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The timeless chickpea

Big hearts pulse within pods

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Front cover photo
Teresa Millán

FOR AUTHORS

Legume Perspectives is an international peer-reviewed journal aiming to interest and inform a worldwide multidisciplinary readership on very different aspects of legume research and use, including genetics, agronomy, animal production, human nutrition and health and economics.

Our journal prefers review articles on different legume species and crops and various legume research topics. The structure of review articles is rather loose by not strictly following structure of original research articles. Please write your article so that it will assist in the exchange of information between people working in different expert fields of legume research: write to the length requested; provide a review of the most important information on your topic; try to explain specialist words, unusual jargon and acronyms; emphasise results and conclusions; choose titles carefully and add subheadings that tell readers something. *Legume Perspectives* prefers a clear, simple and comprehensive writing style that would make its articles interesting and useful for both academic and amateur audience.

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EDITORIAL

We are pleased to present this issue of Legume Perspectives devoted to chickpea, a highly valued food legume with continuously increasing international demand. The characteristics that make this legume special include high drought tolerance, wide adaptation, high nutritional qualities and diversified food uses. This issue is aimed at providing information on the recent developments in global chickpea research directly from the experts. The topics covered include general aspects of the crop, such as origin, phenology and adaptation, genomic resources, major abiotic and biotic constraints, agronomy and nutritional quality. In addition, reports from major chickpea growing countries on current status of chickpea production, constraints and major achievements have been provided. We hope that the information provided here would be useful to the readers and further stimulate interest in the crop and interactions among chickpea researchers. On behalf of the International Legume Society, we wish to thank all the authors for their valuable contributions.

Pooran Gaur and Teresa Millán
Managing Editors of
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Carte blanche to...

...Juan Gil

A good companion of Man

The first reference about the chickpea is found in the Iliad by Homer (about 1000-800 BC), where the arrows of Helenus, son of Priam, bouncing away from the breastplate of Melenaos are compared with beans and Terebinthos (chickpeas), being thrown by the winnower. Chickpea has been a traditional food since ancient times in the Mediterranean diet and were very early introduced (3rd to the 1st centuries B.C) in Southern India where is today a basic food ingredient, after Columbus time was introduced in America y more recently in Australia. It is an ingredient of numerous successful recipes all over the world, as the Spanish "Cocido" or the delicious "Hummus" now in fashion all over the world. It has been considered a cheap protein source food for poor people but also it has been demonstrated nutraceutical proprieties very appreciated in the developed countries.

Like other annual legume, chickpea cultivation could contribute to maintain a sustainable agriculture by improving soil fertility and, as a rotation crop, by allowing the diversification of agricultural production systems. Average world chickpea yield has improved during the past decades but it is still quite low despite its agronomical importance. Today is possible to achieve high and stable yields by developing cultivars better adapted to stresses in local environments. Especially Ascochyta blight, Fusarium wilt, pod borer, drought and cold are major constraints to yield improvement and adoption of this crop by farmers. Taking into in account its high nutritional and health values and the possibility to increase yield and yield stability, chickpea could became an important crop in many countries including semiarid regions. ■

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Chickpea in history

by José I. CUBERO[1,2]

Abstract: Domesticated in its native region (S.E. Turkey), probably as a single event, chickpea is present in old Near East archaeological remains (8-9 millenia B.C; it is easily identified by its peculiar "ram head" seed shape.) However, it was only well established in the Bronze Age, spread quickly in the Mediterranean area. It was introduced in India by Aryans in the first millennium BC and in Southern Russia a few centuries BC Chickpea was the first crop that crossed the Atlantic Ocean as it was transported as food in the Columbus fleet in his first travel of discovery in 1492.

Key words: chickpea, crop history, domestication, distribution

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Chickpea was likely domesticated in S.E. of Turkey, in a small area close to the Syrian border between the Tigris and the Euphrates rivers. This is the only place where its wild ancestor (*Cicer arietinum* ssp. *reticulatum*) as well as its close relative (*C. echinospermum*) has been found; only the former is fully interfertile with the cultigen (5). Molecular analysis also point to *C. reticulatum* as the wild progenitor (7). The domestication seems to have occurred as a single event, not only because of the restricted geographical distribution of the wild species populations, but also because recent molecular studies show a very low genetic variation of the cultigen (ssp. *arietinum*), in spite of the large amount of seed variability found in the cultivated forms (6).

The ram-headed chickpea seed shape allows for easy identification in archaeological remains. But even when there are not such remains, its names allow for linguistic evidence of its cultivation as, for example, in dynastic Egypt: "falcon beak" in texts of the XVIII dynasty, ca. 1,400 BC with the name kept in Coptic (2).

A few seeds have been discovered in Near East pre-pottery levels (PPNB, ca. 8,000 BC) in Jericho and near Damascus, very far from its birthplace; some seeds were found in NW Syria in strata belonging to PPNA, dated ca. 8,500 BC suggesting a very early domestication. At least two silent millennia follow. Only in the early Bronze period (5th millennium BC) can be already considered as a well established crop (4) in the Near East; from the 4th millennium BC on findings are frequent, especially in the Mediterranean region; however, the oldest findings up to now in Cyprus are only dated in 6th to 5th centuries BC in spite of its proximity to both the Anatolian coast and to the Near East agricultural cradle.

From that period onwards, chickpea migrated with men as a partner of human history. The crop received very different unrelated names, suggesting a quick adoption by local populations. Chickpea was always a humble crop that almost never appeared on the royal tables, being on the contrary a useful food for both humans and animals; modern research has shown its high biological value. Being a poor man food, there is some difficulty in following its path around the world. A few seeds dated ca. 6,000 BC have been found in Bulgaria, and two millennia later, in Greece (7, 8). Thus, it seems that chickpea belonged to the first agricultural complex reaching Europe through the Black Sea. Crimea could have been the starting point of the crop spreading in Ukraine and Southern Russia; some authors suggest that it was taken there by the Greeks to its Crimean colonies, but the peninsula was not far away from the Danube's Mouth, probably the main Gate to reach Central Europe. In favour of the Greek hypothesis is the fact of the chickpea scarcity in archaeological remains in Crimea, dating only from the so called "Greek Classical phase" of the Crimean Iron Age (4th to 2nd centuries BC).

Chickpea was likely taken to India by the Aryan tribes invading Hindustan in the second millennium BC. Archaeological remains suggest the second half of the first millennium as the most likely date for its adoption; it reached Southern India from the 3rd to the 1st centuries BC (1). Aryan invaders probably took the crop from Iranian tribes as suggested already by De Candolle (3) on linguistic evidence; in fact, peoples south of Caucasus have the same linguistic root for chickpea, related to the Sanskrit. The spreading in India was very successful as shown by the great amount of morphological variation found in India nowadays, the diverse names given to the crop and the many uses by local people.

Although chickpea arrived earlier in Greece (see above), it is almost not mentioned by the first classic authors. Homer (14th century BC) mentions chickpea in the Iliad only once (XIII-336) and it does not appear in the Odyssey nor in the first book on Agriculture, Hesiod's *Works and Days*; it was really poor man's food. Two-three centuries later is mentioned by all the important Greek authors although rather scarcely. One single mention by Plato (Republic, II, 372a-e), several times by Aristophanes (around 400 BC) in his comedies *Peace* (here as roasted, an old way of cooking them indeed), *The Cloud* and, *The Assemblywomen*, suggesting again that chickpea was a popular food for common people. Popular and cheap, as one of the Aristophanes characters says "It is not worth of a single chickpea grain..."

Later on, all classical writers on Agriculture (Teophrastus, Columella, etc.) mention it, although the length devoted to it is, excepting in Al Awam (Arab-Spanish writer, around 1,200 A.D.), rather short and very little informative. Worth mentioning, the tradition holds that Cicero, the famous Roman politician, writer and lawyer, had his name given because its face was his head was "chickpea-shaped"; modern scholars think that, rather, the family names originated in one of his grandparents, a chickpea seller.

It is not known who introduced chickpea in the western Mediterranean countries; its Spanish name ("garbanzo", "garvance" in old French) is not connected to any other known language. A pre-roman origin is likely, but it has also been suggested a gothic one (*arwaits*), but it was not known in the Swiss lakes nor in Northern Italy, thus its introduction from Central Europe in Spain is unlikely. From Greece (*krios*: "ram head") and/or the Balkans (*kíkere*) through Italy (*cicer*, pronounced "kíker" in classic Latin); from the Latin word derives an old Spanish name for pulses, *chícharo*, also given to chickpea.

Be that as it may, chickpea was taken by Spanish colonizers to the New World *already* in 1492. It crossed the Atlantic Ocean already in the first Columbus travel of discovery. The three ships of the fleet had to transport a great amount of chickpea grains as they were also present seven months later in the return trip. Only a good and reliable food could have been taken in such quantities. A humble chickpea seed labelled with a cross was used during a big storm in the way back to Spain to choose one among the terrified sailors to go to Guadalupe Monastery as a pilgrim in case they arrived safely. It was Columbus the man who took the labelled seed… but, although they did safely finish the trip, he never accomplished the promise… ■

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Diversity of the words denoting chickpea in modern European languages

by Aleksandar MIKIĆ

Abstract: Chickpea (*Cicer arietinum* L.) is one of the most ancient Eurasian crops. The Latin *cicer* originated from the Proto-Indo-European root **kek-*, **kik-*, denoting pea (*Pisum sativum* L.), that, during its evolution into its direct derivatives shifted the meaning from *pea* to *chickpea*. Another Proto-Indo-European root, *erəg*^{w}*[h]-*, gave the modern words denoting chickpea in Greek, Spanish, Portuguese and Basque.

