3 replications. Disease observations were recorded at seedling, flowering and full podding stages. There was a considerable variation among genotypes with respect to their disease reaction at three stages of evaluation. It was noted that 20 lines were asymptomatic, 18 were resistant while check was moderately resistant to the blight at seedling stage. Whereas, 29 genotypes were resistant, 9 were moderately resistant and the check was susceptible at flowering stage. At full podding stage, 15 genotypes were resistant, 23 were moderately resistant while check was highly susceptible. On an average, 46.16% resistant genotypes were identified at seedling stage, 74.36% at flower setting stage and 38.47% at full podding stage. The disease severity of moderate resistance genotypes were identified at flower setting stage was 23.08% and at full podding stage it was 58.97%. This study revealed that none of the 39 genotypes was asymptomatic, whereas 36 genotypes were resistant and two were moderately resistant on stage average basis. Variability in blight severity due to differences among the genotypes, among environments, and that due to genotype × environment interaction was highly significant ($P < 0.001$). Genotype × environment (G × E) interaction contributed only 3.33% of total variation, revealing stability of the phenotypic expression across environments. Correlation analysis of disease severities exhibited high association between growth stages. Ultimately, genotypes showing resistance may be exploited for the development of resistant cultivars against blight disease.

4.2 Introduction

Chickpea (*Cicer arietinum*) is the second most important pulse crop after common bean (*Phaseolus vulgaris*) in terms of cultivation and third in production after common bean and field pea worldwide. Globally, it is cultivated in 14.24 million ha producing 9.62 million tons of grain (FAOSTAT, 2014). India accounts for approximately 65% of world chickpea production, followed by Pakistan (9.5%) and Turkey (6.7%) (FAOSTAT, 2007), while in Africa, Ethiopia is the leading chickpea producer. Chickpea is a relatively cheap source of protein (20–23% in the grain), energy (carbohydrates, 40%), oil (3–6%) (Gil et al., 1996) and minerals (Mg, K, P, Fe, Zn, and Mn (Ibrikci et al., 2003) and β-carotene in the developing world (Milan et al., 2006). Chickpea also contributes significantly to sustainability of cereal-legume cropping systems, increasing the yield of cereals through enhancing the soil nitrogen and breaking the disease cycles of important cereal pathogens (Pande et al., 2011).

In Ethiopia, chickpea is important and play a vital role in providing food for the poor people of this country. It is generally cultivated under rainfed agriculture system. It is cultivated on 239,747.51 ha with production of 4,586,82 tons (CSA, 2015). The average grain yield of chickpea in Ethiopia is 1.9 tons ha^{-1}. Despite the large area under chickpea cultivation, total production and productivity is low and there is a wide gap between potential (5 tons ha^{-1}) and actual yield (1.9 tons ha^{-1}). The major cause of low yields in chickpea is its susceptibility to a number of biotic and abiotic stresses. Among biotic stresses, ascochyta blight caused by *Ascochyta rabiei* (Pass.) Labr. is a widespread foliar disease that causes extensive crop losses (up to 100%) in favourable environmental conditions (Pande et al., 2011). The disease occurs in major chickpea growing areas of the world (Nene and Reddy, 1987; Kaiser and Muehlbauer, 1989; ICARDA, 1996; Akem, 1999; Khan et al., 1999; Kaiser et al., 2000; Chongo et al., 2003b). Disease epidemics in Ethiopia and other major chickpea growing areas of Africa (Kenya, Tanzania and Malawi) has been reported (Pande et al., 2010; Kimurto et al., 2013). Besides the lack of early maturing cultivars suitable for the short growing season of Ethiopia, chickpea production has been limited by ascochyta blight. Ascochyta blight infection and disease progression occur from 5 to 25°C with an optimum temperature of 16-20°C, and a minimum of 6 hour leaf wetness. Disease severity increases with the increase in relative humidity (Trapero and

Kaiser, 1992). Cloudiness and prolonged wet weather favor rapid development and spread of the disease.

It has been reported that chickpea blight disease can be controlled by the foliar application and seed dressing fungicides (Reddy and Singh, 1984; Malik et al., 1991; Rauf et al., 1996; Pande et al., 2005), use of disease free seed and destruction of diseased plant debris (Chaube and Pandey, 1986). As chickpea is a rain fed crop and is grown under low input conditions, continuous seed treatment with fungicides are not possible (Chaudhry et al., 2006). Fungicides are also not eco-friendly, and increase input costs when applied on larger area, therefore not recommended. Further, pathogen of *Ascochyta rabiei* is highly variable and comprises of various pathotypes or races (Ilyas et al., 2007).

Therefore, resistant chickpea genotypes against blight disease are the cheapest, most effective, efficient and environment friendly method to control the disease (Erskine et al., 1994: Ye et al., 2000; Ilyas et al., 2007). As the time passes the previously released resistant cultivars are becoming susceptible to this disease due to the occurrence of new pathotypes or races of *ascochyta rabiei* (Hussain and Malik, 1991; Jamil et al., 1995; Armstrang et al., 2001; Jamil et al., 2010). Hence, there is a dire need to continuously explore and identify the new sources of resistant chickpea germplasm and its incorporation into high yielding quality commercial chickpea varieties (Bashir et al., 1997). For this reason, the present study was designed to evaluate chickpea genotypes for resistance to ascochyta blight disease in Ethiopia.

4.3 Materials and Methods

4.3.1 Experimental Sites

The study was conducted at two experimental sites of the Debrezeit Agricultural Research Center (Alem Tena and Minjar) in Ethiopia. The two sites were selected as they represent semi-arid smallholder farming systems. Experimental field at Alem Tena substation is located under the region of Oromia and Minjar is located at under the region of Ahmara. Alem Tena is located at latitude 8^0 14' N, longitude 38^0 54' E and altitude of 1700 m above sea level. Experimental site at Minjar is located at 8^0 45' to 8^0 55' N latitude, 39^0 15' to 39^0 45' E longitude and altitude of 1710 meters above sea level. Both sites are characterized by plane topography largely used for crop cultivations.

4.3.2 Experimental Period

The experiments were carried out during the period from (August -February) for two years (2014/15-2015/16).

4.3.3 Soil Type

According to MSDARDB Minjar Shenkora district has different soil types suitable to harvest various kinds of grains. The most dominant soil type in the study area is brown soil its coverage in the woreda (district) is about 46.5% of the total area. Even though their area coverage is very low there are also other types of soils, these are gray soil, black soil and red soil possessing the share of the total area 19.5%, 19% and 15% respectively. The soil at Alem Tena is very light sandy soil with low water holding capacity. Soil types of this experimental site include 50% clay, 32% sand, and 18% silt (Assefa et al., 2000). The topography of the both experimental fields was low land (< 1900) under the Agro Ecological Zone.

4.3.4 Climate of the Study Area

Climate has a great effect in shaping the day to day social, economic and cultural activities of human beings. Since Ethiopia is a mountainous country the distribution of temperature and rainfall depends mainly on the altitudinal variation. As a result there are five agro climatic zones in the country. The topography of Minjar Shenkora is found between the ranges of 1040 meter and 2380 meters above sea level. Due-to this range of altitude the study area accommodates three agro climatic regions- Kola, Woinadega and Dega. According to the MSEARDB report

largest area of the Minjar Shenkora district is found under the woinadega agro climatic region accounting about 70.9 % of the total area. The rest of the study area lies under kola and Dega climatic regions accounting 24.8 % and 4.3 % share of the total area respectively. According to North Shewa Agricultural and Rural Development Bureau, Minjar Shenkora district has annual average temperature range between 13.21^0c and 23.02^0c. The area receives 800 - 1000mm annual rainfall. Alem Tena is a lowland area (< 1900 m.a.s.l) located in the Rift Valley and with well-drained sandy soils. It has an elevation of 1700 m which is characterized by semi-arid climate receiving a mean annual rainfall of 500mm which is quite erratic and with an average annual temperature ranges $13\text{-}27^0$c. Both sites are characterized by plane topography largely used for crop cultivations.

4.3.5 Land Preparation

The land of the experimental fields at both locations (Alem Tena and Minjar) was ploughed with a power tiller. Later on, the land was ploughed and cross-ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering all the stubbles, crop residues and uprooted weeds were collected and removed from the main field and the land was ready. Whole experimental land was divided into unit plots maintaining the desired spacing. The gross plot size was $4.8m^2$ accommodating 4 rows of 4m in length and row to row and plant to plant spacing of 40cm and 10 cm, respectively.

4.3.6 Experimental Design and Treatments

The experiment was conducted in Randomized Complete Block Design with three replications at both locations of Alem Tena and Minjar. The whole area of each experimental field at both locations was divided into three blocks and each block was again divided into four unit plots. Thirty nine chickpea genotypes obtained from ICARDA and ICRISAT were screened for their resistance against *Ascochyta rabiei* under field conditions during the long rains (August-January) in 2014–2015. The 39 lines were selected based on previous yield and preliminary evaluation for ascochyta blight during growing season. The screening followed ascochyta blight standardized procedure developed by ICRISAT and ICARDA. Test material was sown in 40cm row spacing and inter planted with susceptible cultivar which serves as spreader line after every two rows. Infested debris was scattered between rows (Pande et al., 2005; ICARDA, 2003). Chickpea

infected debris were scattered between rows at emergence and the trial was inoculated with a conidium suspension of *Ascochyta rabiei*. This was because the environment was adequately humid and wet to allow sufficient infections primarily from the stubble and also from plants in the spreader rows that were infected from spores generated in pycnidia from the stubble. The crop was raised with cultural practices to maintain healthy crop growth. The material for present investigation comprised 39 genetically diverse genotypes of chickpea including two standard check varieties viz. Arerti (resistant) and Mariye (susceptible check). A highly susceptible variety, mariye was repeatedly planted after every two test entries to ensure uniform spread of the disease in the field. The disease data were recorded at three stages of plant growth i.e. at seedling stage, flowering stage and at full podding stage (near physiological maturity).

