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RESEARCH PAPER

Evaluation of chickpea genotypes for resistance to Ascochyta blight (*Ascochyta rabiei*) disease in the dry highlands of Kenya

Paul K. KIMURTO[1], Bernard K. TOWETT[1], Richard S. MULWA[1], Nancy NJOGU[1], Lilian J. JEPTANUI[1], Gangarao N.V.P.R. RAO[2], Said SILIM[2], Peter KALOKI[2], Paul KORIR[1] and Joseph K. MACHARIA[1]

[1] Egerton University, Faculty of Agriculture, Department of Crops, Soils and Horticulture, P.O Box 536-20115, Egerton-Kenya
[2] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), P.O Box 39063-00623, Nairobi, Kenya

Summary. Chickpea (*Cicer arietinum*) is an edible legume grown widely for its nutritious seed, which is rich in protein, minerals, vitamins and dietary fibre. It's a new crop in Kenya whose potential has not been utilized fully due to abiotic and biotic stresses that limit its productivity. The crop is affected mainly by Ascochyta blight (AB) which is widespread in cool dry highlands causing up to 100% yield loss. The objective of this study was to evaluate the resistance of selected chickpea genotypes to AB in dry highlands of Kenya. The study was done in 2 sites (Egerton University-Njoro) and Agricultural Training centre-ATC-Koibatek) for one season during long rains of 2010/2011 growing season. Thirty six genotypes from reference sets and mini-core samples introduced from ICRSAT were evaluated. There were significant (P<0.001) differences in AB responses and grain yield performance in test genotypes in both sites. AB was more severe at Egerton-Njoro (mean score 5.7) than ATC-Koibatek (mean score 4.25), with subsequent low grain yield. Genotypes ICC7052, ICC4463, ICC4363, ICC2884, ICC7150, ICC15294 and ICC11627 had both highest grain yield in decreasing order (mean range 1790-1053 Kg ha^{-1}) and best resistance to AB. Further evaluation is needed in other multi-locations and their use in breeding program determined especially because of their undesirable black seed color. Commercial varieties (LDT068, LDT065, Chania desi 1, and Saina K1) were all susceptible to AB, but with grain yield >1200 Kg ha^{-1}. The findings of the study showed that chickpea should be sown during the short rains (summer) in the dry highlands of Kenya when conditions are drier and warmer and less favorable for AB infection. However yield could be increased by shifting the sowing date from dry season to long rain (winter) thus avoiding terminal drought if AB resistant cultivars with acceptable agronomic traits could be identified.

Key words: *Cicer arietinum*, biotic stress, host plant resistance.

Introduction

Chickpea (*Cicer arietinum*) is the second most important legume after common bean (*Phaseolus vulgaris*) followed by field pea *(Pisum sativum)* and third in production among the legumes grains worldwide. Globally, it is cultivated in 11.67 million ha producing 9.31 million tons of grain (FAOSTAT, 2008). 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).

Amongst temperate pulses, chickpea is the most heat and drought tolerant and is suitable for low-fertility soils. Commercially, there are two chickpea

Corresponding author: P. Kimurto
Fax: +254 51 2217827
E-mail: kimurtopk@gmail.com, pkimurto@egerton.ac.ke

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types; Desi chickpeas (small, brown coloured seeds) and Kabuli chickpeas (large, cream/white coloured seeds).

The major constraints to yield improvement and adoption of the crop by farmers include Ascochyta blight (AB) (*Ascochyta rabiei)*, Fusarium wilt (FW) (*Fusarium oxysporum)*, pod borer (*Helicoverpa armigera*), drought and cold/low temperature. Therefore, improving resistance to biotic and tolerance to abiotic stresses as well as a general increase in dry matter (DM) and yield are major aims of chickpea breeders, agronomists and other scientists around the world.