Key words: chickpea, *Cicer arietinum*, etymology, European languages, lexicology

Chickpea (*Cicer arietinum* L.) is one of the most ancient Eurasian crops, as witnessed by numerous archaeological findings. The well-known Latin noun *cicer* has its ultimate origin in the Proto-Indo-European root **kek-*, **kik-*, denoting pea (*Pisum sativum* L.) (1). During the evolution of this root into its direct derivatives, including Proto-Italic that gave Latin, a shift of meaning occurred in most cases from *pea* to *chickpea*. The only attested exception is the extinct Old Prussian, renown for its remarkable conservation. The words denoting chickpea in most modern Germanic or Italic languages, including the Armenian one, are the present descendants of the Proto-Indo-European **kek-*, **kik-*. Another Proto-Indo-European root, *erəg*^{w}*[h]-*, gave the modern words denoting chickpea in Greek, Spanish and Portuguese, with a subsequent borrowing by Basque. ■

Acknowledgements

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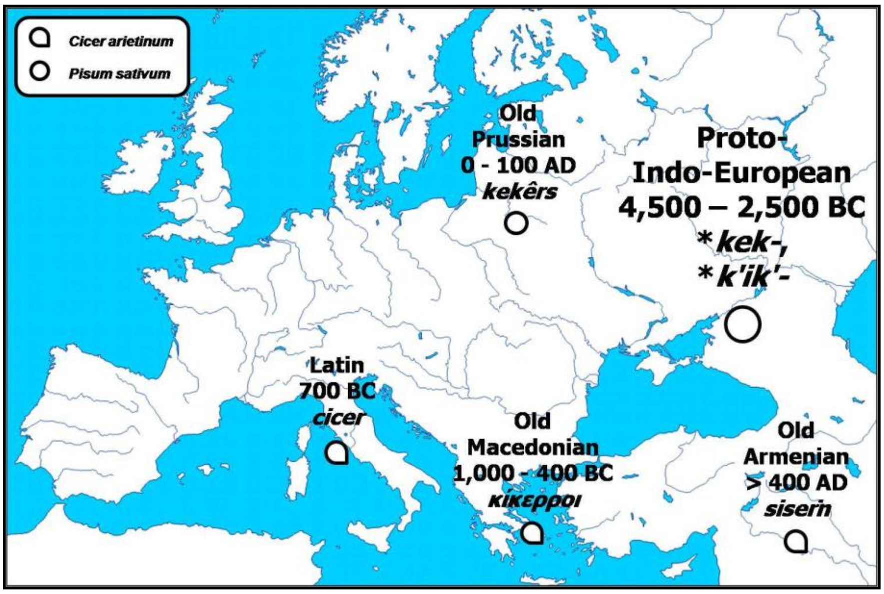

Figure 1. Initial evolution of the Proto-Indo-European root **kek-*

Table 1. Some words denoting chickpea in several modern European languages

Family	Branch	Language	Word denoting chickpea
Afro-Asiatic	Semitic	Maltese	cicra
Altaic	Turkic	Turkish	nohud
Déne-Caucasian	Basque	Basque	garbantzu; txitxirio
	Caucasian	Lak	nuhuṭ
Indo-European	Baltic	Lithuanian	avinžirnis; nutas
	Celtic	Irish	piseánach
		Welsh	gwygbysen
	Germanic	Danish	kikært
		German	Kichererbse
		Norwegian	kikert
		Swedish	kikärt
	Hellenic	Greek	ρεβιθιά
	Indo-Iranian	Kurdish	nok
	Italic	French	pois chiche
		Italian	cece
		Portuguese	ervanço
		Spanish	garbanzo
	Slavic	Bulgarian	leblebiya
		Czech	cizrna
		Polish	ciecierzyca
		Russian	nut
		Serbian	leblebija; naut
Kartvelian	Georgian	Georgian	mukhudo
Uralic	Finno-Permic	Finish	kikherne
	Ugric	Hungarian	csicseriborsó

An evolutionary perspective on the role of phenology in the specific adaptation of chickpea

by Jens D. BERGER

Abstract: Chickpea provides an excellent example for the role of phenology in specific adaptation as the species evolved from a narrowly distributed northern Mediterranean winter annual to a warm season crop as a result of changes in farming practice and distribution. The advent of spring-sowing and subsequent spread to warmer climates in the south and southeast modified selection pressures: elevating the role of terminal drought and high temperature stress, and reducing the role of low winter temperatures. This led to the evolution of regionally-appropriate regulation of phenology through the loss of the vernalization response, increasing temperature response as vegetative phase temperatures increase from north to south, and temperature-photoperiod compensation in Mediterranean germplasm. These mechanisms allow chickpea to match phenology with growing season length and avoid its principal stresses: the almost ubiquitous terminal drought and winter cold- largely confined to Mediterranean climates. This is essential understanding for the further improvement of chickpea, to allow us to focus on adaptive traits that augment, rather than oppose the crop's principal strategy of stress avoidance rather than tolerance.

Key words: chickpea evolution, phenology, specific adaptation

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Introduction

Phenology, the study of study of cyclic and seasonal natural phenomena, especially in relation to climate, plays a dominant role in the adaptation of all plants, but arguably is most important in annuals. The annual life cycle, where senescence (death) terminates the reproductive phase, trades-off biomass and seed production against stress avoidance, because the former is usually associated with a long life cycle, while the latter is typically associated with the opposite. Chickpea is a particularly good candidate for demonstrating the importance of phenology in the annual adaptive strategy because of its unique evolutionary path which exposed the crop to different stresses as its distribution widened from its narrow Mediterranean origins in the late 10th millennium b.p (2, 12). Accordingly, this paper will chart the evolution of chickpea, emphasising how changing farming practices and geographic location exerted different selection pressures that shaped the phenology of the crop.

Evolution of chickpea, and its dissemination in time and space

Among the West Asian Neolithic crop assemblage, chickpea has a unique evolutionary trajectory, passing through a series of bottlenecks from its origins as a narrowly distributed Mediterranean winter annual (*Cicer reticulatum*) to its current status as a South Asian and spring-sown Mediterranean crop (2). Neolithic chickpea remains are relatively common throughout the Eastern Mediterranean, where the crop was presumably sown in autumn and grown as a winter annual, like all the other West Asian Neolithic crops. After the Neolithic, chickpea appears to suffer a decline, reappearing in the Bronze Age in South Asia and in a much reduced, more southern Mediterranean distribution (Fig. 1). Abbo et al. (3) attribute this Mediterranean decline to the catastrophic effects of Ascochyta blight, and suggest that re-emergent Bronze Age chickpea was spring-sown to avoid this disease pressure, coinciding with the introduction of new spring-sown crops like sorghum millet etc., and reflecting traditional farming practices documented by ancient Greek and Roman scholars. Subsequently, chickpea consolidated its distribution in South and West Asia (both of which still dominate global production today), and appeared in Ethiopia in the Iron Age (Fig. 1). Chickpea was then spread throughout the Mediterranean basin by the Greeks, Romans and Phoenicians, introduced to the New World by the Spanish and Portuguese in the 16th century AD, while kabuli types moved to India through Central Asia via the Silk Road in the 18th century (12). More recently chickpea breeding programmes began in the United States, Australia (first cultivar, Tyson, released in 1979) and Canada.

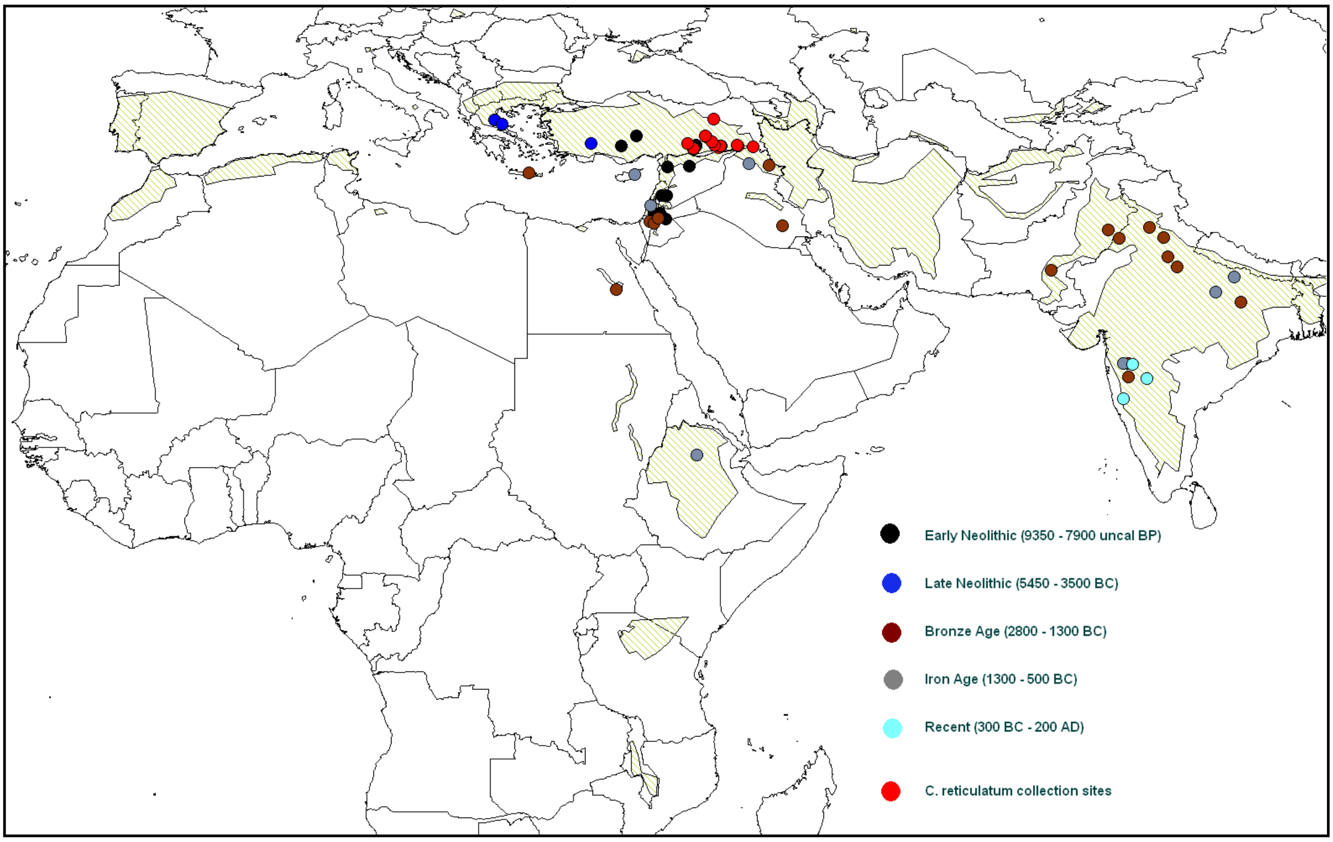

Figure 1. Dissemination of chickpea across the old world, from narrowly distributed Mediterranean winter annual (*C. reticulatum*, the wild progenitor) to widespread crop (crosshatched shading), based on archaeological sites containing ancient chickpea or *Cicer* species (12)

The spread of chickpea exposed the crop to different climates. In the Mediterranean basin there is a southerly gradient of decreasing rainfall, increasing seasonal temperature and winter rainfall proportion, which tends to a SE gradient from the Eastern Mediterranean to Central Asia (7). The newer chickpea growing regions of Central Asia, southern Europe, the western United States, Chile, and southern Australia also have typically Mediterranean climates with relatively low annual, winter-dominated precipitation (7). South Asia, responsible for ca. 75% of global production is characterized by high precipitation, summer dominant rainfall environments, where chickpea is grown in the subsequent dry (rabi) season on stored soil moisture (7). The same is the case for newer chickpea regions in East Africa, Peru and to a lesser extent, eastern Australia. The South Asian growing season is considerably warmer than that in the Mediterranean, with a strong southerly gradient of increasing winter temperature (8). Accordingly, in South Asia there is a latitudinal trend of decreasing growing season length moving from north to south. In eastern Australia, summer rainfall increases from south to north, and the chickpea production in northern NSW and southern Queensland uses both stored soil and in-season moisture (7).