4.3.7 Data Collection and Analysis

Since ascochyta blight affects all aerial parts of the plant, the disease reaction of individual genotypes in both sites were recorded on whole plant basis 40 days after emergence (DAE) on 6 randomly selected plants per plot using a 1–9 rating scale similar to those utilized by Jan and Wiese (1991), Sharma et al. (1995) Chen and Muehlbauer (2003), and Pande et al. (2011), where 1= no visible symptoms; 2= minute lesions prominent on the apical stems; 3= lesions up to 5–10 mm in size and slight drooping of apical stems; 4= lesions obvious on all plant parts and clear drooping of apical stems; 5= lesions on all plants parts, defoliation initiated, breaking and drying of branches slight to moderate; 6= lesions as in 5, defoliation, broken, dry branches common, some plants killed; 7= lesions as in 5, defoliation, broken, dry branches very common, up to 25% of plants killed; 8= symptoms as in 7 but up to 50% of the plants killed and 9= symptoms as in 7 but up to 100% of the plants killed. Based on the disease score, test genotypes were categorized for their reaction to ascochyta blight infection according to Pande et al. (2006) scale where, 1,asymptomatic (HR); 1.1–3.0, resistant (R); 3.1–5.0, moderately resistant (MR); 5.1–7.0, susceptible (S); and 7.1–9.0, highly susceptible (HS). The whole plant disease ratings were averaged across plants and replicates to generate a mean disease rating for each genotype before analysis. Diseased and total plants were counted at seedling, flowering and at near maturity stages of the crop and percentage of plants infected in each genotype was calculated. Cumulative blight severity data for each genotype in each location was used in data analysis. The disease ratings were subjected to analysis of variance and means separated using LSD ($P < 0.05$) using Genstat release 18.2; Rothamsted Experiment Station, Herpenden, Herts AL52JQ, UK).

4.4 Results and Discussions

4.4.1 Results

The present study was carried out to find out the chickpea genotypes which is responsible for resistance to ascochyta blight infection. The results from the analysis of variance revealed a considerable variation towards disease reaction among chickpea genotypes (Table 4.1). Mainly three types of disease reaction i.e., resistant, moderately resistant and susceptible were noticed in these genotypes. Susceptible check (mariye) showed severe symptoms of disease on all parts of the plant with disease severity rating mean of 5.7 (susceptible). It was observed that none of the 39 genotypes was highly resistant/asymptomatic, whereas 36 genotypes were resistant and two were moderately resistant (Tables 4.1). Most of the resistant genotypes were of indigenous origin and developed through breeding. The number of resistant genotypes was higher that might be due to use of resistant material in the study obtained from national and international sources.

Blight severity of most of the chickpea accessions varied greatly between locations and years. The performance of each genotype was not always stable through all environments. This was also confirmed by the different frequency distribution of genotypes in each location over the two years suggesting a genotype × environment interaction. Subsequent analysis of variance of blight severity showed that the effects of genotype, environment and the genotype × environment interaction for blight severity were all highly significant ($P < 0.001$) (Table 4.1). Among the three sources of variation (genotype, environment and genotype × environment) the largest portion of variability for blight severity was accounted for by genotypes (56.06%), followed by environment (40.61%) and genotype ×environment interaction (3.33%).

Table 4.1: Average disease reaction of 39 chickpea accessions against ascochyta blight disease during main season 2014/15-2015/16.

Genotype	Type	Alem Tena	Minjar	Average Severity	Resistance level	Seed Colour
ARERTI	Kabuli	1.8	2.7	2.3	Resistant	White Cream
FLIP09-126C	Kabuli	1.7	3.0	2.3	Resistant	White
FLIP09-127C	Kabuli	1.8	2.8	2.3	Resistant	Cream
FLIP09-142C	Kabuli	1.9	2.9	2.4	Resistant	White
FLIP09-144C	Kabuli	1.6	2.2	1.9	Resistant	White Cream
FLIP09-153C	Kabuli	1.6	2.7	2.1	Resistant	Cream
FLIP09-172C	Kabuli	1.4	3.4	2.5	Resistant	White
FLIP09-174C	Kabuli	1.7	1.8	1.8	Resistant	Cream
FLIP09-186C	Kabuli	1.9	2.4	2.2	Resistant	Cream
FLIP09-1C	Kabuli	2.3	3.2	2.8	Resistant	Cream
FLIP09-204C	Kabuli	2.2	2.3	2.2	Resistant	White
FLIP09-205C	Kabuli	2.4	2.8	2.6	Resistant	White
FLIP09-206C	Kabuli	1.7	3.2	2.4	Resistant	White
FLIP09-211C	Kabuli	2.3	3.1	2.7	Resistant	White
FLIP09-212C	Kabuli	1.8	2.6	2.2	Resistant	white
FLIP09-215C	Kabuli	1.6	2.3	1.9	Resistant	white
FLIP09-224C	Kabuli	1.6	2.9	2.2	Resistant	White Cream
FLIP09-250C	Kabuli	1.7	2.2	2.0	Resistant	White
FLIP09-251C	Kabuli	2.2	2.2	2.2	Resistant	White
FLIP09-252C	Kabuli	1.6	2.4	2.0	Resistant	White
FLIP09-253C	Kabuli	1.4	2.3	1.9	Resistant	White
FLIP09-254C	Kabuli	1.8	2.6	2.2	Resistant	White Cream
FLIP09-281C	Kabuli	1.7	2.6	2.1	Resistant	Cream
FLIP09-48C	Kabuli	2.3	3.6	2.9	Resistant	white
FLIP09-4C	Kabuli	2.4	3.0	2.7	Resistant	White
FLIP09-55C	Kabuli	2.1	3.1	2.6	Resistant	cream
FLIP09-6C	Kabuli	3.4	3.0	3.2	Moderately resistant	White
FLIP09-70C	Kabuli	1.8	3.2	2.5	Resistant	Cream
FLIP09-73C	Kabuli	2.2	3.0	2.6	Resistant	White
FLIP09-78C	Kabuli	1.6	3.4	2.5	Resistant	White
FLIP09-79C	Kabuli	1.9	2.7	2.3	Resistant	White
FLIP09-82C	Kabuli	2.2	3.2	2.7	Resistant	White
FLIP09-87C	Kabuli	1.9	2.7	2.3	Resistant	Cream
FLIP09-89C	Kabuli	2.1	3.1	2.6	Resistant	White Cream
FLIP09-92C	Kabuli	2.4	2.3	2.4	Resistant	White
ICCV-11514	Desi	2.0	2.9	2.4	Resistant	Brown
ICCV-92944	Desi	5.0	1.9	3.4	Moderately resistant	Brown

ICCV-96836	Desi	2.1	2.0	2.1	Resistant	Brown
Mariye	Desi	6.2	5.2	5.7	Susceptible	Dark Brown
Mean		**2.1**	**2.8**	**2.5**		
SE	**0.60**					
Years	***					
Site	***					
Variety	***					
Site x Variety	***					

*** =*indicate significance level at 0.001*

The disease severity and seed colour of 39 chickpea genotypes at seedling, flowering and full podding stage is presented in Table 4.1. There was high significant variation between genotypes for their disease reaction ($P < 0.001$). The categorization of germplasm showed that at seedling stage 20 genotypes were highly resistant, 18 were resistant and local check was moderately susceptible. Whereas, 29 genotypes were resistant, 9 were tolerant/moderately resistant and one was susceptible (check) at flower setting stage. On the other hand, at late stage 15 genotypes were resistant, 23 were moderate susceptible and check was highly susceptible (Table 4.2 and Figure 4.1). The disease severity at physiological maturity stage increased invariably in all the genotypes as compared to that at seedling stage. On an average basis 51.28% high disease resistance was recorded at early stage. The disease reaction of the present study revealed that 46.16% resistance genotypes were screened at seedling stage, 74.36% at flower setting stage and 38.47% at full podding stage. The disease severity of moderate resistance genotypes were screened at flower setting stage was 23.08% and at full podding stage it was 58.97%. Only susceptible check (mariye) genotype exhibited moderate resistance at seedling stage.

The results showed that chickpea accessions had significant genetic variation between genotypes for their disease reaction at three stages i.e., at seedling, flowering and full podding stage. Our study revealed that at seedling stage majority of the genotypes were highly resistant whereas, at flower setting stage majority of the genotypes were resistant and at full podding stage majority of the genotypes appeared to be moderate resistance.

Table 4.2: Disease response of 39 chickpea accessions against ascochyta blight disease at growth three stages and average severity during 2014/15-2015/16 growing season.

Genotypes	Seedling	Flowering	Full Podding	Average Severity
ARERTI	1.33	2.58	2.83	2.25
FLIP09-126C	1.17	2.75	3.08	2.33
FLIP09-127C	1.17	2.67	3.00	2.28
FLIP09-142C	1.17	2.67	3.33	2.39
FLIP09-144C	1.00	2.17	2.50	1.89
FLIP09-153C	1.00	2.33	3.08	2.14
FLIP09-172C	1.00	3.17	3.17	2.45
FLIP09-174C	1.00	2.00	2.33	1.78
FLIP09-186C	1.17	2.58	2.83	2.19
FLIP09-1C	1.33	3.25	3.75	2.78
FLIP09-204C	1.00	2.50	3.17	2.22
FLIP09-205C	1.50	3.08	3.33	2.64
FLIP09-206C	1.17	2.92	3.25	2.44
FLIP09-211C	1.17	3.17	3.83	2.72
FLIP09-212C	1.00	2.67	2.83	2.17
FLIP09-215C	1.00	2.42	2.42	1.94
FLIP09-224C	1.00	2.92	2.75	2.22
FLIP09-250C	1.00	2.25	2.67	1.97
FLIP09-251C	1.17	2.42	3.08	2.22
FLIP09-252C	1.17	2.17	2.67	2.00
FLIP09-253C	1.00	2.33	2.33	1.89
FLIP09-254C	1.17	2.67	2.67	2.17
FLIP09-281C	1.00	2.42	3.00	2.14
FLIP09-48C	1.00	3.67	4.17	2.94
FLIP09-4C	1.33	2.83	4.00	2.72
FLIP09-55C	1.33	2.92	3.58	2.61
FLIP09-6C	1.33	3.50	4.83	3.22
FLIP09-70C	1.00	3.00	3.50	2.50
FLIP09-73C	1.17	3.25	3.33	2.58
FLIP09-78C	1.00	3.00	3.50	2.50
FLIP09-79C	1.00	2.42	3.50	2.31
FLIP09-82C	1.00	3.25	3.92	2.72
FLIP09-87C	1.00	2.58	3.33	2.31
FLIP09-89C	1.00	2.83	4.00	2.61
FLIP09-92C	1.50	2.58	3.00	2.36
ICCV-11514	1.00	3.00	3.33	2.44
ICCV-92944	2.67	3.67	4.00	3.44
ICCV-96836	1.00	2.17	3.00	2.06
Mariye	3.18	6.65	7.23	5.70

Most of the genotypes that showed high resistance and resistant response at seedling stage appeared to be moderate resistance at physiological maturity stage. Although little information on the resistance is available, a detailed research based on this material is needed to throw light on it. On average basis, thirty six accessions showing resistance reaction may be utilized in breeding programme to develop resistant varieties against ascochyta blight disease (Table 4.2). Development of disease is slow in resistant lines and fast in susceptible lines.