In Kenya, chickpea is a relatively new crop grown by small scale farmers in Eastern provinces and Rift valley areas. It has however spread and is currently adapted to varied agro-ecological zones such as dry highlands, medium altitudes and also in dry lowlands with annual rainfall range of 250–550 mm per annum (Kibe and Onyari, 2007; Mulwa *et al*., 2007; Onyari *et al*., 2010). Production of chickpea however has been declining over the last 10 years, but recent efforts to introduce improved cultivars from ICRISAT in the dry highlands as a rotation crop has shown significant increase and adoption of new varieties with yields ranging between 1.0–3.5 t ha^{-1} (Kibe and Kamithi, 2007; Kimurto *et al.*, 2008; 2009; ICRISAT, 2008; Thagana *et al*., 2009). Chickpea improved soil fertility due to fixing of substantial nitrogen and improved maize yields by 24–68% in a cereal-legume rotation system (Cheruiyot *et al*., 2001, Cheruiyot *et al*., 2002). As manure chickpea improved soil structure (Wakindiki, and Yegon, 2011) of acidic soil in Uasin Gishu, Kenya, as well as reducing passion fruit Fusarium wilt if it preceded passion fruit in the rotation in Egerton-Njoro, Nakuru (Mwangi *et al*., 2009). Currently the crop is gaining popularity among large scale wheat, maize and barley farmers as a rotation crop in the Rift valley dry highlands during the short rains. Evaluation of its ability to reduce losses caused by the new Maize lethal Necrotic Disease (MLND) (Wangai *et al*., 2012) as rotational legume in dry highlands are underway. In Arid and semi-arid lands (ASALS), chickpea is also recognized as a mitigation strategy towards the prevailing climate change effects (MOA, 2011), due to its early maturity and heat- and drought-tolerance characteristics. Hence, promotion of chickpea as a cash and food crop is currently underway in the country.

However, as mentioned previously, the large scale adoption and productivity of the crop is affected by several abiotic and biotic stresses. Ascochyta blight, a necrotrophic fungus caused by the pathogen *Ascochyta rabiei* (Pass.) Labrousse., is a widespread major foliar disease that causes extensive grain yield losses (up to 100%) and reduces quality especially in dry highlands of Kenya. In Kenya and other major chickpea growing areas of Africa (Ethiopia, Tanzania, Malawi), chickpea is traditionally sown on residual moisture after long rains (in rotation with cereals) and as a consequence it experiences terminal drought during the growth period especially in summers (dry seasons). Similar conditions are experienced in Asia, North Africa and other regions with Mediterranean climate, where chickpea is sown in spring and growth period is in dry summers, resulting in poor biomass development and yield (Millan *et al*., 2006; Varshney *et al*., 2009). In both regions of Africa, sowing earlier during the long rainy season (winter) would reduce terminal drought stress, expand the vegetative growth period and improve the seed yield significantly up to 3 t ha^{-1}. However, this is rarely adopted by the farmers because the cool and wet weather, typical for long rainy seasons or Mediterranean winters, favors the development of AB epidemics as in most regions of the world where the crop is commonly grown (Gaur and Singh, 1996a; Gaur and Singh, 1996b; Pande *et al*., 2005) like North America, Pakistan, Northwest India and Australia.

Several epidemics of AB causing complete yield loss have been reported in Pakistan, India, European countries and Mediterranean regions (Hawtin and Singh, 1984; Singh *et al*., 1984; Kaiser *et al*., 1998; Pande *et al*., 2005). Currently, AB is the most important yield-limiting factor in Australia and Canada, potentially affecting 95% of the area sown to chickpea (Knights and Siddique, 2002; Gan *et al*., 2006). AB has also been reported in Latin America (Kaiser *et al*., 2000) and North Africa (Akem, 1999). Since Kenyas' dry highlands are cool (15–25°C), wet and humid (>500 mm rainfall) during the growing season, it favors disease development, often resulting in 100% yield losses.