Phenological response

Thus, because of the early Mediterranean change from autumn- to spring-sowing, and concomitant spread of the crop to warmer climates to the south and south east (Fig. 1), chickpea avoided winter both in time and space. As a result, compared to its wild progenitor from SE Anatolia, chickpea evolved under warmer temperatures, longer days, lower rainfall, and greater exposure to terminal drought. Moreover, spring sowing, considerably after the Mediterranean winter rains, exposed chickpea to a deeper water soil profile, arguably pre-adapting it for South Asian expansion.

These environmental changes exerted considerable selection pressure on chickpea phenology. The annual plant lifecycle uses appropriate phenology to avoid stress, and balances this against biomass production. The annual lifecycle is as long as the environment will allow. As rainfall becomes more variable (i.e. habitats become more stressful, or likely to be disturbed by terminal drought), reproduction and senescence is advanced, reducing the capacity for biomass production (11). Conversely, with increasing rainfall, annual plants delay their phenology, giving them more time to capture resources, accumulate biomass and maximize their yield potential. As foreshadowed by the previous discussion, the principal climatic stresses in the chickpea distribution range are winter cold and terminal drought. The former is largely confined to Mediterranean climates, where Ascochyta exerts additional selection pressure, while the latter is almost ubiquitous, but occurs at different times, according to season length.

Chickpea is very sensitive to low temperatures, both at the reproductive stage (5, 9), but also in the early vegetative phase (14), when annual plants are typically at their most tolerant. Vegetative frost stress leads to considerable mortality in chickpea, and selection for tolerance was one of the highest priorities for breeders attempting to re-establish autumn sowing in the Mediterranean (14). At flowering, chickpea is particularly chilling sensitive, delaying pod set at mean flowering temperatures as high as 21 °C (tailing off after 17.5 °C), due with negative effects on pollen germination, viability, and stigmal load (9). This is important because a delay in pod set increases the crop's exposure to terminal drought stress, reducing seed yield throughout much of the crop range. There is little useful variation for chilling tolerance within domesticated chickpea, even when comparing germplasm collected from contrasting warm and cold habitats (9). Terminal drought can reduce chickpea yields by 70% (10). Although chickpea has some traits often associated with drought tolerance or postponement, such as a capacity for osmotic adjustment or to extract more water than other pulses, yield under terminal drought is consistently negatively correlated with phenology, implying that drought escape is the principal adaptive strategy in the crop (4).

A comparison of chickpea germplasm from different origins confirms the strong selection pressure on phenology. Fig. 2 shows a 16 day range in flowering time, with the latest material coming from Central Asia, followed by Eastern Australia, Northern India and the Mediterranean, and then Western Australia, Ethiopia, Central and Southern India. Dates of podding and maturity are strongly correlated with flowering (r = 0.89 and 0.57), and show similar, albeit reduced ranges (Fig. 2). This pattern aligns well with Grime's (11) predictions: late material is sourced from cool and/or long season environments (e.g. Azerbaijan, Turkey, Northern India), while early material comes from regions with the early onset of terminal drought (e.g. Central and Southern India). This tendency of phenology matching growing season length in specifically adapted material is confirmed by regional G × E studies. In Australia, early flowering chickpea performs best in southern Mediterranean climates, while later cultivars yield well in the increasingly summer dominant rainfall of the north east (10). Similarly in India, warm southern locations favour early flowering, while the opposite is the case in the north (6).

How is phenology controlled? Regional selection pressure on the regulation of phenology

The examples outlined above suggest that phenology is under strong regional selection pressure. Indeed, recent studies indicate how evolution has selected for contrasting phenological mechanisms among different habitats in chickpea and its wild relatives (1, 5, 8). While the annual wild relatives are almost uniformly vernalization responsive, chickpea has lost the capacity to regulate flowering time in response to a low temperature stimulus (1, 5). Given that the annual wild relatives have retained a northern Mediterranean winter annual lifecycle, while chickpea has escaped low temperatures in both space and time, moving to systems and regions which impose increased terminal drought stress, it is likely that this mode of regulating phenology was actively selected against in the evolution of the crop.

This leaves only ambient temperature and photoperiod as environmental triggers that can regulate chickpea phenology (13); both of which are under contrasting regional selection pressures (8). Ambient temperature response is under very strong environmental selection pressure, being directly correlated (r = 0.8) to the mean temperature of the vegetative phase at the site of collection. Thus, temperature response increases from winter- to spring-sown Mediterranean and eastern Australian material, and then to north, central and southern India (8). As a result, as vegetative temperatures increase from the Mediterranean to South Asia, and then from north to south, locally evolved chickpea flowers increasingly early, escaping terminal drought through regionally appropriate phenology. Germplasm origin also affects the relationship between photoperiod and temperature response. In Eastern Mediterranean material a strong negative relationship (r = -0.77) enables temperature insensitive genotypes to compensate through a strong photoperiod response, allowing chickpea to avoid the twin Mediterranean stresses of low winter/spring temperatures and terminal drought (8). Moreover, this negative relationship is likely to have been essential for enabling the expansion of the crop to warmer southern climates, where a strong photoperiod response is very maladaptive (8).

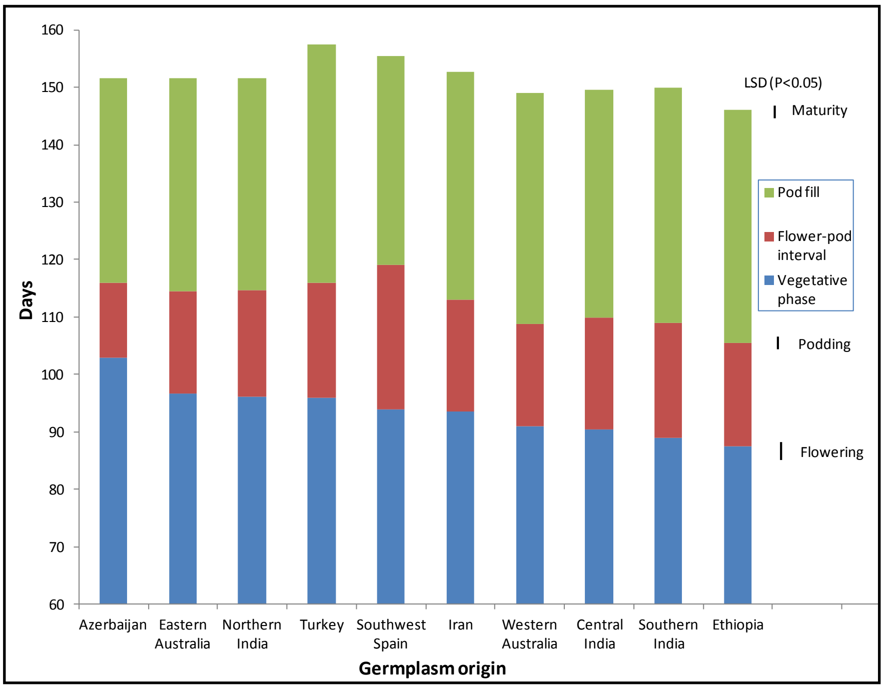

Figure 2. Phenology (flowering, podding and maturity) of chickpea germplasm collected from the Mediterranean basin, Africa, Australia, Central and South Asia. Data was recorded in a Western Australian field experiment at Merredin in 1999 (4)

Conclusions

The evolution of chickpea from its origins as a narrowly distributed northern Mediterranean winter annual modified the selection pressures exerted on the crop; elevating the role of terminal drought and high temperature stress, and reducing the role of low temperatures in winter. These changes exerted strong selection for regionally appropriate phenology to maximize growing season length within the constraints of terminal drought and low reproductive chilling tolerance (8). As a result, chickpea lost its capacity to respond to vernalization (1, 5), but became increasingly responsive to growing season temperatures as it spread to warmer regions in the south and southeast, facilitating drought escape through the early completion of its lifecycle. This adaptation was greatly facilitated by the negative relationship of photoperiod and temperature response in Mediterranean germplasm. The former is ideal in northern spring-sown Mediterranean systems because it facilitates escape from both reproductive chilling and terminal drought stress, but wholly maladaptive in warmer, low latitude, terminal drought-prone South Asian environments, where flowering is initiated under reducing, rather than increasing daylength.

This evolutionary trajectory probably led to other changes in chickpea. Compared to its wild relatives and other Mediterranean legumes, chickpea has little capacity to tolerate low temperatures in both vegetative and reproductive phases (5, 9, 14), whereas reproductive heat tolerance appears to be much more common (9), reflecting the intensity of these selection pressures in the lifecycle.