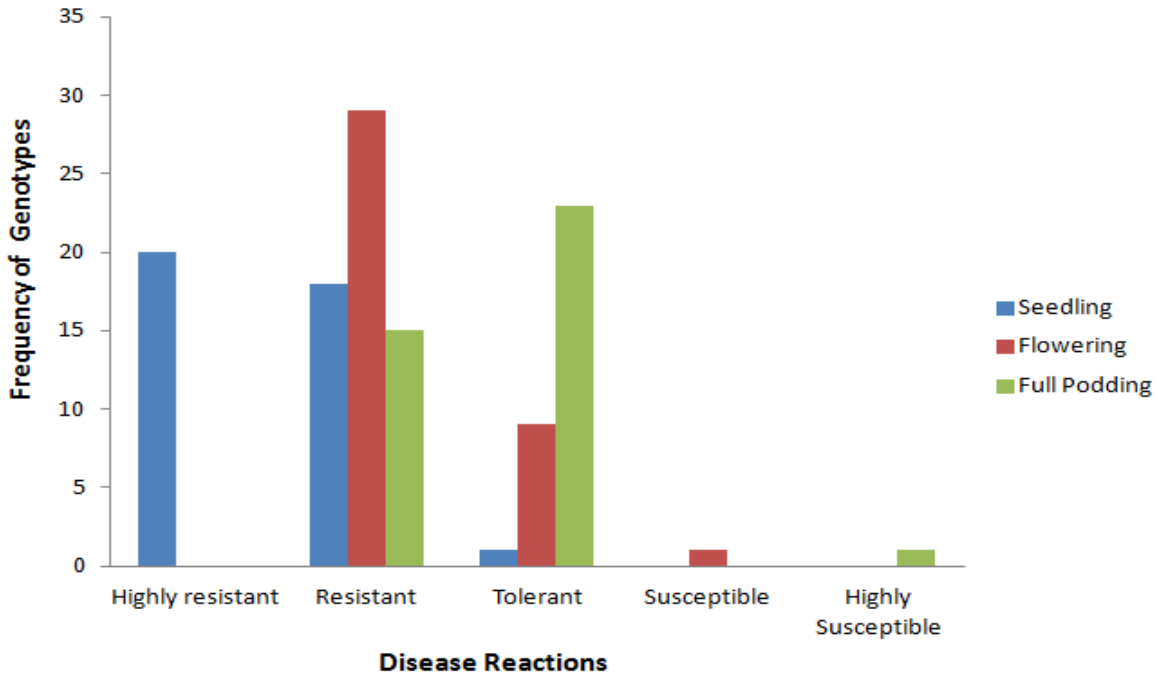

Fig. 4.1. Frequency of chickpea accessions for ascochyta blight disease reaction at growth stages

It was observed from the present study that Ascochyta blight infection was most severe at full podding stage, thus it is suggested that severity scores on large number of germplasm at full podding under field conditions should be sufficient in identifying resistant genotypes. The resistant genotypes from this study should be further screened and at the same locations to confirm resistance at full podding. None of the genotypes was highly resistant on average basis which indicate the conducive environmental conditions for disease during screening period. Meanwhile, the resistant genotypes will be used to introgress the trait into susceptible high yielding varieties.

There were significant differences in AB responses between genotypes at both sites (Table 4.1). Amongst tested genotypes, FLIP09-144C, FLIP09-174C, FLIP09-215C, FLIP09-250C, FLIP09-252C and FLIP09-253C had low disease rating of 1.8-2.0 and the only symptoms seen were minute lesions prominent on the apical stems (Table 4.1). Three lines viz. FLIP09-153C, FLIP09-281C and ICCV-96836 had disease rate of 2.1. Genotype FLIP09-6C (Kabuli) and ICCV-92944 (Desi) had moderate disease reaction with disease score between 3.0-3.4 and 1.9-5.0 respectively in both sites. These genotypes had lesions up to 5-10 mm in size and slight drooping of apical stems to lesions on all plants parts, defoliation initiated, breaking and drying of branches slight to moderate. The seed colour of these genotypes were white and brown respectively. All the other genotypes were resistant to AB with average score of > 3.1 in both sites and most of these genotypes had white seed colour. There were lower disease scores of 1.4-2.4 at Alem Tena site as compared to Minjar which had disease scores of 1.8-3.6 for all these genotypes.

The average maximum disease severity of 5.7 was recorded on Mariye variety (check) and minimum average disease severity was 1.8 which was recorded on FLIP09-174C. Disease severity indicate that most of the test genotypes (36) exhibited resistant response while genotypes viz; FLIP09-6C and ICCV-92944 were moderately resistant and only Mariye genotype (check) was susceptible in this study (Table 4.1). In Ethiopia, present available genotypes are mostly susceptible to chickpea ascochyta blight. In this scenario chickpea lines showing resistance behavior against Ascochyta blight are potential new varieties cultivars other agronomic are superior or they may be used in breeding program to develop resistant varieties.

4.4.1.1 Correlation Analysis

The estimates of correlation coefficients for disease reaction between disease stages of chickpea genotypes was computed (Table 4.3). The present study revealed a significant association between average severity and seedling stage (r = 0.65**), flower setting stage (r = 0.96**) and full podding stage (r=0.95**). There was a positive and significant relationship between disease reaction at early and full podding stage (r = 0.44**). Positive and significant correlation between seedling stage and flowering stage (r = 0.49**).

Table 4.3: Correlation analysis among three disease stages (seedling, flowering and full podding) of chickpea genotypes in Ethiopia.

Stage	Seedling Stage	Flowering Stage	Maturity Stage	Severity
Seedling Stage	1.00			
Flowering Stage	0.49**	1.00		
Maturity Stage	0.44**	0.92**	1.00	
Severity	0.65**	0.96**	0.95**	1.00

** = *Significant at 0.05*

Similarly, disease reaction at flowering stage shows a strong significant correlation with full podding stage (r = 0.92**). It was concluded based on correlation results that field condition was in linear relationship and it was suggested to screen large chickpea genotypes at seedling stage and then only resistant and moderate resistant accession could be screened at flowering or adult plant stage.

4.4.2 Discussions

AB caused by *Ascochyta rabiei* is a devastating disease of chickpea gaining importance day by day due to prevalence of weather conditions in the country. Since chickpea is grown under rainfed environments, continuous use of fungicide seed treatments increases input costs for large production area, thus not recommended (Chaudhry et al., 2006). The best option available for integrated management strategy to control these diseases is to exploit host plant resistance mechanism to identify the sources of resistance in existing chickpea germplasm (Duzdemir et al., 2014). Screening germplasm and breeding lines for disease resistance is a comprehensive task, which encompasses different approaches. Among the options available, field trials are regarded as powerful tools to identify sources of resistance as they reflect the natural conditions to which the selected material will be eventually subjected to. In this study, chickpea genotypes were evaluated in different locations to identify genotypes resistant to AB across geographical locations in Ethiopia. AB severity on these genotypes were significantly affected by the environment (location) and their interaction. Significant effects of interaction between chickpea genotype and environment suggested that the pathogen populations, in term of virulence genes, varied across different geographical locations although the possibility that the different genotypes could also respond differentially to different environmental conditions cannot be excluded (Kulakarni and Chopra, 1982).

Our results indicates that the ascochyta blight infection was more severe at Minjar (2.8) than Alem Tena because Minjar is located in higher altitude with higher humidity than Alem Tena which favored rapid development and spread of the pathogen due to cool wet conditions in these areas. Similarly, Pande et al. (2005) and Gaur and Singh (1996) also noted that cool and wet weather favors the development of AB epidemics in most regions of the world where the crop is commonly grown.

The worldwide collection of cultivated chickpea germplasm has very low frequency of resistance to *Ascochyta rabiei* (Reddy & Singh, 1984). The present study revealed a considerable variation for AB severity between the genotypes. The disease severity on 39 chickpea genotypes was recorded at seedling, flowering and full podding stage (Table 4.1). The results showed that chickpea accessions had significant genetic variation between genotypes for their disease reaction at three stages i.e., at seedling stage, flowering stage and full podding stage. Similar results was reported by Iqbal et al. (2010). Our results found 20 genotypes to be highly resistant with disease score 1, 18 genotypes found resistant with disease score 1 to 3, and Mariye (check) was moderately resistant with disease score 3.1 to 5 at seedling stage. At flowering stage 29 genotypes were resistant, 9 moderately resistant and 1 cultivar (check) was susceptible. At full podding stage, 15 genotypes were resistant, 23 moderately resistant and 1 genotype (check) was highly susceptible. Present findings are in line with earlier studies of Iqbal et al., 2010; Hassan et al., 2012; Dubey and Singh, 2003; Shah et al., 2015. Many others also reported the sources of resistance under field conditions (Alma et al., 2003; Iqbal et al., 2004; Chaudhry et al., 2005 ; Bashir et al., 2006). Development of resistance level in some genotypes at two stages might be due to activation of their resistant genes at different plant stages or because of variation in mode of infection at various stages (Ilyas et al., 1991, Reddy and Singh, 1984, 1990). The variation in pathogenicity of the fungus used for screening could be another plausible explanation for change in their behavior to disease reaction. This question is yet to be resolved by conducting more experiments on mode of inheritance and infection of Ascochyta blight.