Ascochyta rabiei survives either on or in seed or plant debris in form of mycelium, pycnidia, and the teleomorph stage (Kaiser, 1997) and spreads via airborne spores. The sexual (teleomorph) state helps in long-term survival of the pathogen, but there is no work done in Kenya on the presence of this state that is known to the authors. AB can be controlled by fungicide treatment, but it is not economical and is

potentially hazardous to the environment (Nene and Reddy, 1987; Chang *et al*., 2007) and also presents high risk of fungicide resistance due to use of site-specific mode of action such as QoI fungicides (azoxystrobin and pyraclostrobin) (Gossen and Anderson 2004; Wise and Gudmestad, 2009). Therefore, host plant resistance (HPR), as a major component of integrated disease management (IDM) is the most economical approach to manage this disease since most growers keep their own planting seed. Pande *et al*., (2005) and Reddy and Singh (1990) noted that IDM strategy would include: use of pathogen-free seed, seed treatment, crop rotation practice, deep ploughing to bury infested debris, use of disease-resistant genotypes and strategic application of foliar fungicides (during seedling and early podding). In addition, the identification of the resistance in cultivated chickpea genotypes would facilitate their introgression into adaptable, commercially grown varieties and also would allow a shift to sowing into the wet long rainy season (April-August) for increased yield and productivity. In this study, chickpea genotypes from reference sets and mini-core samples from ICRISAT were evaluated with the aim of identifying high yielding and AB resistant/tolerant chickpea genotypes for growing in Kenya.

Materials and methods

Study sites

The study was conducted at 2 sites (Agricultural Training Centre ATC-Koibatek and at Egerton University, Njoro, Kenya) in 2010–2011 long and short rains seasons. ATC-Koibatek (latitude 1º 35′ S, and longitude 36º 66′ E) lies at altitude 1890 m above sea level (a.s.l.) in agro-ecological zone Upper midlands (UM4), with low agricultural potential. Average annual rainfall is 767 mm and mean temperature ranges between 18.2–24.3ºC; mean annual minimum and maximum temperature are 10.9°C and 28.8°C respectively. Soils are Vitric Andosols with moderate to high soil fertility, well drained deep to sandy loam soil (Jaetzold and Schmidt, 1983). Egerton University, Njoro (0° 23′S and 35° 35′E) lies at altitude 2265m a.s.l. in Lower Highland (LH2 – LH3) agro ecological zones and has a sub humid modified tropical climate. The annual average rainfall of the area is 931 mm and mean temperature ranges between 16–19.1ºC and mean maximum and minimum temperature are 22.7°C and 7.9°C, respectively. Soils are Mollic Andosols (Jaetzold and Schmidt, 1983).

Experimental design and treatments

Thirty six genotypes from reference sets and mini-core samples which were part of 300 chickpea germplasm introduced from ICRISAT (with varied root traits, pod borer resistance and advanced breeding lines for yield) were evaluated for *Ascochyta rabiei* resistance during the long rains (April-August) in 2010–2011 growing season. The 36 lines were selected based on previous yield and preliminary evaluation for AB during dry season (October–February). The four commercial varieties (LDT065-ICCV 00108, LDT068-ICCV00305, Chania Desi1-ICCV97105 and Saina K1-ICCV 95423) that were included in the study have moderate to low resistance to AB, but they have not been evaluated for AB since they are recommended for planting during dry season. Chania Desi 1 and LDT065 are Desi types with brown colour while LTD068 and Saina K1 are Kabuli types with white seeds. They have yield potential of 1.2–3 t ha^{-1}. Kenya Ngara local is a local cultivar with low yield potential of 0.5–1.5 t ha^{-1} and dark seeded with moderate resistance to AB.

The test germplasm were evaluated in the field in a 6×6 Lattice design, spaced at 0.4m between rows and 0.1m seed spacing within rows with plot sizes of 6 rows each measuring 5 m long, in 3 reps. The screening followed AB standardized procedure developed by ICRISAT and ICARDA with modifications whereby test material is sown in 0.4 m row spacing and interplanted with susceptible cultivar which serves as indicator/spreader line after every 4–8 rows. Infested debris was scattered between rows (Pande *et al*., 2005; ICARDA, 2003). In this study the susceptible early maturing cultivar (JG 62) (check) was sown as an indicator/spreader row between every 6 rows of test material and around the trial plot. Chickpea infected debris were scattered between rows at emergence and the trial was not inoculated with a conidium suspension of *A. 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 recommended package of practices was followed to raise the crop (Gaur *et al*., 2010).