This is essential understanding for the further improvement of chickpea, to allow us to focus on adaptive traits that augment, rather than oppose the crop's principal strategy of stress avoidance rather than tolerance. For example, in the pursuit of improved yield under terminal drought the escape strategy should not be compromised. To this end, improved chilling tolerance to hasten the reproductive phase (9), parsimonious vegetative water use (16) and reproductive heat tolerance (10) to maximise seed filling are preferred over traits that may extend the growing season at the cost of reproductive investment, such has osmotic adjustment (15) or deep, profuse root development (16). Conversely, these traits may be supported in longer season environments by augmenting the crop's capacity to acquire resources, and extend the growing season during a time when yield development is not limited by low temperatures. ■

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Genomic resources in chickpea

by Teresa MILLÁN[1]*, Eva MADRID[2] and Rajeev K. VARSHNEY[3]

Abstract: Chickpea has considerably increased the genomic resources in recent years providing highly saturated genetic maps including anonymous or gene-specific markers targeting some agronomic traits of interest. In addition, the publication of the two draft genome sequences of Kabuli and Desi chickpea types opens a new era in genomic tools. Furthering in our understanding of the association betweenphenotypic traits (Quantitative Trait loci-QTL-or genes)with the trasncriptome and gene annotation provided by genome sequencing data will be the future challengeto be able to exploit with success marker-assisted Selection (MAS).

Key words: chickpea, genomics, marker-assisted selection

Introduction

DNA marker technology made possible the generation of genetic maps ensuring the use of MAS and positional cloning of genes of interest. Chickpea genetic maps using bi-parental populations from narrow and wide crosses were initiated in the nineties and had a great step forward with the incorporation of STMS/SSR (Sequence Tagged Microsatellite Sites/Simple Sequence Repeat) and ESTs (Expressed Sequence Tags) based markers. Those locus specific markers provided the possibility to comparemaps in different populations, to unify nomenclature for linkage groups, establish reference maps and provide anchor points for comparing the genomes of the model species *Medicago truncatula* and chickpea (7, 9, 13). In recent times, Next Generation Sequencing (NGS) technologies have been effectively generated in chickpea large-scale transcriptome data together with genomic markers based on Single Nucleotide Polymorphisms (SNPs) facilitating the development of highly saturated second generation genetics maps (5). Those maps have been developed in Recombinant Inbred Line (RIL) populations including markers from Simple sequence repeat (SSR), Expressed Sequence Tag (EST), Intron Spanning Region (CISR), Genic Molecular Markers (GMMs), BAC-end derived SSR (BES-SSR), Diversity Arrays Technology (Dart) or Tentative Orthologous Genes (TOGs) (4, 11) (Table 1).

Marker-assisted breeding in progress

First chickpea genetic maps were mainly focussed in the location of genomic areas controlling disease resistances, some agronomic traits and few quality components (Table 2). Successful results in marker-assisted backcrossing (MABC) for drought tolerance and fusarium wilt have been achieved mainly using STMS makers. STMS have been widely used in chickpea because their extensive probability of finding polymorphism however the prediction of favourable alleles is less accurate than using gene-specific markers. Examples of allele-specific markers were obtained for genomic areas related to ascochyta blight resistance: CaETR for QTL_{AR1} and SCY17 for QTL_{AR2}proved to be successful in predicting resistant accessions (6).

An approach to progress in the detection of candidate genes has been the development of Near Isogenic Lines (NILs) (1). Phenotypic variation observed between pairs of NILs can be assigned directly to the restricted target region of genome that differs between them.

Broaden genomic resources: sequencing projects

Very recently the first draft of the chickpea genome sequence was published. This project was undertaken by the International Chickpea Genome Sequencing Consortium (ICGSC) led by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with University of California in Davis, BGI-Shenzhen, University of Cordoba and several other organizations (12). The consortium featured the reference genome of the kabuli type CDC Frontier chickpea variety and re-sequenced the genomes of 90 cultivated and wild genotypes from 10 different countries. This publication reported the draft genome sequence of ~ 738-Mb which contains an estimation of 28,269 genes. Examination of synteny with other legumes revealed extended (> 10 kb) conserved syntenic blocks with *M. truncatula.* The draft sequence of a desi genotype has also become available now (520 Mb assembly covering 70% of the predicted 740 Mb genome length and more than 80% of the gene space) (8).

Comparison of phenotypic traits located in genetic maps, expression studies and the complete genome sequence will be a very powerful tool in the future, facilitating genetic enhancement and breeding todevelop improved chickpea varieties.

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Table 1. Second generation genetic maps developed in chickpea based on RIL populations

Newly developed markers	N° of loci	Coverage (cM)	Average inter marker distance (cM)	Reference*
SSR, GMMs, CISR	300	766.56	2.55	(4)[a]
BES-SSR,DarT	1291	845.56	0.65	(11)[a]
EST-SSR, ITPs, SNPs	406	1497.7	3.68	(2)[a]
SNPs, SSR	368	1808.7	1.7	(3)[b]
CKAMs, TOGs-SNPs	1328	788.6	0.59	(5)[a]

*a: map in population derived from C. *arietinum* ICC 4958 x C. *reticulatum* PI 489777;
b: map in population derived from ICCV2 x JG62

Table 2. Traits and locus-specific markers localized in different linkage groups of the chickpea genetic map (10)

Linkage group (LG)	Traits	Gene/QTL	Indicative Markers*
LGI	β-carotene	QTL	GA11, TA122
	Seed weight	QTL	GA11
	Days to first flower	QTL	H1F022, GAA40
LGII	Fusarium wilt race 0	*Foc-0₂/foc-0₂*	TA59, TS47
		foc-1	H3A12, TA110
		foc-2	TA96, H3A12
		foc-3	H1B06y, TA194
		foc-4	TA96, CS27
		foc-5	TA27, TA59, TA96
	Ascochyta blight	*ar1*, QTL_{AR1}	GA16, TA194, TR
	Seed weight	QTL	TA110-TAA60
	Days to first flower	QTL	H4B09, H1B06
LGIII	Growth habit	*Hg*	Pgd-c
	β-carotene	QTL 2	TA64, STMS28
	Days to flower	QTL	TS57, TA127, TA142
	Ascochyta blight	QTL	STMS28, TS12, TA64
LGIV	Seed testa color	*T3*	*P*
	Flower color	*P, B/b*	TA61
	Seed coat thickness	*Tt/tt*, QTL	*B/b*
	Seed number	QTL	TA130
	Seed weight	QTL	GA24, STMS11, GA2
	Days to flower	QTL	GAA47
	Ascochyta blight	QTL_{AR1}, QTL_{AR2}	CaETR, $SCY17_{590}$
LGV	Fusarium wilt race 0	*Foc-0₁/foc-0₁*	$OPJ20_{600}$, TR59
LGVI	Single/Double pod	*s*	TR44, TA80
	Seed weight	QTL	TA120,TR40
	Days to flower	QTL	TS57, TA127
	Ascochyta blight	QTL	TA176
	Botrytis grey mould	QTL	SA14-TS71rts36r
LGVII	Rust	*Uca1/uca1*	TA18, TA180
LGVIII	Lutein concentration	QTL	TA25
	Seed weight	QTL	$OPE09_{1594}$-$MER05_{1645}$
	Ascochyta blight	QTL	TA3, TS46, TS45, H3C11a
	Botrytis grey mould	QTL	TA25, TA144, TA159,TA118

Final remarks

The current focus in applied breeding is leveraging biotechnological tools to develop more and better markers to allow marker assisted selection with the hope that this will speed up the delivery of improved cultivars to the farmer. To date, progress in marker development and delivery of useful markers has been increasingly fast in chickpea. Nowadays, markers currently targeting resistance genes or QTL are in majority microsatellite type but high-throughput SNP genotyping platforms are overtaking SSR as the choice of markers type to be used in the screening of germplasm collections (5). Besides, the development of transcript maps and information of the genome sequence will increase marker density in the genomic regions controlling traits of interest. Available tools facilitate the identification of gene families involved in resistance mechanism as NBS-LRR genes, or the analysis of orthologous genes related with agronomics traits (i.e. flowering time, growth habit, double podding etc.) present in other legumes. Similarly, recent advances in genomic technology will assist the exploiting of natural diversity by association mapping conducted on germplasm collections. ■

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Drought and heat tolerance in chickpea

by Pooran GAUR*, Samineni SRINIVASAN and Rajeev VARSHNEY

Abstract: Chickpea is largely grown rainfed on residual soil moisture after the rainy season. Terminal drought is a major constraint to chickpea production, particularly in the semi-arid tropics. Similarly, exposure of chickpea to heat stress (≥ 35 C) at flowering and podding is known to result in drastic reductions in seed yields. Efforts have been made to develop cultivars that can escape (early maturity) or avoid/tolerate (greater extraction of water from the soil, enhanced water use efficiency) terminal drought. Large genetic variations exist for reproductive stage heat tolerance in chickpea. Many heat tolerant genotypes have been identified through screening of germplasm/breeding lines under heat stress conditions in the field. A heat tolerant breeding line ICCV 92944 has been released for cultivation in Myanmar (as Yezin 6) and India (as JG 14).

Key words: early maturity, root systems, heat stress, marker-assisted breeding

Introduction

Drought and heat are the most serious abiotic constraints to chickpea production globally. It is estimated that drought and heat stresses together account for about 50% of the yield losses caused by abiotic stresses. Chickpea is predominantly grown as a rainfed crop on residual soil moisture stored during the previous rainy season with very less or no rainfall during the growing season. The soil moisture recedes to deeper soil layers with the advancement in crop growth and the crop experiences increasing soil moisture deficit at the critical stage of pod filling and seed development (called terminal drought) (3). Terminal drought is a major constraint to chickpea production in over 80% of the global chickpea area. The extent of terminal drought stress varies depending on previous rainfall, atmospheric evaporative demand, and soil characteristics such as type, depth, structure, and texture.

Heat stress (temperatures > 35 C) at the reproductive stage is increasingly becoming a serious constraint to chickpea productivity because of large shift in chickpea area from cooler long-season environments to warmer short-season environments, increasing chickpea area under late sown conditions due to increasing cropping intensity, and expected overall increase in temperatures due to climate change (5).

Drought tolerance

The mechanisms for adaptation of plants to moisture stress environments are broadly classified into three categories (a) drought escape, (b) drought avoidance (dehydration postponement) and (c) drought tolerance (dehydration resistance). Early phenology (early flowering, early podding and early maturity) is the most important mechanism to escape terminal drought stress. Drought avoidance can be achieved by water uptake by the roots from deeper soil layers, by osmotic adjustment and by reducing water loss (stomata conductance or by reduction in leaf area). Drought tolerance refers to the ability of cells to continue metabolism at low leaf water status.