On stage average, it was observed that none of the 39 genotypes were highly resistant, whereas 36 genotypes were resistant, two genotypes were found moderate resistant and 1 variety (check) was susceptible. During screening, it was found that most of genotypes were resistant. This shows that most of chickpea germplasm have good source of resistance genes that can further be exploited and incorporated into commercial cultivars. The resistance of chickpea genotypes

against Ascochyta blight disease is due to either a single dominant gene or recessive gene (Reddy & Singh, 1993). Ascochyta blight has a wide range of resistance from different sources having different genes of resistance (Collard et al., 2003). Different genes conferring different levels of resistance could be introduced into commercial cultivars through gene pyramiding to facilitate increased level and durability of resistance in the commercial cultivars (Tekeoglu et al., 2000).

In Ethiopia, present available germplasm is mostly susceptible against chickpea blight. Iqbal et al. (2010) screened 145 genotypes against ascochyta blight and wilt diseases. Most of the genotypes were susceptible to highly susceptible which in contrary with present study. Iqbal et al. (2002) evaluated 356 chickpea germplasm accessions from different origins and none of the genotypes was highly resistant. However, only 7 genotypes were resistant and 75 were moderately resistant. Similarly, Bokhari et al. (2011) evaluated the resistance level of ten cultivars of chickpea and observed that maximum number of varieties were susceptible under field conditions. Pande et al. (2005) also listed several sources of AB resistance at ICARDA, ICRISAT and other regions with similar resistance levels as those identified in this finding. To date the different varieties of different research institutes are mostly susceptible to present races of *Ascochyta rabiei* (Ghanzanfar et al., 2010). Thus, only those genotypes having resistance genes of both local and exotic can be released as commercially grown varieties (Nasir et al., 2000). The identification of sources of resistant germplasm against chickpea AB has been done by many authors in the past (Bashir et al., 1985; Hussain et al., 2002; Shah et al., 2005; Atta et al., 2006; Sarwar et al., 2012; Kimurto et al., 2013; Ahmad et al., 2013; Ali et al., 2013). Many other workers have also reported the occurrence of moderate resistance to Ascochyta blight. Many sources of resistance to *Ascochyta rabiei* have been reported during the last 50 years and generally these reports were based either on field observation during natural epidemics or on artificial inoculation tests in the field or greenhouse (Bashir et al., 1985, 2006; Alam et al., 2003; Iqbal et al., 2004; Chaudhary et al., 2005).

A comprehensive study on the number of genes conferring resistance against chickpea blight, their nature, and diversity is essential for exploiting resistance sources in resistance breeding programme (Ilyas et al., 2007). The information on the resistance to *Ascochyta rabiei* detected in the present study provided a clear clue that there is sufficient genetic variation in chickpea for this trait that can be exploited for disease control by pyramiding disease resistance.

4.4.3 Conclusions

Chickpea blight is important destructive diseases worldwide. Options available so far are the management or to use cultivars having stable resistance to this disease. Worldwide chickpea breeding efforts are continuing to pyramid ascochyta resistant genes from various sources including wild *Cicer* species. Due to the introduction of new virulent strains there is continuous need to screen and develop new varieties using different breeding techniques against virulent strains to create variability to obtain sustainable yield. This study to identified sources of resistance to ascochyta blight of chickpea with great potential for use in breeding programs. Results from present study revealed that considerable variation was found for resistance against ascochyta blight. Most of genotypes were resistant against chickpea blight indicating good source of resistance genes in Ethiopia chickpea germplasm and further need thorough testing over the years and locations for their direct use as a variety or their involvement in future chickpea improvement. These genotypes may be used directly as varieties in areas having high incidence of these diseases after evaluating them for high yield and other agronomic traits. There was a common relationship between disease severities at three stages. This indicated that different genotypes could be utilized according to prevalence of disease at various growth stages.

CHAPTER FIVE

EVALUATION AND SELECTION OF HIGH YIELDING EARLY MATURING CHICKPEA LINES FOR PRODCUCTION IN ASCOCHYTA BLIGHT-FREE POST-RAINY SEASON

5.1 Abstract

Progress in chickpea breeding has been constrained by lack of good early maturity varieties that can be produced in the post-rainy season. Field experiments were conducted during 2014/2015 growing season to evaluate yield and yield components of early maturing chickpea. The experiment was carried out in a randomized complete block design in three replications at Debre Zeit Research Station. Fifteen chickpea lines obtained from ICRISAT were evaluated. Chickpea genotypes were significantly different for evaluated traits. Days to 50% flowering ranged from 43 to 53 and plant maturity from 103 to 111 days. Number of days to 50% podding ranged from 68 to 77. The mean of days taken to end podding was 89.4 days with range of 86 and 94. Line DZ-2012-CK-00019 produced highest grain yield (1960kg/ha) followed by DZ-2012-CK-00015(1950kg/ha) and DZ-2012-CK-00031(1719kg/ha). Correlation studies showed that seed yield was significantly and positively correlated with first pod height, number of primary branches, hundred seed weight, biomass yield, harvest index, pod weight and seed weight. Path analysis indicated that, seed weight exerted the maximum positive direct effect on grain yield followed by days taken to flowering, days taken to end podding, number of pods per plant and biomass yield. Thus, seed weight, number of pods per plant and biomass yield could be used as a selection index for chickpea improvement. The implication of the results of this study may be possible for development of chickpea in drought tolerance. The present results enhance the progress in combining early phenology traits with resistance to ascochyta blight and drought tolerance. Multi- location and multi- year evaluations are needed to identify lines that are early maturing and resistant to most pathotypes and in different environments.

5.2 Introduction

Chickpea a normally cold season legume, is grown in over fifty countries in a wide range of environments and cropping systems. An important component to be considered for crop adaptation to the different environments is phenology (the time to flowering, podding and maturity) (Gaur et al., 2009, 2012). Phenology plays critical role in adaptation of chickpea cultivars to different environments (Berger et al., 2004, 2006). Chickpea can mature in a wide timeframe ranging from 80 to 180 days depending on the genotype, growing conditions and environments (Gaur et al., 2008). However, in about two-thirds of chickpea growing areas, the crop growing season is short (90-120 days) because of terminal drought or heat stresses. Early maturity in chickpea helps the crop in escaping terminal drought and heat stresses. Chickpea is largely grown on receding soil moisture after the rains. Terminal drought and heat stresses are the major abiotic constraints it faces in the semi-arid tropics, where it is grown under rainfed conditions. Early maturity is also important for the summer-grown crop in SAT environments (as in Ethiopia) as the crop often encounters end of season drought (Gaur et al., 2008, 2012; Anbessa, 2006; Toker and Canci, 2006; Toker et al., 2007).

Considerable progress has been made in development of early and extra-early chickpea cultivars in both desi and kabuli types. Several cultivars with high yield potential, early maturity and resistance to fusarium wilt are available and their adoption is showing impact on enhancement of chickpea production in some short-season SAT environments (Zope et al., 2002; Guar et al., 2004; Ketema et al., 2005; Gaur et al., 2008). There is also progress in combining early phenology traits with resistance to ascochyta blight. However, the level of ascochyta blight resistance in these lines remains low and need to be enhanced (Ketema et al., 2005; Gaur et al., 2008). According to Kumar and Abbo (2001), lack of genetic knowledge is mainly responsible for the slow progress in chickpea breeding in general.

Most sources of ascochyta blight resistance identified in chickpea germplasm are late maturing. It may be so because these germplasm originated from cooler long season environments where ascochyta blight frequently occurs (Gaur et al., 2008). There are variable reports on relationship between phenology and resistance to ascochyta blight in chickpea. A negative correlation between days to flower and resistance to ascochyta blight was reported by Lichtenzveig et al. (2002). Later, this group identified one of the ascochyta blight resistance quantitative trait loci

(QTLs) linked with one of the loci for time of flowering (Lichtenzveig et al., 2006). However, in another study this group found no relationship between phenology and ascochyta blight resistance and suggested no constraints in combining ascochyta blight resistance with early phenology (Bonfil et al., 2006). There are reports on developing early maturing ascochyta resistance lines (Singh and Reddy, 1992, 1994, 1996; Clarke et al., 2004; Bonfil et al., 2007). There are also reports on successful efforts on inducing mutations for early phenology in late maturing ascochyta blight resistant lines. For example, two induced mutants from ascochyta blight resistant line FLIP 90-73C flowered and matured 25 to 30 days earlier than the parental line (Omar and Singh, 1995). Thus, chickpea cultivars for SAT must have resistance to ascochyta blight. Developing early maturing cultivars with high resistance to ascochyta blight is a major objective in ICRISAT's chickpea breeding program (Ojiewo et al., 2014).

Chickpea has recently become an important pulse crop in Ethiopia. The expansion of this crop production in Ethiopia is partially limited by ascochyta blight along with lack of early maturing varieties suitable for the short growing season. Successful production of chickpea in Ethiopia requires use of genotypes with early maturity characteristics in addition to resistance to ascochyta blight. The chickpea breeding program in Ethiopia has a major focus on development of ascochyta blight resistant cultivars that can mature early in SAT environments (Ojiewo et al., 2014). Early maturity is an important strategy of matching crop duration with the period of favorable growing conditions to minimize the impact of drought conditions. Also, reducing the duration of crop growth in chickpea will increase and stabilize yield to a great extent (Anbessa, 2006). Besides the lack of early maturing cultivars suitable for the short growing season, expansion of chickpea production has been limited by ascochyta blight. In Ethiopia, yield loss caused by an ascochyta blight epidemic and was attributed to cool, wet weather, which persisted throughout the growing season (Amin and Fufa, 2014 and Asrat, 2015).

Specific niches for early chickpea cultivars cultivation of chickpea in wheat-fallows and other late sown conditions chickpea is subjected to late sowing in certain situations, such as delayed maturity of preceding crop, delay in field preparation due to excessive soil moisture, increase in cropping intensity. The late sowing of chickpea leads to reduction in the duration of crop growing season. Considerable area is available for chickpea cultivation under late sown conditions in Ethiopia and provides an opportunity for expanding chickpea area, which is very

much needed for diversification of cereal-based cropping systems. Early maturing cultivars with heat tolerance will be required for these conditions.