Disease scoring

Since AB 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), Chen and Muehlbauer (2003), Sharma *et al*., (2005) 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 AB infection according to Pande *et al*. (2006) scale where, 1,asymptomatic (A); 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.

Determination of grain yield

Grain yield (Kg ha^{-1}) was determined at maturity by harvesting and threshing the pods from the 4 middle rows of each plot.

Data analysis

The disease ratings were subjected to Friedman's non-parametric analysis of variance while yields was analyzed using ANOVA and means separated using LSD (P<0.05) using Genstat release 12.0 (Steel *et al*., 1990).

Results

There were significant differences in AB responses between the genotypes at both sites (Table 1). Amongst test genotypes, ICC7052, ICC4463, ICC4363, ICC2884, ICC7150, ICC15294, ICC11627 and ICC2210 had low disease rating between 1.3–1.5 and disease incidence <10%. Genotypes ICC9755, ICC5639, ICC12324 and ICC8752 similarly had very low disease scores between 1.8–2.5 in both sites and the only symptoms seen were minute lesions prominent on the apical stems. These genotypes were however dark brown to dark green seeded (Table 1). Genotype IG10500 had moderate resistance with disease score between 2–3.5 in both sites (Table 1). Unfortunately, all the other commercial varieties released in Kenya were susceptible to AB with mean disease scores >5.1 in both sites. These varieties include LDT068 (ICCV00305), LDT065 (ICCV00108), Chania Desi 1 (ICCV97105), Saina K1 (ICCV95423), Annigeri and the local cultivar (Kenya Ngara local). There were however lower disease scores between 4.5–5.5 at ATC-Koibatek as compared to Egerton-Njoro which were >6 for all these genotypes. AB disease symptoms were observed on all plant parts with defoliation, breaking and drying of branches in observed chickpea plants. Most of these genotypes had either brown or white seeds.

The other 11 genotypes including ICC12916, ICC9002, IG72109, ICC4973 and ICC37 and ICC 16207 had disease scores ranging between 7.3–8, with majority having either white or brown seed colours (Table 1). Most of these genotypes had lesions on all plant parts with vegetative defoliation, breaking and drying of branches and between 25–50% plant parts were killed by the disease.

There were significant (P<0.001) differences in yield performance of test genotypes in both sites (Table 2). The interaction between genotype and environment (sites) also significantly (P<0.01) affected the grain yield production amongst test genotypes. Grain yield was higher at ATC-Koibatek (mean 933.5 Kg ha^{-1}) than Egerton-Njoro (mean 646.5 Kg ha^{-1}) (Table 2). Genotypes ICC7052, ICC2884, ICC15294, ICC7150, ICC4463, ICC9755 and LDT068 had highest mean grain yield in both sites ranging between 1238–2283 Kg ha^{-1} (Table 2). Most of these genotypes were resistant to AB (mean scores 1.3–1.8) except LDT068 which was moderately susceptible (scores 5.1). As compared to the first group, commercial varieties (LDT065, Chania Desi 1, Saina K1 and Annigeri) had lower grain yield ranging between 1031–1246 Kg ha^{-1}, but they were all susceptible to AB with mean disease scores >5.5 in both sites. Genotypes ICC5639, ICC4363, ICC11627 and ICC8752 also had relatively higher yield ranging between 1089–1178 Kg ha^{-1}

Table 1. Mean Ascochyta blight scores (scale 1–9 where 1, no disease and 9, dead plants) for 36 test chickpea genotypes in ATC-Koibatek and Egerton-Njoro, Kenya.