Figure 1. A chickpea crop severely affected by terminal drought stress

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Chickpea breeding program at ICRISAT has placed high emphasis on development of early maturing varieties for enhancing adaptation of chickpea to environments prone to terminal drought stress (4). There is wide variability for time to flowering in chickpea germplasm, which provides opportunity for developing chickpea cultivars with desired earliness. Several early maturing high yielding cultivars have been developed, e.g., ICCV 2 (Swetha in India, Wad Hamid in Sudan and Yezin 3 in Myanmar), ICCV 92311 (PKV Kabuli 2 or KAK 2 in India) and ICCV 92318 (Chefe in Ethiopia) in kabuli type and ICCC 37 (Kranthi in India), ICCV 88202 (Sona in Australia, Yezin 4 in Myanmar and Pratap chana 1 in India) and ICCV 93954 (JG 11 in India) in desi type. Adoption of early maturing varieties has shown high impacts on enhancement of chickpea area and productivity in short-season environments, e.g. Myanmar and southern India. Super early breeding lines have been developed (e.g. ICCV 96029) which further expand opportunities for cultivation of chickpea in areas and cropping systems where the cropping window available for chickpea is narrow and in specific situations where early podding is highly desired, for example in vegetable purpose crop (used for immature green grains).

Most breeding programs use grain yield under moisture stress for selection of genotypes with enhanced drought avoidance/tolerance. In most cases the material is exposed to terminal drought by growing the crop under rainfed conditions or under rainout shelters. Grain yield is a complex trait controlled by many genes and highly influenced by the environment. Thus, early generation selection for drought avoidance/tolerance is not effective because of low heritability. Lack of uniform spread of soil moisture/drought stress in the field further reduces efficiency of selection. Hence advanced breeding lines are evaluated at multiple locations and over the years.

Several studies in the recent years have focused on identification of morphological and physiological traits associated with drought avoidance/tolerance. Experiments conducted at ICRISAT demonstrated that a prolific root system contributes positively to grain yield under terminal drought conditions (8). Despite well recognized importance of root traits in terminal drought tolerance, limited efforts have been made to breed for improved root traits because the screening for root traits is a destructive and labor intensive process and difficult to use in large segregating populations. Some breeding programs have used genotypes with deep and vigorous root system, such as ICC 4958, as one of the parents in crosses, but selection of breeding lines was invariably for seed yield under water-stress conditions rather than on root traits.

Identification of molecular markers linked to major genes controlling root traits can facilitate marker assisted breeding (MAB) for root traits. There has been considerable progress in development of molecular markers and expansion of genome map of chickpea in recent years (6). A genomic region carrying a transcription factor or quantitative trait loci (QTL) that controls several drought tolerance related traits including some root-traits was located on LG4 from two intra-specific RIL mapping populations (ICC 4958 × ICC 1882 and ICC 283 × ICC 8261) at ICRISAT. This genomic region was introgressed in one desi chickpea cultivar (JG 11) from ICC 4958 (desi type) and in two kabuli chickpea cultivars (KAK 2 and Chefe) from ICC 8261 (kabuli type) using marker-assisted backcrossing (MABC). A set of 20 BC3F4 lines generated from the cross involving JG 11 as recurrent parent was evaluated at 3 locations in India and one each in Kenya and Ethiopia. Several BC3F4 lines giving significantly higher yield than the cultivar JG 11 were identified at each location (7). The initial results from the evaluation of MABC lines are encouraging and suggest the scope of effective use of marker-assisted breeding for improving drought tolerance in chickpea.

Heat tolerance

Chickpea being a cool season food legume suffers heavy yield losses when exposed to heat stress at reproductive (flowering and podding) stage. The optimal temperatures for chickpea growth range between 10 C and 30 C. Reproductive phase (flowering and seed development) of chickpea is particularly sensitive to heat stress. A few days of exposure to high temperatures (≥ 35 C) during reproductive phase can cause heavy yield losses through flower and pod abortion. Recent studies indicate that the high temperatures reduced pod set in chickpea by reducing pollen viability and pollen production per flower (1, 2).

A simple and effective field screening technique for reproductive stage heat tolerance in chickpea has been developed at ICRISAT, Patancheru in southern India. Patancheru (latitude 17° 36' 10" N, longitude 78° 20' 39" E), is an ideal location for screening chickpea for heat tolerance because it has a warm and short growing season (90-100 days) for chickpea. Long-term weather data was used to decide the sowing time that would coincide the reproductive phase of the crop with high temperatures (> 35 C). At Patancheru, chickpea is normally sown in the month of October and harvested in January/February. It was found that if chickpea is sown in the month of February, the highest temperatures would be generally above 35 C starting from the initiation of flowering to crop maturity. Though the October-sown crop can be grown on residual moisture without any supplementary irrigation, the February-sown crop has to be irrigated frequently (at 10-15 days interval). It was found that number of filled pods per plant in late-sown crop can be considered as a selection criterion for reproductive stage heat tolerance.

The recent studies on screening of chickpea genotypes for heat tolerance indicate existence of large genotypic variation for reproductive stage heat tolerance in chickpea. Several heat tolerant genotypes have been identified which include landraces (e.g. ICC 1205, ICC 1356, ICC 4958, ICC 6279, ICC 15614), breeding lines (e.g. ICCV 07104, ICCV 07105, ICCV 07108, ICCV 07109, ICCV 07110, ICCV 07115, ICCV 07117, ICCV 07118, ICCV 98902) and cultivars (e.g. JG 14, JG 16, JG 130, JAKI 9218, JGK 2, KAK 2).

Figure 2. A heat sensitive (left) and a heat tolerant (right) line of chickpea grown under heat stress conditions at ICRISAT, Patancheru

The availability of effective, efficient and simple field screening technique for heat tolerance greatly facilitate chickpea breeding for heat tolerance. The general breeding scheme includes growing of segregating populations (F_4 or F_5) under late sown conditions for selecting heat tolerant plants based on the number of filled pods per plant. Then, single plant progenies are developed from the selected heat tolerant plants and evaluated further for grain yield and other desired traits (resistance to key diseases, seed traits, etc) under normal and heat stress conditions.

A heat tolerant breeding line ICCV 92944 has been released for cultivation in Myanmar (as Yezin 6) and India (as JG 14) and becoming popular for sowing under late-sown conditions (e.g. rice fallows). In addition, several other popular cultivars (JG 16, JG 130, JAKI 9218, JGK 2, KAK 2) were found to be heat tolerant.

Marker-assisted selection for heat tolerance can further accelerate breeding process and facilitate combining different desired traits. Recombinant inbred lines (RILs) have been developed from crosses between highly tolerant and highly sensitive lines for heat tolerance. These are being evaluated to identify molecular markers linked to heat tolerance genes. Efforts are also being made to identify candidate genes for heat tolerance. It is anticipated that several new heat tolerant cultivars of chickpea will be released in the coming years and provide greater choices to the farmers. ■

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Salt tolerance in chickpea: Towards an understanding of sensitivity to salinity and prospects for breeding for improved resistance

by Timothy D. COLMER[1]* and Vincent VADEZ[2]

Abstract: Chickpea (*Cicer arietinum* L.) is sensitive to salinity, although genotypes showsignificant variation in tolerance. The reproductive phase appears to be particularly salt-sensitive.Importantly, recent screening experiments have been conducted to maturity with evaluation of seed yield under saline conditions, The genetic variation appears to be sufficient to breed for improved salt tolerance, but heritability of tolerance requires further study, only minor QTLs for salt tolerance have been identified, and the physiological basis of genotypic differences in tolerance is unclear; so, screening and selection of progeny will likely be a bottleneck in improvement of salt tolerance in chickpea.

Key words: *Cicer arietinum*, NaCl, ion toxicity, soil salinity, water relations

Soil salinity is a major stress factor that restricts crop yields in many parts of the world(4). Salinity continues to increase in many regions, affecting previously productive land in dryland and irrigated farming systems, and especially in areas where total annual evaporation is high. Chickpea is sensitive to salinity – this sensitivity is very evident when chickpea is compared to other species in cropping systems, for example bread wheat.

The impacts on chickpea of salinity have been reviewed (1). Salinity impacts on germination, plant establishment, nitrogen-fixation, vegetative growth, flowering, podding and seed filling; but the sensitivity to salinity differs between these processes/stages and in various genotypes. Germination appears relatively more salt tolerant than vegetative growth, but with the reproductive phase being particularly salt-sensitive (1, 6, 7).

The adverse effects of salinity on plants (3) are usually considered in terms of the impact of excess ions in the soil on plant water relations (i.e. the 'osmotic effect' of salinity) and of high tissue ion concentrations, typically Na^+ and/or Cl^-, resulting in tissue injury (i.e. 'ion toxicity'). In addition, the disruption by high Na^+ of plant K^+ and Ca^{2+} homeostasis also contributes to the adverse effect of salinity on salt-sensitive species.

Salinity reduces the amount of water that chickpea crops can extractfrom soil, causing water deficits and also limiting carbon capture and therefore growth and yield (1). In addition, the build-up of ions in leaves can result in necrosis, but whether high tissue Na^+ or Cl^- (or both) cause the damage is unclear, and tolerance is only sometimes correlated with differences in tissue ion concentrations (1). For example, differences in seed yield under saline conditions among a large and representative set of germplasm was not related to differences in shoot tissue Na^+ concentration (7). Whether genotypes differ in 'tissue tolerance'should be explored; the term 'tissue tolerance' is used by us to meanthe maintenance of functional tissues (e.g. capacity for photosynthesis) despite high internal Na^+ and Cl^- concentrations.