Early maturity is a key agronomic trait for chickpea breeding in Ethiopia. Few progress has been made in developing earlier maturing varieties. This prompted us to look for novel strategies to induce earliness. The effective coordinated action of the genes for these traits would therefore reduce the seasonal length requirement of chickpea and subsequently minimize production risk. Understanding of the physiological and genetic bases of earliness of crop maturity and conceptualizing genetic strategies of reducing crop duration should enable breeders to better bridge the gap between the apparent and desired level of earliness in chickpea in Ethiopia. Therefore, the main objective of this study was to evaluate yield and yield components of early maturing chickpea grown under rainfed conditions of Ethiopia.

5.3 Materials and Methods

Field experiments was conducted in the experimental field at Debre Zeit Agricultural Research Center (latitude 08° 44' N, longitude 38° 58' E and altitude 1900 m), Debre Zeit, Ethiopia. A set of 15 (10 kabuli type and 5 Desi type) early and extra early maturing chickpea lines including two standard checks ('Ejere' and 'Minjar') were evaluated for phenology (time to flowering, podding and maturity), yield and yield components at Bishoftu during in 2014/15 main growing season. Randomized complete block design was used with three replications. The gross plot size was 4.8m^2 accommodating 4 rows of 4m length. The seeds were sown using spacing of 30cm between rows and 10cm between plants on 27 Aug 2014. Harvesting was done from two central rows of each plot (2.4m^2) on 24 Dec 2014. Seedbed was well prepared through two perpendicular plowing and removing residual of the previous crop and weeds. The Pesticides were also applied to control major diseases and insects prevailing in the area. Hand weeding was practiced as frequently as needed. Data on plant phenology (time to flowering, podding and maturity), yield and yield components were collected at the recommended time and subjected to statistical analysis using R software.

5.4 Results and Discussions

5.4.1 Results

The performance of 15 different characters for fifteen chickpea lines (10 kabuli and 5 desi) are presented in Table 5.1. Significant differences were observed for all the characters studied among the tested genotypes. This indicated that the genotypes under investigation possess genetic variations and divergence for various quantitative traits. Among these characters large amount of variance had been recorded for grain yield followed by biomass yield (Table 5.1). The treatment means of various quantitative traits for different groups of early and extra early cultivars during 2014/15 main season is presented in Table 5.1.

Phenological stages of chickpea development were significantly affected by genotypic difference among the studied chickpea lines (Table 5.1). The overall mean for days to first flowering was 40 days with the earliest genotype DZ -2012-CK-00075 first flowering in (35.7 days) followed by DZ-2012-CK-00031 (36.3) and DZ-2012-CK-00074 first flowering in (37.7 days) (Table 5.1). Control plants Ejere and Minjar first flowered in 38 and 39 days respectively. Based on the results, days to 50% flowering of tested genotypes significantly ($p \leq 0.05$) varied from 43.3 days in DZ -2012-CK-00075 to 52.7 days in DZ-2012-CK-00022 with overall mean of 47 days (Table 5.1). The difference between the earliest and the latest maturing genotypes was 10 days. Only 4 lines took less number of days (ranging between 41- 45 days) than the standard checks Minjar (47.7 days) and Ejere (44.7 days) to attain 50% flowering (Table 5.1).

Days to maturity of tested genotypes ranged from 103 days to 111 days (Table 5.1). The difference between the earliest and the latest maturing genotypes was 8 days. DZ-2012-CK-00023 took maximum days to mature (111 days) followed by DZ-2012-CK-00076 (110) days, while DZ-2012-CK-00019 took minimum days (103 days) to mature. The standard checks Ejere (110 days) and Minjar (108 days) tended to mature earlier than four chickpea genotypes (Table 5.1). This indicate that days to maturity of nine tested genotypes were less than that of check line, Minjar. In general low yielding genotypes required relatively more days to maturity than the high yielding ones. This indicates grain yield in chickpea is negatively correlated with days required to maturity (Table 5.2). The reason here could be because environmental stresses (terminal drought) set in before maturity of late maturing genotypes, limiting their yields.

Table 5.1. Mean performance of 15 characters for 15 early and extra early chickpea genotypes

Genotypes	DFF	DF	DFP	DEP	DM	FPH	NPB	PPP	SPP	100 SW	BMY	YLD	HI	PW	SW
DZ-2012-CK-00015	40.3	48.0	70.7	86.7	106.7	10.7	2.0	23.9	27.3	38.9	4722	1950	0.36	67.6	52.4
DZ-2012-CK-00017	39.7	47.0	74.0	89.0	107.3	18.3	1.9	19.2	20.0	40.3	5417	1569	0.25	58.7	44.6
DZ-2012-CK-00019	39.3	46.3	73.3	88.0	103.0	13.6	2.7	20.7	20.7	44.2	4861	1960	0.37	60.7	46.5
DZ-2012-CK-00020	43.0	51.3	72.7	90.0	104.7	18.1	1.3	31.5	31.4	22.8	2871	1086	0.38	45.1	35.4
DZ-2012-CK-00022	44.7	52.7	71.0	91.7	108.7	14.8	1.7	22.9	20.7	23.0	2222	914	0.47	38.6	29.6
DZ-2012-CK-00023	39.3	43.7	72.7	90.7	111.0	11.3	1.7	20.6	20.6	23.4	2083	486	0.24	44.3	30.3
DZ-2012-CK-00031	36.3	44.7	67.7	86.0	108.0	14.4	2.4	17.4	16.2	48.5	4758	1719	0.39	54.1	40.3
DZ -2012-CK-00039	40.7	47.0	70.7	89.0	104.0	16.7	2.3	23.9	22.2	40.3	2962	1035	0.32	53.7	40.3
DZ-2012-CK-00074	37.7	44.0	71.0	90.0	107.3	16.3	1.6	17.9	18.3	30.9	2583	1000	0.36	52.3	39.3
DZ -2012-CK-00075	35.7	43.3	69.7	94.3	108.7	13.0	2.2	16.0	14.1	33.9	2399	732	0.31	27.7	20.8
DZ-2012-CK-00076	43.7	48.3	76.7	92.0	110.3	12.3	1.7	19.3	16.6	31.3	3194	1035	0.31	37.2	28.7
DZ-2012-CK-00079	40.7	50.7	74.7	87.7	107.0	11.5	2.2	23.8	26.5	41.8	2778	762	0.28	67.2	52.5
DZ-2012-CK-20011S-0041	38.7	46.3	73.0	87.3	106.0	12.9	2.3	19.4	21.4	39.6	3103	1043	0.32	58.7	46.6
MINJAR	39.3	47.7	69.3	90.3	108.3	16.1	2.1	27.3	27.1	38.8	2963	1051	0.34	62.2	47.0
EJERE	38.3	44.7	70.3	88.7	110.0	15.1	1.1	15.1	13.2	39.0	2361	525	0.23	34.2	26.3
Grand Mean	**39.8**	**47.0**	**71.8**	**89.4**	**107.4**	**14.3**	**1.9**	**21.3**	**21.1**	**35.8**	**3285**	**1124**	**0.3**	**50.8**	**38.7**
Minimum	**35.7**	**43.3**	**67.7**	**86.0**	**103.0**	**10.7**	**1.1**	**15.1**	**13.2**	**22.8**	**2083**	**486**	**0.2**	**27.7**	**20.8**
Maximum	**44.7**	**52.7**	**76.7**	**94.3**	**111.0**	**18.3**	**2.7**	**31.5**	**31.4**	**48.5**	**5417**	**1960**	**0.5**	**67.6**	**52.5**
CV (%)	**10.59**	**11**	**5.82**	**6.11**	**3.88**	**25.28**	**26.2**	**43.4**	**50.6**	**36.88**	**53**	**73**	**33.2**	**49.5**	**50.5**
SE	**0.63**	**0.8**	**0.62**	**0.82**	**0.62**	**0.54**	**0.08**	**1.34**	**1.59**	**1.97**	**261**	**122**	**0.02**	**3.8**	**2.91**

DFF= days to first flowering, DF= days to 50% flowering, DM= days to maturity, NPB= Number of primary branches, FPH= First pod height, DFP = Days to 50% podding, DEP=Days to end podding, PPP = Number of pods per plant, SPP = Number of seeds per plant, HSW = Hundred seed weight, YLD= grain yield/ha, BMY= biomass yield/ha, HI= harvest index , PW= Pod weight, SW= Seed weight, CV = coefficient of variation SE = standard error.

In the present study, number of primary branches per plant was significantly ($P<0.001$) different among the chickpea lines tested. The number of primary branches ranged from 1.1 to 2.7. Among genotypes, DZ-2012-CK-00019(2.7) genotype had exhibited the maximum number of primary branches followed by DZ-2012-CK-00031(2.3), which were significantly taller than standard checks, Minjar (2) and Ejere (1.1) (Table 5.1).

According to analysis of variance, days to 50% podding significantly varied from 67.7 days to 76.7 among chickpea lines (Table 5.1). The highest number of days was observed in genotypes DZ-2012-CK-00076 (76.7 days) followed by DZ-2012-CK-00079(74.7 days) and DZ-2012-CK-00017(74 days); and the lowest number of days was observed in genotypes DZ-2012-CK-00031 (67.7 days) followed by standard check Minjar (69.3 days).

The mean of days taken to end of podding was 89.4 days with ranged from 86 to 94.3 days. Line DZ -2012-CK-00075 (94.3 days) had the highest number of days taken to end of podding and the lowest number of days to end of podding was observed with DZ-2012-CK-00031(86 days) genotype. The standard checks, Minjar and Ejere had 90.3 days and 88.7 days to end of podding in this study.

In this study, the range of first pod height was between 10.7 and 18.3 cm with mean of 14.3 cm and the differences for first pod height for the tested genotypes was significant ($p< 0.001$). The longest first pod height was observed on DZ-2012-CK-00017(18.3 cm) followed by DZ-2012-CK-00020 (18.1 cm) and line DZ-2012-CK-00015 has short first pod height which was 10.7 cm.