Genotype	ATC-Koibatek	Egerton-Njoro	Mean	Resistance level	Seed colour
ICC7052	1.2	1.5	1.3	Resistant	Brown
ICC4463	1.2	1.5	1.3	Resistant	Dark brown
ICC4363	1.2	1.5	1.3	Resistant	Black
ICC2884	1.3	1.5	1.5	Resistant	Dark brown
ICC7150	1.4	1.5	1.5	Resistant	Black
ICC15294	1.5	1.5	1.5	Resistant	Brown
ICC11627	1.5	1.5	1.5	Resistant	Dark green
ICC2210	1.5	1.5	1.5	Resistant	Dark green
ICC9755	1.5	2	1.8	Resistant	Dark green
ICC5639	1.5	2.5	2	Resistant	Brown
ICC12324	1.5	2.5	2	Resistant	Brown
ICC8752	2	3	2.5	Resistant	Brown
IG10500	2	3.5	3.1	Moderately resistant	White/Cream
LDT068	5	5.2	5.1	Susceptible	Brown
LDT065	4.5	6.5	5.5	Susceptible	White
ChaniaDesi1	4.5	6.5	5.5	Susceptible	Brown
ICC13124	4.5	6.5	5.5	Susceptible	Brown
Annigeri	5	6.5	5.8	Susceptible	Brown
KenyaNgaralocal	5.5	6.5	6	Susceptible	Brown
SainaK1	5	7	6	Susceptible	White
ICC2065	3.5	8.5	6	Susceptible	White
ICCV96329	6.5	7.5	7	Susceptible	White
ICC8855	5	9	7	Susceptible	White
ICC2072	5.5	8.5	7	Susceptible	White
ICC8718	5.5	8.5	7	Susceptible	White
ICC12916	6	8.5	7.3	Highly susceptible	Brown
ICC9002	5.5	9	7.3	Highly susceptible	White
IG72109	6.5	8.5	7.5	Highly susceptible	White
ICC14098	6	9	7.5	Highly susceptible	Brown
ICC11378	6	9	7.5	Highly susceptible	Brown
ICC4973	6.5	8.5	7.5	Highly susceptible	White
ICCC37	7	8	7.5	Highly susceptible	White
ICC11664	7	8.5	7.8	Highly susceptible	Brown
ICC2242	7	9	8	Highly susceptible	White

(*Continued*)

Table 1. *Continues.*

Genotype	ATC-Koibatek	Egerton-Njoro	Mean	Resistance level	Seed colour
ICC2969	7.5	8.5	8	Highly susceptible	White
ICC16207	7.5	8.5	8	Highly susceptible	White
Mean	4.25	5.7	4.9		
SE	0.45				
Site	***				
Variety	***				
Site×variety	**				

*, ** and *** indicate significance levels at 0.05, 0.01 and 0.001, respectively.

Table 2. Mean grain yield (Kg ha^{-1}) for 36 test chickpea genotypes in ATC-Koibatek and Egerton-Njoro, Kenya.

Variety	ATC-Koibatek	Egerton-Njoro	Mean
ICC7052	2600	1967	2283.5
ICC2884	2055	1569.5	1812.3
ICC15294	1689	1400	1544.5
ICC7150	1876	1051	1463.5
ICC4463	1400.5	1236	1318.3
LDT068	1550	1052	1301.0
Chania Desi 1	1444	1048.5	1246.3
ICC9755	1499.5	977.5	1238.5
LDT065	1439.5	998.5	1219.0
Saina K1	1345	1033	1189.0
ICC5639	1195	1161.5	1178.3
ICC4363	1289	1062	1175.5
ICC11627	1422.5	917.5	1170.0
ICC8752	1335.5	843.5	1089.5
Annigeri	1429.5	634.4	1031.8
IG10500	1001.1	734.5	867.8
ICCV96329	953.5	622.5	788.0
ICC12324	871.0	675.4	773.0
ICC13124	799.5	610.5	705.0
Kenya Ngara local	781.0	622.2	701.5
ICC2210	725.9	553.5	639.3
ICC8855	472.5	289.5	381.0
ICC12916	411.5	289.5	350.5
ICC11664	367.5	178.5	273.0
ICC8718	355.5	178.5	267.0
ICC2072	367.0	161.3	264.0
ICC9002	366.5	160.5	263.5
IG72109	341.6	181.2	261.0
ICC2969	350.5	161.5	256.0
ICC14098	339.6	151.5	245.3
ICC2242	328.6	161.5	244.8
ICC16207	273.4	157.3	215.0
ICC11378	267.0	123.5	195.3
ICC2065	261.5	105.5	183.5
ICC4973	245.0	98.0	171.5
ICCC37	159.5	108.0	133.8
Mean	933.5	646.5	790.0
SE	40.1		
Site	*		
Variety	***		
Site×variety	***		
$LSD_{site*variety}$	113.0		