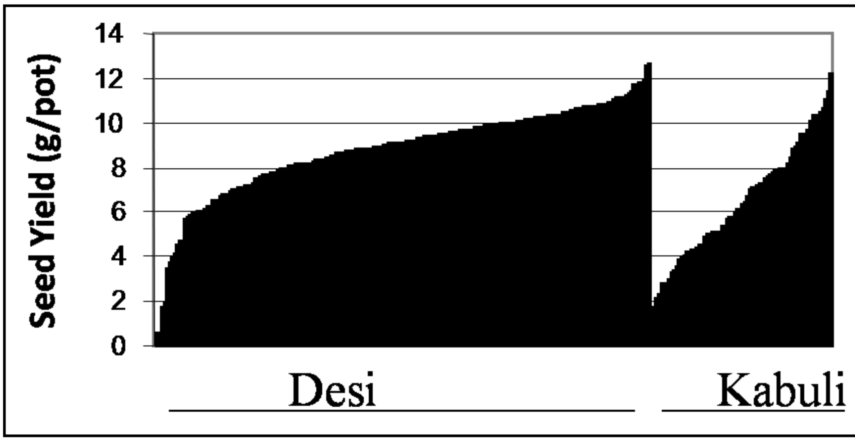

Figure 1. Seed yield under saline conditions in a large and representative range of chickpea genotypes. The figure shows large variation in both Desi and Kabuli types, although overall, the Kabuli types had lower seed yields in the saline soil (1.17 g NaCl kg^{-1} soil) than the Desi types. Experiment conducted in an outdoor pot system at ICRISAT. For more, see (7).

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In addition to the effects on chickpea (1) from the osmotic and specific-ion components of salinity stress (3), salinity can cause large reductions in nodulation, nodule size and nitrogen-fixation capacity (1). The resulting lower nitrogen status caused by a dysfunctional rhizobium-plant symbiosis under saline conditions would likely add to the lesions already discussed above for chickpea when exposed to salinity, and further restrict growth and yield in saline soils.

Effort to breed more salt tolerant varieties of chickpea has been limitedto date, although selections with reasonable salt tolerance (for chickpea) have been released (e.g., KarnalChana 1 or CSG8962 in India). Several studies have highlighted diversity in salt tolerance within chickpea (2, 7) and importantly large variation in seed yield (per plant) in saline soils has been demonstrated (7, Fig. 1). Among chickpea genotypes, there is considerable variation in seed yield in saline soils for both desi and kabuli types, but the kabuli types are generally more salt-sensitive than the desi types (Fig. 1). Although there is genetic variation for salt tolerance in chickpea, knowledge of the genetic and physiological basis of the differences between genotypes is poor, hampering parental selections for possible pyramiding of key traits as has been proposed for breeding of salt tolerance in rice (10).

The reproductive stages appear to be particularly sensitive to salinity. A recent large scale screening for yield under salinity showed that tolerance, i.e. high yield under saline conditions, was related to the capacity of maintaining and filling a large number of pods (7, Fig. 2). The photographs show two genotypes with similar vegetative growth in saline soil, but with very different reproductive success in these saline conditions (Fig. 2). To date, only minor QTLs for salt tolerance have been identified in chickpea (8), being consistent with results of a genetic analysis which revealed the complex regulation of salt tolerance in chickpea (5). However, a few QTLs with substantial effect on traits related to yield under saline conditions, such as the number of pods and therefore seeds per plant, have been identified (8).

Additional research is needed, therefore, to develop efficient screening and selection techniques of progeny (e.g., based on phenotypic traits, possible marker-assisted selection, and ultimately grain yield in saline conditions). Screening strategies should focus on traits which contribute to high yield in saline soils. Difficulties in screening and selection are further heightened by the typically large variability in soil salinity in fields. Recently, it was found that yield in saline soil was related to the capacity of producing more flowers and to a high number of tertiary branches (9). These traits were identified both under saline and non-saline conditions, pointing to constitutive traits being important for yield in saline soils. A priority will also be to understand the basis of the sensitivity of reproduction to salinity. Moreover, as reproduction is sensitive to other stresses, such as drought, our on-going work will evaluate the possibility of reproductive stage tolerance mechanisms being beneficial across stresses.

The need for crops with improved salt tolerance, including the gains likely if the high sensitivity of chickpea to salinity can be overcome, means the challenges towards improvement of salt tolerance in chickpea should be of priority for future research. ■

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Figure 2. Photographs of a tolerant (left) and a sensitive (right) genotype of chickpea when grown in saline soil (1.17 g NaCl kg^{-1} soil). The picture shows similar vegetative development but large differences in the number of pods between the tolerant and the sensitive genotypes. Both genotypes produced pods by this stage in the non-saline controls. Experiment conducted in an outdoor pot system at ICRISAT. For more, see (7).

Resistance to Ascochyta blight in chickpea (*Cicer arietinum* L.)

by Suresh PANDE* and Mamta SHARMA

Abstract: Ascochyta blight (AB), caused by *Ascochyta rabiei* is a major disease of chickpea (*Cicer arietinum* L.), capable of causing complete yield losses in areas where cool, cloudy, and humid weather persists during the crop season. The fungus mainly survives between seasons through infected seed and in infected crop debris. Despite extensive pathological and molecular studies, the nature and extent of pathogenic variability in *A. rabiei* has not been clearly established. Deploying resistant cultivars of chickpea along with seed treatment and foliar application of fungicides are commonly recommended for AB control. However, host plant resistance is the most economical and sustainable AB management option. Therefore, in this paper we focus on HPR as the major component for integrated management of AB, with emphasis on future research priorities.

Key words: *Ascochyta rabiei*, resistance, screening techniques, epidemiology, chickpea

The Aschochyta blight

Ascochyta blight (AB), caused by fungal pathogen *Ascochyta rabiei* (Pass.) Labrousse, is the most devastating disease of chickpea and can cause up to 100% grain yield and quality losses in areas where cool, cloudy and humid weather (15-25 °C and > 150 mm rainfall) occurs during the crop season (5). The disease has been reported from 34 countries across six continents (3). The recent cultivation of chickpea in Australia and Canada has shown it can spread rapidly to new production areas. In Australia, chickpea production increased rapidly until 1999 but was then limited by outbreaks of AB. The disease is currently the most important yield limiting factor, potentially affecting 95% of the chickpea area in Australia (4). In Western Canada, the chickpea production area increased rapidly from 800 ha in 1995 to 700 000 ha in 2000 and continued to increase, but the incidence of AB in these areas resulted in >70% yield losses.

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Sign and symptoms of Ascochyta blight

Symptoms of AB can develop on all aerial parts of a plant. Seed-borne infection leads to brown lesions at the stem base of emerged seedlings. Subsequently, the lesions enlarge in size, girdle the stem causing its breakage and death of the plant. Numerous pycnidia develop on the necrotic lesions. In the field, AB may initially appear as small patches (foci) of blighted plants, but can rapidly spread across an entire crop under favorable temperature and rainfall. Plants are attacked at any growth stages, depending on the inoculum availability. However, AB is most prominent during the flowering to early podding growth stages. Airborne conidia and ascospores, infect younger leaves and produce small water-soaked necrotic spots that rapidly enlarge and coalesce. Conidia may also be water-borne and splash dispersed to infect foliage tissue on the same or nearby plants. Subsequently, symptoms spread rapidly to all aerial parts including leaves, petioles, flowers, pods, branches, and stems, which lead to rapid collapse of tissues and death of the plant. Development of pycnidia in concentric rings on lesions is the characteristic symptom of *A. rabiei* infection. Lesions that develop on leaves and pods appear circular with brown margins and a grey centre that contains pycnidia, while lesions developing on petiole, stems and branches are elongated. The lesions that develop on apical twigs, branches and stems differ in size and in later stages girdle the affected plant parts. The regions above the girdled portion are killed and may break off. Diseased pods with visible blight symptoms often fail to develop any seed. Pod infection often leads to seed infection through the testa and cotyledons. Infected seed can be discoloured and possess deep, round or irregular cankers, sometimes bearing pycnidia visible to the naked eye. Infection during the pod maturation stage often results in shriveled and infected seed (6, 7).

Survival, development and spread of Aschochyta blight

The causal agent of AB (*Ascochyta rabiei*) survives either on or in seed or plant debris in the form of mycelium, pycnidia and various teleomorphic stages (2). Seed transmission of *A. rabiei* and airborne spores can lead to disease spread and establishment of compatible mating types in new areas and thus the development of the teleomorph. Seed transmission ensures random distribution of the pathogen in a field, providing many primary infection foci. Movement of infected chickpea seed is responsible for introducing AB into Canada, Iran, Australia and USA (2). Conidia and ascospores are responsible for secondary spread of the disease. Subsequent wetting, rain splash and strong winds disperse conidia developed on diseased plant parts, particularly if conidia are contained in droplets (1).

Ascochyta blight infection and disease development occur at a temperature range of 5-30 °C with an optimum of 20 °C, and 17 h of wetness is essential to produce severe infection. Dry periods (6-48 h) immediately after inoculation sometimes increase disease severity. Disease severity increases with increasing periods of darkness after inoculation.

Identification and deployment of host plant resistance

The preliminary step for exploiting HPR is the development of reliable and repeatable techniques for large scale screening of germplasm and breeding lines. Several techniques suitable for AB resistance screening under field and greenhouse conditions have been developed (5). Resistance screening using cut-twig and detached leaf techniques correlated with greenhouse screening (6). Disease rating scale commonly followed is a 1–9 scale, where 1 = no visible lesions on any plants and 9 = profuse lesions on all plants, stem girdling on more than 50% of the plants and many plants killed (6).

Deployment of resistant genotypes is the most effective way to minimize yield losses due to AB. In several studies conducted in different chickpea growing areas of the world, few sources of resistance to AB were identified (Table 1). The development of AB resistant genotypes (Table 2) has made it possible to sow the crop during winter in the Mediterranean region and reintroduce the chickpea cultivation in Australia thereby increasing the chickpea production potential. In the absence of highly resistant sources, no single strategy in breeding for AB-resistant cultivars is likely to succeed. A combination of different strategies needs to be developed and utilized. The release of several cultivars, possibly with known reactions in different races/pathotypes, will be useful in case the resistance breaks down in one of the cultivars.

Integrated disease management

Adoption of integrated disease management (IDM) practices is essential for economical and effective control of AB. Moderate levels of HPR can be combined with other cultural practices and/or application of minimum dosage of fungicides for control of AB. The location-specific recommended IDM practices include: (a) use of pathogen free seed, (b) seed treatment with fungicides, (c) practice of crop rotation, (d) deep ploughing of chickpea fields to bury infested debris, (e) use of disease resistant genotypes, and (f) strategic application of foliar fungicides.