Number of pods per plant had shown significant differences between chickpea lines ($P< 0.01$) (Table 5.1). The highest number of pods per plant was produced by DZ-2012-CK-00020 (31.7) followed by Minjar (27.3), DZ-2012-CK-00079(23.8), DZ-2012-CK-00022 (22.9), while Ejere produced minimum number of pods per plant (15.1) which was significantly lower than that of Minjar (27.3).

Number of seeds per plant was significantly different ($p < 0.001$) among the tested genotypes and DZ-2012-CK-00020 showed the highest number of seeds per plant (31.4g) followed by DZ-2012-CK-00015 (27.3g), Minjar (27.1g), and DZ-2012-CK-00079 with (26.5g). This line, DZ-2012-CK-00020 produced higher seed yield due to the production of high number of filled pods and less number of false pods, supported by high first pod height (Table 5.1). The lowest seed yield per plant value (13.2g) was recorded in standard check Ejere genotype followed by DZ -2012-CK-00075(14.1g) and DZ-2012-CK-00031(16.2g).

The weight of 100 seed varied significantly from 22.8 to 48.5 g (Table 5.1). This result showed a wide range of variability among the genotypes. The maximum 100 seed weight (48.5g) was observed in DZ-2012-CK-00031 which was different from all other lines. There were 5 genotypes which had larger seed size (38.9 to 45.8 g) than Minjar (38.8 g). In this study, large

number of genotypes showed smaller seed size than Minjar. Among these genotypes, DZ-2012-CK-00020 was recorded the least in 100-seed weight (22.8 g).

The results of the study also indicated that chickpea grain yield, biomass yield and harvest index were significantly affected by genotypic difference (Table 5.2). The highest grain yields obtained from DZ-2012-CK-00019, DZ-2012-CK-00015 and DZ-2012-CK-00031 whose mean seed yields were 1960kg/ha, 1950kg/ha and 1719kg/ha, significantly out yielded the standard check Minjar (1051kg/ha). However, none of the test genotypes markedly out yielded the best yielding (3450kg/ha). Pod weight and seed weight showed insignificant variability among tested genotypes.

A comparative anyalysis of the performance of top yielding lines and low yielding lines in respect of seed yield implies days to flowering was low and days to maturity was high for most of high yielding lines, as compared to low yielding lines. As a result maturity period was high in most of high yielding lines relative to maturity period of low yielding lines. This is due to the fact that early flowering prolonged reproductive phase which is a major yield determinant. However, duration of crop maturity is a function of genotype, environment or their interaction. Therefore, early flowering lines do not necessarily mature lately and some late flowering genotypes have a short reproductive period and mature simultaneously with earlier flowering ones.

5.4.1.1 Correlation between Seed Yield and Yield Attributes

The associations of different yield attributes with seed yield is summarized in (Table 5.2). Seed yield had significant positive association with days to first pod height ($r = 0.32^{**}$), number of primary branch ($r = 0.32^{**}$), hundred seed weight ($r = 0.31^{**}$), biomass yield ($r = 0.91^{**}$), harvest index ($r = 0.57^{**}$), pod weight($r = 0.42^{**}$) and seed weight ($r = 0.45^{**}$) whereas days to end of podding ($r = -0.42^{**}$) and days taken to maturity ($r = -0.50^{**}$) had significant negative correlation with seed yield. All other traits showed insignificant association with seed yield in this experiment.

Table 5.2. Correlation coefficients of yield and yield contributing traits in chickpea, 2014-2015

Traits	DFF	DF	DFP	DEP	DM	FPH	NPB	PPP	SPP	100 SW	BM Y	YLD	HI	PW
DFF														
DF	0.86**													
DFP	0.40**	0.40**												
DEP	0.27	0.23	0.40**											
DM	-0.09	-0.09	0.32**	0.52**										
FPH	0.07	0.11	-0.16	-0.28	-0.4**									
NPB	-0.20	-0.12	-0.01	-0.02	-0.10	-0.27								
PPP	0.49**	0.42**	0.07	0.15	-0.08	0.05	0.09							
SPP	0.39**	0.37**	0.08	0.11	-0.08	0.04	0.09	0.92**						
100SW	-0.51**	-0.44*	-0.27	-0.48*	-0.25	0.01	0.54**	-0.20	-0.14					
BMY	0.02	0.03	-0.08	-0.51*	-0.5**	0.35**	0.36**	0.13	0.09	0.48**				
YLD	0.04	0.08	-0.09	-0.42*	-0.5**	0.32**	0.32**	0.18	0.12	0.31**	0.9**			
HI	-0.03	0.06	-0.12	-0.11	-0.16	0.14	0.02	0.08	0.01	-0.09	0.27	0.57*		
PW	-0.09	-0.07	-0.11	-0.31*	-0.30	0.08	0.40**	0.60**	0.70**	0.39**	0.44*	0.42*	0.09	
SW	-0.06	-0.05	-0.08	-0.32*	-0.29	0.09	0.41**	0.61**	0.71**	0.39**	0.46*	0.45*	0.11	0.99**

*, ** = *Significant at 1% probability*

Moreover, days to first flowering was positively and significantly correlated with days to 50% flowering ($r = 0.86^{**}$), days to 50% podding ($r = 0.40^{**}$), number of pod per plant ($r = 0.49^{**}$) and number of seed per plant ($r = 0.39^{**}$) and it was only negatively and significantly correlated with hundred seed weight ($r = -0.51^{**}$). There was a significant and positive correlation of days taken to flowering with days 50% podding ($r = 0.40^{**}$), number of pods per plant ($r=0.42^{**}$) and number of seed per plant ($r = 0.37^{**}$) and significantly and negatively associated with hundred seed weight ($r = -0.44^{**}$) at $p < 0.01$. The present study showed that days to 50% podding has insignificant relationship with all tested lines except days to end of podding and days taken to maturity which show positive significant association. Results of the present study indicated that the days taken to end of podding revealed significant positive association with days to maturity ($r = 0.52^{**}$) and showed negative significant relationship with hundred seed weight ($r = -0.48^{**}$), biomass yield ($r = -0.51^{**}$), pod weight($r = -0.31^{**}$) and seed weight ($r = -0.32^{**}$). In the present study, no correlation was found between days to maturity and all other yield contributing traits except first pod height and biomass yield which negatively and significantly associated with days to maturity.

The degree of association was positive and highest between pod weight and seed weight (r = 0.99**) followed by seed weight and seed yield per plant (r = 0.71**), pod weight and seed yield per plant (r = 0.70**), number of pod per plant and seed weight (r = 0.61**) and number of pod per plant and pod weight (r = 0.60**). There appeared to be no positive relationship between number of pod per plant and seed yield in this finding.

5.4.1.2 Path Coefficient Analysis

Path analysis is a standard partial regression coefficient measuring the direct influence of one variable upon the other and permits separation of correlation coefficients into components of direct and indirect effects. The data pertaining to direct and indirect effects of fifteen examined characters on seed yield were estimated by path coefficients analysis. The direct and indirect effects of seed yield components on seed yield are shown in Table 5.3 and the direct effects are shown in bold.

In this study, path analysis showed that the direct effects of days taken to 50% flowering, days taken to end of podding, number of pod per plant, biomass yield and seed weight were positive, whereas all the other traits gave negative direct effects. Path analysis revealed that seed weight was the major contributor to seed yield (0.4233). The main reason for significant effect of seed weight was due to the close positive correlation of this character with seed yield (0.45^{**}). The second highest positive direct effect on seed yield was days taken to end podding (0.0364) followed by days taken to flowering (0.0291), number of pod per plant (0.0259). Direct effect of biomass yield was also positive and low (Table 5.3).

Days taken to first flowering produced negative direct effects. However, positive indirect effects via days to flowering, days taken to end of podding, days taken to maturity, number of primary branches, number of pods per plant, hundred seed weight and plant height were neutralized these negative effects. This produced low correlation between seed yield and days taken to first flowering.

Table 5.3. Estimates of direct (bold diagonal) and indirect effect (off diagonal) of various characters to grain yield in early and extra early chickpea genotypes

Traits	DFF	DF	DFP	DEP	DM	FPH	NPB	PPP
DFF	**-0.0152**	0.0252	-0.0113	0.0097	0.0013	-0.0005	0.0036	0.0128
DF	-0.0130	**0.0294**	-0.0114	0.0084	0.0013	-0.0007	0.0022	0.0110
DFP	-0.0061	0.0119	**-0.0281**	0.0145	-0.0045	0.0011	0.0002	0.0018
DEP	-0.0041	0.0068	-0.0112	**0.0364**	-0.0074	0.0018	0.0004	0.0038
DM	0.0014	-0.0028	-0.0089	0.0190	**-0.0142**	0.0028	0.0019	-0.0020
FPH	-0.0011	0.0031	0.0045	-0.0100	0.0060	**-0.0067**	0.0048	0.0013
NPB	0.0030	-0.0035	0.0004	-0.0009	0.0014	0.0018	**-0.0182**	0.0023
PPP	-0.0075	0.0125	-0.0020	0.0054	0.0011	-0.0003	-0.0016	**0.0259**
SPP	-0.0059	0.0109	-0.0024	0.0041	0.0012	-0.0003	-0.0016	0.0239
100 SW	0.0078	-0.0128	0.0077	-0.0173	0.0035	-0.0001	-0.0099	-0.0052
BMY	-0.0002	0.0010	0.0024	-0.0186	0.0072	-0.0023	-0.0066	0.0033
YLD	-0.0006	0.0022	0.0024	-0.0153	0.0071	-0.0021	-0.0058	0.0047
HI	0.0004	0.0019	0.0033	-0.0040	0.0023	-0.0010	-0.0002	0.0023
PW	0.0013	-0.0021	0.0032	-0.0111	0.0042	-0.0005	-0.0072	0.0155
SW	0.0009	-0.0013	0.0022	-0.0116	0.0041	-0.0006	-0.0074	0.0157

Table 5.3 (continues): Estimates of direct (bold diagonal) and indirect effect (off diagonal) of various characters to grain yield in early and extra early chickpea genotypes