*, ** and *** indicate significance levels at 0.05, 0.01 and 0.001, respectively.

which was comparable with those of some commercial varieties like Saina K1 and Annigeri. They also had good resistance to AB with mean scores 1.3–2.5. However, 15 genotypes namely ICCC37, ICC4973, ICC11378, ICC2065, ICC11664, ICC12916, ICCC14098, ICC16207, ICC2072, ICC2242, ICC2969, ICC8718, ICC8855, ICC9002, and IG72109 had lowest grain yield ranging between 133–381 kg ha^{-1}. Majority of these genotypes were white or brown seeded and susceptible or highly susceptible to AB (Table 1).

Ngara local and other genotypes like ICC2210, ICC131124, ICC12324, ICCV96329 and IG10500 had below average mean yield of 790 kg ha^{-1} and susceptible to AB. Most of these genotypes were brown or white seeded.

Discussion

The AB infection was more severe at Egerton-Njoro than ATC-Koibatek because Egerton-Njoro is located in higher altitude (LH 2) with higher humidity than ATC-Koibatek (UM 4) 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 study was conducted during the long rainy season (August-July) and low temperatures (10–21°C) and high RH was witnessed during the growing periods which accelerated disease severity especially at Egerton-Njoro. Pande *et al*. (2005) noted that AB infection and disease progression occur from 5° to 25°C with an optimum temperature of 16–20°C, and a minimum of 6 h leaf wetness. In addition, Trapero-Casas and Kaiser (1992) noted that disease severity increases with the increase in relative humidity (RH), cloudiness and prolonged wet weather which favor rapid development and spread of AB disease.

Overall genotypes that had higher resistance to AB also had higher grain yield although this varied between the two sites (Egerton-Njoro and ATC-Koibatek) (see Table 2). The low yield in Egerton-Njoro is because of high disease incidence which could have damaged vegetative plant parts and killed some plants, reducing yield. In addition, the warm and drier conditions found in ATC-Koibatek could have favored higher grain yield production than Egerton-Njoro which is colder and wetter.

A number of genotypes were identified with both AB resistance with scores between 1.8–2.5, low disease incidence (<10%) and higher yield (>1238 Kg ha^{-1}) than the commercial varieties. There were few exceptions like genotypes ICC5639, ICC4363, ICC11627 and ICC8752 which had lower yield (1089–1178 Kg ha^{-1}) and high resistance to AB. The low disease incidences were associated with only minute lesions prominent on the apical stems, an indication that they were also resistant to AB infection like the first group. 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 study.

Although some of these genotypes combined both high yield and disease resistance, and hence are ideal for adoption by farmers, most of these resistant genotypes were black seeded, especially the Desi types. This is with exceptions of genotypes ICC7052 and ICC15294 which were brown seeded. The findings indicate that the resistance mechanism could be associated with synthesis of certain group of phenolic compounds. They can therefore be more useful in breeding programmes in improving resistance of farmer preferred commercial varieties, though the genetics of inheritance of color needs to be investigated. Overall most of the resistant types which had white seeds were Kabuli types, indicating greater inherent resistance amongst Kabuli than Desi to AB. This is in agreement with Millan *et al*. (2006) and Singh (1987) who noted that Kabuli × Desi crosses are used in many breeding programs to combine genes for cold tolerance, resistance to AB and long vegetative growth more frequently found in Kabuli types, with genes for heat and drought tolerance, resistance to Fusarium wilt and early flowering prevalent in Desi types.