Table 1. Ascochyta blight reaction of 29 resistant breeding lines to *Ascochyta rabiei* in controlled environment and field screening (6)

Breeding lines	Ascochyta blight reaction (1-9 scale)[A]									
	Controlled environment				Field[B]					
	Patancheru				Ludhiana			Dhaulakuan		
	2005	2006	2007	Mean	2005	2006	Mean	2008	2009	Mean
ICCV 04524	2.0	2.0	2.0	2.0	3.0	3.0	3.0	2.0	3.0	2.5
ICCV 04525	2.3	2.0	2.6	2.3	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 04526	2.3	2.6	2.0	2.3	2.3	2.7	3.0	3.0	2.0	2.5
ICCV 04537	2.3	2.0	2.6	2.3	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 98811	2.7	2.5	2.9	2.7	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 98816	2.3	2.6	2.3	2.3	2.7	2.7	2.7	-	2.0	2.0
ICCV 04523	2.7	3.0	2.4	2.7	2.0	2.0	2.0	2.0	2.0	2.0
ICCV 05571	2.8	3.0	2.6	2.8	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 04052	3.0	2.0	4.0	3.0	3.0	3.0	3.0	-	-	-
ICCV 04530	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	-	3.0
ICCV 05546	3.7	3.0	2.3	3.0	2.7	2.3	3.0	3.0	-	3.0
ICCV 05514	3.0	2.3	3.7	3.0	3.0	3.0	3.0	2.0	2.0	2.0
ICCV 04505	3.3	3.0	2.7	3.0	2.7	2.3	3.0	3.0	2.0	2.5
ICCV 05502	3.0	3.3	2.7	3.0	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 05512	2.7	4.0	2.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ICCV 04509	2.3	4.0	2.7	3.0	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 05547	3.7	3.0	2.3	3.0	3.0	3.0	3.0	3.0	-	3.0
ICCV 05551	3.7	3.0	2.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ICCV 05503	2.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	-	3.0
ICCV 05511	2.3	4.0	2.7	3.0	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 05513	2.7	3.0	3.3	3.0	2.3	3.7	3.0	3.0	2.0	2.5
ICCV 05515	3.0	3.3	2.7	3.0	3.3	2.7	3.0	3.0	2.0	2.5
ICCV 05523	3.0	3.0	3.0	3.0	4.0	2.0	3.0	3.0	2.0	2.5
ICCV 05532	2.7	3.3	3.0	3.0	3.3	2.7	3.0	3.0	2.0	2.5
ICCV 98818	3.0	3.3	2.7	3.0	3.0	3.0	3.0	3.0	3.0	3.0
ICCV 04512	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 05530	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 04513	3.0	3.7	2.3	3.0	3.0	3.0	3.0	3.0	2.0	2.5
ICCV 05531	3.0	3.3	2.7	3.0	3.0	3.0	3.0	2.0	2.0	2.0
ICC 4991 (Sus. check to AB)	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	7.0	8.5
SEM	0.25	0.25	0.26		0.25	0.31		0.28	0.34	
SED	0.35	0.35	0.36		0.36	0.44		0.38	0.42	
Cv (%)	13.95	12.71	14.48		13.67	16.19		14.75	15.84	
l.s.d. (5%)	0.71	0.71	0.74		0.73	0.89		0.81	0.71	

Table 2. Some chickpea lines released in different countries, with acceptable level of resistance to Ascochyta blight (5)

Accession	Country of origin	Country of release	Released name	Year of release
ILC 72	N.A.[a]	Italy	Califfo	1990
ILC 72	N.A.	Spain	Fardan	1985
ILC 195	USSR	Egypt	Giza 195	1995
ILC 195	USSR	Morocco	ILC 195	1986
ILC 195	USSR	Turkey	ILC 195	1986
ILC 200	USSR	Spain	Zegri	1985
ILC 202	USSR	China	ILC 202	1988
ILC 237	Spain	Oman	ILC 237	1988
ILC 411	Iran	China	ILC 411	1988
ILC 464	Turkey	Cyprus	Kyrenia	1987
ILC 482	Turkey	Algeria	ILC 482	1988
ILC 482	Turkey	France	TS 1009	1988
ILC 482	Turkey	Iran	ILC 482	1995
ILC 482	Turkey	Iraq	Rafidain	1992
ILC 482	Turkey	Jordan	Jubeiha 2	1990
ILC 482	Turkey	Lebanon	Janta 2	1989
ILC 482	Turkey	Morocco	ILC 482	1986
ILC 482	Turkey	Syria	Ghab 1	1986
ILC 482	Turkey	Turkey	Guney Sarisi 482	1986
ILC 484	Turkey	Libya	ILC 482	1993
ILC 533	Egypt	Georgia	Elixir	2000
ILC 915	Iran	Sudan	Jebel Marra-1	1994
ILC 1335	Afghanistan	Sudan	Shendi	1987
ILC 2548	USSR	Spain	Almena	1985
ILC 2555	Ethiopia	Spain	Alcazaba	1985
ILC 3279	USSR	Algeria	ILC 3279	1988
ILC 3279	USSR	China	ILC 3279	1988
ILC 3279	USSR	Cyprus	Yialosa	1984
ILC 3279	USSR	Iran	ILC 3279	1995
ILC 3279	USSR	Iraq	Dijla	1992
ILC 3279	USSR	Italy	Sultano	1990
ILC 3279	USSR	Jordan	Jubeiha 3	1990
ILC 3279	USSR	Syria	Ghab 2	1986
ILC 3279	USSR	Tunisia	Chetoui	1987
ILC 6188	France	Italy	Ali	1998

Conclusion

Management of AB using resistant cultivars is essential to provide increased and stable chickpea yields throughout the world. Wherever possible, HPR should be emphasized over chemical control as the most environmentally friendly and economic, AB control strategy. Selection of resistant sources for genetic improvement programs and cultivars should be based on resistance to AB at vegetative, flowering and podding stages, since many lines resistant in the vegetative stage can be susceptible at the podding stage. Resistance to AB in chickpea cultivars has historically been overcome by new pathotypes of *A. rabiei*, hence the genotypes intended for release to farmers should be selected based on multilocation multi-season field trials. Durable resistance may only be possible if arrays of resistance genes are combined providing different mechanisms of resistance against all races in a single cultivar. ■

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Resistance to Fusarium wilt in chickpea

by Weidong CHEN[1]*, Patricia CASTRO[2] and M. Jose COBOS[3]

Abstract: Fusarium wilt of chickpea is a devastating disease caused by different races of Fusarium *oxysporum* f. sp. *ciceris* (Foc). The different races incite specific reactions in chickpea differential sets with symptoms that can be either yellowing or wilting syndrome. Due to the genetic specificity in the interaction between *Foc* races and chickpea genotypes, identifying the prevailing race(s) in a given region is crucial. Using resistant genotypes is the most economical and practical means to manage Fusarium wilt of chickpea. Genetics of resistance is known to be oligogenic and molecular markers have been identified linked to fusarium resistance genes. Pyramiding the resistance genes implementing marker-assisted selection will provide durable resistance in future varieties.
Key words: Chickpea, Fusarium wilt, *Fusarium oxysporum* f. sp. *ciceris*, races, quantitative trait loci, near-isogenic lines

Fusarium wilt of chickpea is a destructive disease and is distributed in almost all chickpea producing regions of the world (11). The disease is caused by the fungal pathogen *Fusarium oxysporum* f. sp. *ciceris* (Foc). The pathogen is soilborne and can persist in soil for many years even in the absence of host plant. The soilborne nature and longevity of the pathogen makes management of this disease difficult. The pathogen invades and multiplies in vascular bundles of chickpea roots, and its mass of spores and mycelium plugs vascular bundles, and reduces water uptake inducing wilting symptoms (Fig. 1). Beside the mechanic blockage of vascular bundles, other secondary metabolites may also be involved in causing disease symptoms such as yellowing. *Foc* has eight physiological races designated as 0, 1A, 1B/C, 2, 3, 4, 5 and 6. The races are differentiated based on their ability to incite specific reactions of a set of chickpea differentials (Fig. 2), and they cause two types of symptoms – yellowing syndrome caused by races 0, and 1B/C, and wilting syndrome caused by races 1A, 2, 3, 4, 5 and 6. Yellowing syndrome includes progressive yellowing of leaves and vascular discoloration, whereas wilting syndrome includes fast chlorosis, flaccidity and vascular discoloration without leaf yellowing. The wilting syndrome is more destructive and economically more important than the yellowing syndrome. Other forms of resistance (or susceptibility, depending on the point of view) are late wilting exemplified by extended latent period (e.g. late on-set of wilt symptom), and slow wilting showing normal onset of wilt symptoms but slow progress in wilt development. Late wilting has been described in response to both races 1 and 2, whereas slow wilting has been reported in response to races 0, 2, 3 and 5 (1, 4, 7). Because of the genetic specificity in the interaction between Foc races and chickpea genotypes, identifying the prevailing race(s) in a given region and selecting and developing chickpea cultivars with corresponding resistance genes are critical in managing Fusarium wilt of chickpea. Another complicating factor is that there are other pathogens that may also cause wilt or wilt-like symptoms. For example, *Fusarium redolens* is found causing wilt symptoms on chickpea in Morocco, Pakistan and Spain (9). Care should be taken to identify the pathogens and separate those wilt and wilt-like diseases from Fusarium wilt, particularly for deploying resistance genes in managing Fusarium wilt.

Using resistance is the most economical and practical means to manage Fusarium wilt of chickpea. Resistance genes have been identified for the Foc races, and the genetic is usually monogenic or oligogenic and recessive in nature. One gene each is known to condition resistance to races 3 and 5 (4, 5, 8). Two independent genes are known to govern resistance to race 0 and race 4. There are two different three-gene systems each conditioning resistance to races 1 and 2 (11). In the resistance to race 1, presence of any one of the three genes provides resistance in the form of late wilting, whereas a combination of any two of the three genes confers complete resistance to race 1. Likewise, in the case of race 2, complete resistance requires a combination of any two of the three genes in a recessive form, whereas late wilting results from presence of any one of the three genes. Resistance genes for race 1B/C and race 6 have not been reported yet, and resistance to slow wilting has been related to minor genes (1, 4, 11). For the known resistance genes, several of them are clustered together in the chickpea genetic map, particularly on linkage group (LG) 2 where genes (*foc-0*$_2$, *foc-1*, *foc-2*, *foc-3*, *foc-4*, *foc-5*) for resistance to six races (0, 1, 2, 3, 4 and 5) are located (10, 11). Moreover, one gene that confers resistance to race 0 (*foc-0*$_1$) and a putative QTL (Quantitative Trait Loci) related to race 5 were mapped on LG5 (4).