Traits	SPP	100SW	BMY	YLD	HI	PW	SW
DFF	-0.0326	0.0046	0.0001	0.0359	0.0002	0.0316	-0.0254
DF	-0.0310	0.0039	0.0002	0.0739	-0.0005	0.0255	-0.0193
DFP	-0.0071	0.0024	-0.0004	-0.0835	0.0009	0.0405	-0.0335
DEP	-0.0094	0.0042	-0.0026	-0.4133	0.0008	0.1088	-0.1351
DM	0.0071	0.0022	-0.0026	-0.4884	0.0012	0.1054	-0.1219
FPH	-0.0037	-0.0001	0.0018	0.3141	-0.0011	-0.0290	0.0361
NPB	-0.0074	-0.0048	0.0018	0.3126	-0.0001	-0.1409	0.1725
PPT	-0.0774	0.0018	0.0006	0.1777	-0.0006	-0.2126	0.2571
SPP	**-0.0841**	0.0012	0.0005	0.1225	-0.0001	-0.2486	0.2988
100 SW	0.0115	**-0.0089**	0.0025	0.3066	0.3066	-0.1397	0.1637
BMY	-0.0079	-0.0043	**0.0051**	0.8914	-0.0019	-0.1550	0.1965
YLD	-0.0105	-0.0028	0.0046	**0.9806**	-0.0042	-0.1501	0.1897
HI	-0.0010	0.0009	0.0013	0.5580	**-0.0073**	-0.0328	0.0459
PW	-0.0587	-0.0035	0.0022	0.4132	-0.0007	**-0.3561**	0.4203
SW	-0.0594	-0.0034	0.0024	0.4395	-0.0008	-0.3536	**0.4233**

The direct effects of days to 50% flowering on seed yield was positive, whereas it had positive indirect effects through days taken to end of podding, days taken to maturity, number of primary

branches, number of pods per plant, hundred seed weight, biomass yield and pod weight. However, it exerted negative indirect effects on grain yield through other traits.

Days taken to maturity had a negative direct effects. But, it had positive indirect effects through days taken to first flowering, days taken to end of podding, first pod height, number of primary branches, number of seed per plant, hundred seed weight, harvest index and plant weight. The negative indirect effects via days taken to flowering, days taken to 50% podding, number of pods per plant, biomass yield and seed weight cancelled the positive effects resulting in negative association between days to maturity and seed yield.

The study shows days taken to 50% podding had a negative direct effects but maximum positive indirect effects through days taken to flowering, days to end of podding and plant weight. The positive direct effect of days taken to end of podding on seed yield was counterbalanced by its indirect effect via mainly days to maturity, days to 50% podding, number of seeds per plant and seed weight which finally resulted in negative correlation with seed yield. The residual effect determines unaccounted variability of the dependent factor (seed yield).

The direct effect of number of primary branch was negative whereas it had a positive indirect effect mainly through days to first flowering, number of pods per plant and seed weight however it exerted negative effect on grain yield via other traits. The number of pods per plant had a maximum positive direct effect and indirect effect via days taken to 50% flowering, days taken to end of podding days to maturity, hundred seed weight, biomass index and seed weight.

The direct effects of number of seeds per plant was negative and the positive indirect effects through days taken to maturity, number of pod per plant and seed weight cancelled the negative effect resulting high positive correlation between number of seed per plant and seed yield. Hundred seed weight and biomass yield contributed to seed yield mainly via positive indirect effect of days taken to maturity, days to 50% podding and seed weight. The direct effects of harvest index and plant height was negative but maximum positive indirect effect was observed through seed weight. The highest positive direct of seed weight on seed yield was counterbalanced by its indirect effect through days taken to maturity and days to end of podding which finally resulted in positive and low correlation with seed yield.

5.4.2 Discussions

The considerable range of variation recorded in all traits among tested lines provided a good opportunity for improving chickpea. Among these characters large amount of variation was recorded for grain yield. The maximum grain yield was recorded in the line DZ-2012-CK-00019, while the lowest yield was obtained by the genotype DZ-2012-CK-00023.

Days to 50% flowering of tested genotypes significantly varied from 43 days in DZ -2012-CK-00075 to 53 days in DZ-2012-CK-00022 with overall mean of 47 days. Similarly, average days taken to maturity was same compared to other study in Myanmar (Win, 2011). Win (2011) genotype which can flower earliest in 42 days. Serraj et al. (2003) also reported kabuli type line which can flower in 44 days which was able to grow fast on the conserved receding soil moisture and mature before the moisture depletion from the deeper soil layers. Early flowering character is beneficial for both early maturity and high grain yield (Anbessa, 2006). Kumar and Rao (2001) provided evidence that the super-early flowering chickpea germplasm ICCV 96029 matured early as well. Extra early lines may be exploited in the improvement of chickpea for short growing environment, such that flowering and pod setting of the crop occur before water stress becomes a serious limiting factor.

Line ICCV-09304 can mature in 101 days which is less than standard checks Ejere (110 days) and Minjar (108 days). The present study indicated that days to maturity of nine tested genotypes were less than that of both check genotypes. Results further revealed that in general low yielding genotypes required relatively more days to maturity than the high yielding ones. The highest yielding lines tended to have slightly shorter days to maturity than the check varieties. Growth duration determines water requirement and probability of exposure to stress, both of which decrease in early flowering genotypes (Blum, 1996). For most crop species, breeding for shorter duration is a major objective, not only to match phenology to season length but also to fit into more intensive crop rotations (Win, 2011). Since, ICRISAT had classified chickpea varieties matured in < 85 days as extra early, 85- 115 as early and > 115 days as late maturing varieties, all chickpea lines used in this study can be regrouped as early maturing. It is also noteworthy that this classification was based on trials conducted in India where chickpea maturity duration is rather short. It is therefore not surprising if some lines classified as extra-early would be reclassified under Ethiopian conditions. The relative durations and timing of pre and post

flowering growth has been shown to have important effects on morphology and economic yield of chickpea (Roberts et al., 1980).

Number of primary branch per plant varied among chickpea the tested lines. High variability in the number of primary branches of chickpea lines was also observed by Amhed et al. (2003) and Win (2011). Islam et al. (2008) reported that low yielding genotypes produced lower number of secondary branches per plant. Although DZ-2012-CK-00020 was recorded with a highest number of pods per plant, this genotype produced low yield. It might be due to the lowest seed size of these genotypes occasioned by seed shriveling due to drought stress. Similar findings have been reported by Islam et al. (2008). The other yield contributing characters also shows considerable variability among tested genotypes. The variation in yield components and seed yield among the chickpea genotypes were also reported by Chandra and Yadav (1997).

5.4.2.1 Correlation Analysis

The possibility of high yield through yield attributes as primary interest in crop improvement requires understanding the amount and the magnitude of correlation among various yield characters. Estimates of results of correlation coefficients between grain yield and yield components of chickpea is presented in Table 5.2. Grain yield displayed significant and positive correlations with first pod height, number of primary branch, 100 seed weight, biomass yield, harvest index, pod weight and seed weight but it was negatively and significantly correlated with Days taken to end podding and days to maturity. Such association indicates the possibility of selection of genotypes with those traits. These results are in close agreement with some earlier reports by Jeena et al. (2005), Aslin et al. (2006), Kanaka et al. (2007), Shiv prakash (2007), Sanjay and Anil (2009) and Abhishek et al. (2012).

Grain yield was negatively correlated with days to maturity. Similar result was reported by Fikru (2004) and Dirriba et al., (2014) who found negative correlation of days to maturity with seed yield. This may be related to the fact that when days to maturity increases, the phenology of the crop enters into the dry spell, which in turn leads to flower abortion, poor pod set, poor pod fill, pod abscission, seed shriveling and eventually loss in yield. On the contrary, positive and significant association grain yield with days to maturity was observed by Gupta et al. (1982); Obaidullah et al. (2006); Raval and Dobariya (2003). This is expected as long as stress factors do not set in at crop reproductive stage. A positive but non-significant association was noted

between seed yield and number of pods per plant. In contrast, several work reported that number of pods per plant was positively and significantly correlated with seed yield in chickpea (Saleem et al., 1999; Khan and Qureshi, 2001; Saleem et al., 2002; Bakhsh et al., 2006; Atta et al., 2008; Azar et al., 2013; Padmavathi et al., 2013; Dirriba et al., 2014). Significant positive correlation of number of primary branch and hundred seed weight with grain yield have been reported by Atta et al. (2008) which was in line with present finding. High significance of number of primary branch shows that improvement of this trait my result an in increment of seed yield. In this study, positive relation was observed between grain yield and seed number per plant and harvest index. Similar results were obtained by Singh et al. (1990), Ciftci et al. (2004), Talibi et al. (2007) and Ozvern (2006).

Days to flowering showed positive and significant correlations with days taken to end podding, number pod per plant, number of seed per plant and 100 seed weight and negative non-significant correlations with days to maturity. However, Arshad et al. (2004) reported negative non-significant correlation of days to flowering with pods per plant and positive non-significant correlation with days to maturity. In this study, days to maturity had insignificant negative association with all traits except first pod height and biomass yield which had negative significant relation with days to maturity. Highly significant positive correlation of days to maturity with primary branches, pods per plant and 100 seed weight has been reported by Singh et al. (1990).

Number of primary branches exhibited positive and significant correlation with 100 seed weight, biomass yield, plant weight and seed weight. Those results were in close agreement with Khan and Qureshi (2001). Moreover, number of pods per plant was highly and positively correlated with number of seed per plant, plant weight and seed weight. Similarly, significant positive association between number of seed per plant and number of pods per plant was reported by Saleem et al. (2002); Dirriba et al. (2014). Correlation analysis shows that a positive and significant correlation between number of seeds yield per plant and days taken to first flowering, days taken to flowering, number of pod per plant, plant and seed weight. Similar results were observed by Saleem et al. (2002).

Hundred seed weight had significant and negative correlation with days to first flowering, days to maturity and days to end of podding. Similar results were observed by Dirriba et al. (2014).

The 100-seed weight was negatively but insignificantly correlated with number of pods per plant and number of seeds per pod. The results were close agreement with Hassan et al. (2005) and Talebi et al. (2007). The correlation coefficients of biomass yield with first pod height, number of primary branches, hundred seed weight, plant weight and seed weight were positive and significant (Ali et al., 2010; Bicer 2005).