Although the grain yield in commercial varieties LDT068 (ICCV00305), LDT065 (ICCV00108), Chania Desi 1 (ICCV97105), Saina K1 (ICCV95423) seems comparatively high (1189-1301 Kg ha^{-1}), harvested seed were highly damaged by disease which intensified into podding stage (results not shown) and quality of seed was also poor because most of the seeds were discolored (black) and possessed deep round or irregular cankers, shriveled, with low seed weight. Genotype IG10500 had moderate resistance with disease score between 2–3.5, but had below average yield in both sites, despite it good seed characteristics (white/cream).

The results of this trial showed that most of the commercial varieties which were introduced from ICRISAT for growing in Kenyas' dry highlands were susceptible to AB, especially during long rains (winter) (when this trial was conducted) when conditions were favorable for the AB disease. It is therefore advisable to grow these varieties during the short rains (summer) when conditions are dry and hot which is less favorable for AB epidemics. In addition, Pande *et al*. (2005) and Navas-Cortes *et al*. (1995) noted that perpetuation of *A. rabiei* through crop debris in tropical countries may be influenced by high temperatures and low rainfall during out-of-season summer months, which decreases the survival of *A. rabiei* in crop debris.

Although sowing earlier during the long rains (winter) would reduce terminal drought stress, expand the vegetative growth period and improve the seed yield tremendously (up to 3000 Kg ha^{-1}), this wouldn't be adopted by the farmers because of these drastic yield losses associated with AB. However, for medium and low altitude areas (<1200 m a.s.l) where it's hot (temperatures 20–35°C), dry, low RH and rainfall (<350 mm rainfall) during the growing season, growing of chickpea is recommended during long rains (April–August) (winter) since these conditions don't favor disease development. Due to low rainfall amounts, of short and poor distribution, chickpea normally experiences terminal drought stress in these regions, as may be the case during short rainy (October–February) seasons in dry highlands (Kimurto *et al*., 2012). Therefore yield could be increased significantly by shifting the sowing date from short to long rainy season (winter) if AB resistant varieties could be identified and avoid terminal drought stress experienced during short rainy season. In addition, yield losses can also be minimized during the long rainy seasons in these areas by fungicide sprays, although this may not be economical for resource poor farmers in most developing countries. Furthermore, recent expansion of chickpea in Kenya as a rotation crop after harvesting cereals, is a result of the introduction and adoption of the new varieties from ICRISAT with yields ranging between 1.0–3.5 t ha^{-1} (ICRISAT, 2008; KEPHIS, 2009; Kimurto *et al*., 2009; Thagana *et al*., 2009).

The lowest yielding genotypes had highest AB susceptibility. The low yields indicates that the AB could have destroyed most plants parts resulting in damage of photosynthetic area, direct damage on seeds and death of many plants in the field. This shows that these genotypes are not suited for sowing in Kenya since they have no resistance to AB as well as low yield potential. Their evaluation in dry semi-arid areas of Kenya where AB is less prevalent is recommended so that their usefulness as commercial varieties of use in breeding program would be determined.

The findings of this study showed that management of AB is essential to provide increased and stable yields in Kenya and Eastern and Central Africa, where conditions are similar. There is a need to conduct surveys to understand the presence of different pathotypes of *A. rabiei* in varied agro-ecozones since knowledge on variability of pathogen is essential in breeding for durable resistance and would overcome the challenge of breakdown of resistance due to development of new pathotypes. This may only be possible if several genes are combined in a single cultivar to provide different mechanisms against all races, and more importantly at several stages (vegetative, flowering and podding). This is because many resistant lines at vegetative stage may be susceptible at podding (Pande *et al*., 2005). Similarly, Knights and Siddique (2002), Pande *et al*. (2005) and and Chen *et al*. (2004) noted that breeding of chickpea for resistance to AB is often limited due to the absence of high levels of resistance in chickpea germplasm, which along with the highly variable pathogen, has precluded the development of varieties with both high and durable resistance. Hence, expanded multi-location and multi-season field trials are essential before varieties are released to farmers to widen the scope of available AB resistant genotypes.

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