Plant and seed weight shows high and significant positive association with number of seed per plant and number pod per plant which was in agreement with earlier report by Saleem et al. (2002). This results indicated that weight of plant tended to increase the seed yield per plant. This can be explained on the basis that total weight of plant is the total photosynthetic that is consumed in seed development that results in higher seed yield.

5.4.2.2 Path coefficient Analysis

It is difficult from correlation alone to decide the major contributor towards seed yield, because of presence of significant correlations of seed yield with yield components. The path coefficients were calculated and partitioned into direct and indirect effects by using seed yield as a dependent variable (Table 5.3).

The direct effect exhibited by days taken to flowering, day taken to end podding, number pod per plant, biomass yield and seed weight were positive, whereas all other traits shows negative direct effects. The highest direct effect on grain yield was observed by seed weight followed by days taken to end of podding. Similarly, high and positive direct effect of number of pod per plant was reported by Saleem et al. (2002); Noor et al. (2003); Atta et al. (2008); Padmavathi et al. (2013) ; Azar et al. (2013) Dirriba et al. (2014). Path analysis revealed that days to flowering produced positive direct effect which was supported by Saleem et al. (1999). A strong positive direct effect of number of days taken to flowering suggests that selection can be made directly through number of pod per plant and pod weight.

The direct effect of days to maturity with grain yield was negative but the correlation coefficient was positive. Since the direct effect was negative, so the direct selection for this trait to improve yield will not be desirable. This results was in agreement with finding of Saleem et al. (1999) and Atta et al. (2008). The direct effect of days to end podding on seed yield was maximum and positive.

Number of primary branches had negative direct effect but number of seed per plant produced positive indirect effects through this traits which was in agreement with report of Saleem et al. (1999). Thus, indirect selection through this traits might be helpful in yield improvement. Number of seed per plant had negative direct effect and indirect effect mainly through number of pod per plant, pod and seed weight. On the other hand, hundred seed weight exhibited negative direct effect on grain yield. This suggests that 100-seed weight was indirectly influenced by the positive effects of days taken to first flowering, days taken to 50% podding, days to maturity, number of seed per plant, biomass yield, harvest index and seed weight. However, this effect was offset by the negative indirect effects through pod weight, days taken to maturity and days taken to end podding, ultimately resulting in the small negative direct effects. Yucel and Anlarsal (2010) also observed the similar type of results in chickpea. However, Khan and Qureshi (2001); Noor et al. (2003); Atta et al. (2008) and Azar et al. (2013) stated that 100 seed weight had direct positive effect on grain yield.

The results of this study indicate the direct effect of biomass on grain yield was positive and its positive indirect effects via days taken to maturity and seed weight. Naveed et al. (2012) reported similar results. Positive direct effects of harvest index on grain yield was reported by Yucel and Anlarsal (2010) and Padmavathi et al. (2013) which was not in line with present investigation.
A negative direct effect of pod weight on seed yield was observed in this study and negative indirect effects via number of pod per plant and number of seed per pant were nullified by its positive indirect effects via days taken to end podding and days taken to maturity. Similar kind of study reported by Saleem et al. (1999).

Path analysis revealed that pod weight had highest negative direct effect whereas it had negative indirect effects mainly via days taken to end podding and number of seed per pod. A strong negative and maximum direct effect of pod weight suggests that selection cannot be made directly through this trait. But, positive direct effect of total pod weight was reported by Saleem et al. (2002). The maximum positive indirect effect on seed yield was observed by seed weight whereas it had positive indirect effect mainly via number of seed per plant and number of pod per plant. A strong positive direct effect of seed weight suggests that selection can be made directly through seed weight.

5.4.3 Conclusions

Phenology is one of the key traits for adaptation of chickpea to different cropping systems, soil environments and climatic conditions. Early phenology (early flowering, early podding and early maturity) helps to escape end-of-season stresses, such as drought and extremes of temperatures, and provides opportunity for growing chickpea in short windows of crop-season available.

Among the evaluated genotypes, there were significant variations in terms of seed yield and its attributes under rainfed conditions. The early-maturing varieties are preferred by most of the farmers because of a stable yield than the late-maturing varieties. The results of present study revealed that DZ -2012-CK-00075, DZ-2012-CK-00023 and DZ-2012-CK-00074 were early flowering genotypes. The earliest matured genotype was DZ-2012-CK-00019 followed by DZ -2012-CK-00039 and DZ-2012-CK-00020 lines. In summary, genotypes such as DZ-2012-CK-00019, DZ-2012-CK-00015 and DZ-2012-CK-00031 were superior in respect of grain yield compared to other genotypes. The early maturing crop, however, may not give higher yield in more favorable season as it cannot accumulate enough total plant biomass due to reduced total photosynthetic period compared to the relatively longer maturing varieties.

Moreover, understanding relationships among chickpea yield and yield components are critical in developing desirable genotypes. Results showed that the biomass yield and harvest index were highly, positively and significantly correlated with seed yield. The present study conducted under rainfed conditions indicated that seed weight and days to end of podding had the maximum contribution in determining grain yield in chickpea. Therefore, for selection programs to improve extra early and supper early maturing of chickpea under residual moisture condition, seed weight, biomass yield and number of pod per plant could be used as a selection index. The implication of the results of this study may be possible for development of chickpea in drought tolerance. The results also enhance the progress in combining early phenology traits with resistance to ascochyta blight and drought tolerance.

CHAPTER SIX

GENERAL DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Discussions

Ascochyta blight disease is a major threat to chickpea production in several regions of Ethiopia. The survey of chickpea ascochyta blight in 2015/16 cropping season in Ethiopia, indicate that the disease had low distribution due to unfavoured weather conditions. Depending on the environmental conditions and the availability of alternate hosts, the deleterious effect of blight can vary from season to season in the same area. Unlike in 2015/16, the growing season 2014/15 was cool and wet; this provided favourable conditions for development of ascochyta blight. The mean temperature of growing season was highest in 2015/16. Rainfall distribution and relative humidity was quite different in both years. As evident from the survey, temperature, relative humidity and rainfall are important factors which influences Ascochyta blight. A combined effect of climatic variabilities may further be explored for a more refined analysis.

Screening germplasm and breeding lines for disease resistance is a comprehensive task, which encompasses different approaches. In this study, chickpea genotypes were evaluated in different locations to identify genotypes resistant to AB across geographical locations in Ethiopia. AB severity on these genotypes were significantly affected by the environment (location) and their interaction. The results indicated that ascochyta blight infection was more severe at Minjar than Alem Tena because Minjar is located in higher altitude with higher humidity than Alem Tena which favored rapid development and spread of the pathogen due to cool wet conditions in these areas. Most of genotypes were resistant against chickpea blight indicating good source of resistance genes in Ethiopia chickpea germplasm. These genotypes may be used directly as varieties in areas having high incidence of these diseases after evaluating them for high yield and other agronomic traits.

Fifteen early maturing chickpea lines were evaluated for yield and yield components. Considerable range of variation recorded in all traits among tested lines provided a good opportunity for improving chickpea. Maturity period of high yielding lines was long relative to low yielding lines. This is due to the fact that early flowering delayed reproductive phase which is a major yield determinant. Grain yield showed high significant positive correlations with

biomass yield, harvest index, seed and pod weight. Such association indicates the possibility of selection of genotypes with those traits. Seed weight has highest direct effect on grain yield. This suggests that selection can be made directly through pod weight, number of pod/plant and number of seed/plant.

6.2 Conclusions

Chickpea is an important food legume grown in ecologically diverse environments. The crop is affected by a host of different pathogens despite its importance. Ascochyta blight disease is a major threat to chickpea production in several regions of Ethiopia. A countrywide survey was conducted in 2015/16 growing season to determine occurrence, prevalence, incidence and severity of the chickpea ascochyta blight disease in chickpea growing regions of Ethiopia. The study revealed that, ascochyta blight disease was not widely distributed and had low incidence and severity during the survey period. The low prevalence of the disease was attributed to unusual drought conditions occurred during that period. This disease should however not be ignored and regular survey could be conducted.

Screening of a set of chickpea genotypes against ascochyta blight showed that most of genotypes were resistant against chickpea blight indicating good source of resistance genes in Ethiopia. However, there is a need to thorough test the genotypes over the multi-years and locations for their direct use as a variety or their involvement in future chickpea improvement. The resistant germplasm screened in this investigation would also be valuable for pyramiding resistance sources for Ascochyta blight and cloning of the resistant genes through differential display expression analysis in future research programs. Correlation analysis indicated linear relationship between three chickpea growth stages for disease severity. This indicated that different genotypes could be utilized according to severity of disease at various growth stages.

Phenology is one of the key traits for adaptation of chickpea to different cropping systems, soil environments and climatic conditions. Early phenology (early flowering, early podding and early maturity) helps to escape end-of-season stresses, such as drought and extremes of temperatures, and provides opportunity for growing chickpea in short windows of crop-season available. The early-maturing varieties are preferred by most of the farmers because of a stable yield than the late-maturing varieties. The level of improvement required in reducing the crop duration in chickpea in Ethiopia is large and could be attained in the long run. Significant reduction in crop

duration could be made by adopting short term strategies of incorporating important genetic traits into genotypes allowing incremental progress. The implication of the results of this study may be possible for development of chickpea in drought tolerance. The results also enhance the progress in combining early phenology traits with resistance to ascochyta blight and drought tolerance.

6.3 Recommendations

The following recommendations are made from present study,

- A regular survey for the assessment of ascochyta blight in chickpea growing areas is suggested to be carried out each year, especially between the months of August and February.
- Meteorological data should also be recorded to determine its relationship to the epidemic occurrence of ascochyta and disease forecasting.
- The genotypes resistant at seedling, flowering and full podding stage, should be utilized in breeding programme to build disease resistant pyramids due to complex nature of *Ascochyta rabiei.*
- Increase number of varieties and collection of germplasms and introduction of resistance source materials and varietal development. Multi- location and multi- year evaluations are needed to identify lines that are resistant to most pathotypes and in different environments.
- More emphasis should be given on development of early maturing varieties possessing early growth vigour, tolerance to high temperature and resistant to ascochyta blight.

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