The selection process for Fusarium wilt through traditional pathogenicity assays is tedious, time-consuming and subject to environmental variations. Thus molecular markers closely linked to the resistance genes are highly desirable for selection in resistance breeding programs. Tremendous research progress has been made in developing and mapping molecular markers for the resistance genes (10, 11). Molecular markers closely linked to resistance genes to races 0, 1A, 2, 3, 4 and 5 have been identified and mapped onto the chickpea genetic linkage maps. Many of these markers have become available for practical use in maker-assisted selection (3, 10).

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Because of the close proximity of several resistance genes on LG2, more precise markers are needed for specific resistance genes to allow more efficient and unambiguous selection. Thus a denser genetic map is required. Also despite the knowledge of the resistance genes, currently very little is known about the mechanisms of resistance. A significant advance in this regard is the recent development of chickpea near-isogenic lines (NILs) segregating for Fusarium wilt resistance. Four pairs of NILs segregating for resistance to races 1A, 2, 3, 4 and 5 were developed (1). In addition to allowing development of higher density maps of this LG2 region, these NILs are valuable resources for identifying functional resistance genes and studying mechanisms of chickpea resistance to Fusarium wilt. Besides, large scale transcriptome analysis in chickpea were carried out during the last years (6). These studies contributed to the saturation of the genetic map and could be useful to identify valuable markers to introduce wilt resistance in chickpea breeding programs. A set of references with highly stable gene expression has been recently identified for several stress-based experiments in chickpea (including Fusarium). These genes represent useful reference standards for future gene expression and transcriptomic studies (2).

Another strategy to develop molecular markers to map genomics region where marker density is low consists of identifying single nucleotide polymorphism (SNPs). This has been hampered by the availability of a limited number of chickpea sequences deposited in the public databases. New sequencing (e.g. 454, Illumina, Solexa) and genotyping technologies will play an important role in the chickpea genomics and reduce the barrier to SNP discovery in its narrow germplasm base. These technologies will enable biotechnologists to target genes that underlie Fusarium wilt rapidly and precisely and are expected to aid in the development of molecular markers for breeding applications. Future challenges for breeding include obtaining higher levels of durable resistance through pyramiding of resistance genes. Implementation of marker assisted selection schemes will offer plant breeders a means to improve selection efficiency reducing the time and resources required to develop new cultivars. ■

Figure 1. A chickpea field ravaged by Fusarium wilt in Turkey (Photo by Mücella Tekeoglu, Turkey)

Figure 2. A growth chamber assay demonstrating specific Foc race - chickpea genotype interactions

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Exploiting host plant resistance for pest management in chickpea

by Hari C. SHARMA*, Pooran M. GAUR, Samineni SRINIVASAN and C.L. Laxmipathi GOWDA

Abstract: Nearly 60 insect species are known to feed on chickpea, of which cutworm, *Agrotis* spp., beet armyworm, *Spodoptera exigua* leaf miner, *Liriomyza cicerina*), aphid, *Aphis craccivora*, pod borer, *Helicoverpa armigera*, and bruchid, *Callosobruchus chinensis* are the major pests worldwide. Low to moderate levels of resistance have been identified in the cultivated germplasm. Wild relatives of chickpea have high levels of resistance to *H. armigera.* Efforts are also underway to utilize molecular techniques to increase the levels of resistance to pod borer. Transgenic chickpea plants with *cryIIa* gene have also been developed. Synthetic insecticides, agronomic practices, nuclear polyhedrosis virus (NPV), and natural plant products have been evaluated as components of pest management in chickpea.

Key words: chickpea, host plant resistance pest management, wild relatives, transgenic plants

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Introduction

Nearly 60 insect species are known to feed on chickpea, of which. cutworms (black cutworm - *Agrotis ipsilon* (Hfn.) and turnip moth - *Agrotis segetum* Schiff.), leaf feeding caterpillars (beet armyworm, *Spodoptera exigua* (Hub.)), leaf miners (*Liriomyza cicerina* (Rondani) and *L . congesta* (Becker)), pea leaf weevil (*Sitona lineatus* (L.)), aphids (*Aphis craccivora* Koch), pod borers (cotton bollworm - *Helicoverpa armigera* (Hub.) and native budworm - *Helicoverpa punctigera* (Wallengren)), and bruchids (Chinese bruchid - *Callosobruchus chinensis* L.) are the major pests (2). The pod borer, *H. armigera* and the aphid, *A. craccivora* are the major pests of chickpea in the Indian Subcontinent. In the Mediterranean region, the most important pest is the leaf miner, *L. cicerina. A. craccivora* is important as a vector of the chickpea stunt disease, while *C. chinensis* is the most dominant pest species in storage. In India, insect pests cause an average of 30% loss in pulses, which at times can be 100%. *H. armigera* – the single largest yield reducing factor in food legumes, causes an estimated loss of 328 million USD in chickpea. Globally, it causes an estimated loss of over 2 USD billion annually, despite over 1 USD billion worth of insecticides used to control this pest (6).

Host-plant resistance

Development of chickpea cultivars resistant or tolerant to insects has a major potential for use in integrated pest management, particularly under subsistence farming conditions in the semi-arid tropics. Resistant varieties derived through conventional plant breeding, marker assisted selection, introgression of genes from wild relatives into cultivated chickpea, or developed through genetic transformation will provide an effective weapon for pest management in chickpea, particularly against the pod borers. Screening for resistance to insects under natural conditions is a long-term process because of the variation in insect density across seasons and locations, and staggered flowering of the test material. Knowledge concerning the periods of maximum insect abundance and hot-spots is the first step to initiate work on screening and breeding for resistance to *H. armigera.* Delayed plantings of the crop and use of infester rows of a sus-ceptible cultivar of the same or of a different species can be used to increase *H. armigera* infestations under natural conditions (6). Artificial infestation with laboratory-reared insects can be used to overcome some of the difficulties encountered in screening the test material under natural infestation. Caging the test plants with larvae in the field or greenhouse is another dependable method of screening for resistance to *H. armigera* (7). Chickpea plants infested with 10 neonate or three third-instars per plant at the flowering stage can be used to screen for resistance to this pest. For valid comparison, resistant and susceptible checks of appropriate maturity should also be included, and infested at the same time as the test genotypes. Detached leaf assay can be used to evaluate a large number of lines for resistance to *H. armigera.*

Pod borer. More than 14,000 chickpea germplasm accessions have been screened for resistance to *H. armigera* at ICRISAT, India, under field conditions. Several germplasm accessions (ICC 506EB, ICC 10667, ICC 10619, ICC 4935, ICC 10243, ICCV 95992, and ICC 10817) with resistance to *H. armigera* have been identified (3, 6), and varieties such as ICCV 7, ICCV 10, and ICCL 86103 with moderate levels of resistance have been released for cultivation (6). However, most of these lines are highly susceptible to *Fusarium* wilt. Therefore, concerted efforts have been made to break the linkage by raising a large population of crosses between the lines with resistance to *H. armigera* and the lines resistant to wilt. Inheritance of resistance to damage by *H. armigera* is largely governed by additive gene action, while dominance genetic variation is predominant in governing the inheritance of antibiosis component of resistance (larval survival and larval weight) and grain yield. Further studies on mechanisms and inheritance of resistance and use of morphological, biochemical, and molecular markers will be useful for increasing the levels and diversifying the basis of resistance to *H. armigera* in chickpea (8).

Leaf miner. Varieties with larger leaflets are preferred by the leaf miner than those with small leaflets. Oxalic acid content in chickpea leaves has been reported to be correlated with the level of resistance to leafminer. ILWC 39, ILC 3800, ILC 5901, and ILC 7738 are resistant to leafminer damage (2). Seven lines (FLIP 2005-1C, FLIP 2005-2C, FLIP 2005-3C, FLIP 2005-4C, FLIP 2005-5C, FLIP 2005-6C, and FLIP 2005-7C) have good agronomic background, seed size, and plant type, and have been distributed to national programs for evaluation under local conditions.

Aphid. Varieties with low trichome density or devoid of trichomes are highly susceptible to aphid, *A. craccivora* damage. The glabrous mutant of chickpea devoid of trichomes, is highly susceptible to aphid damage (Sharma, HC, Unpublished). A number of genotypes/lines were reported to be less susceptible to aphid damage (3).

Figure 1. Chickpea pods damaged by pod bore

Bruchid. High levels of resistance have been observed in desi type chickpeas to bruchids, *Callosobruchus* spp. The chickpea genotypes CPI 29973, CPI 29975, CPI 29976, NCS 960003, K 902, CM 72, CMN 122, and BG 372 have been reported to be resistant to *C. maculatus*. Apart from the cultigens, wild relatives of several grain legumes have shown high levels of resistance to bruchids (3). Lines showing resistance to bruchids usually have small seeds with a rough seed coat. However, such grain is not acceptable to the consumers. Chickpea seed that is split for *dhal* is unattractive to ovipoisiting bruchid females, and therefore, processing the chickpea into split peas or flour immediately after crop harvest can minimize the losses due to these.

Exploitation of wild relatives of chickpea for insect resistance

Based on leaf feeding, larval survival, and larval weights, accessions belonging to *C. bijugum* (ICC 17206, IG 70002, IG 70003, IG 70006, 70012, IG 70016, and IG 70016), *C. judaicum* (IG 69980, IG 70032, and IG 70033), *C. pinnatifidum* (IG 69948), and *C. reticulatum* (IG 70020, IG 72940, IG 72948, and IG 72949, and IG 72964) (6) showed resistance to *H. armigera.* With the use of inter-specific hybridization, it would be possible to transfer resistance genes from the wild relatives to cultivated chickpea. Some of the wild relatives of chickpea may have different mechanisms than those in the cultivated types, which can be used in crop improvement to diversify the bases of resistance to this pest. Accessions of *C. reticulatum* have been used in the crossing program at ICRISAT, and interspecific derivatives evaluated under unprotected field conditions for resistance to pod borer. Many interspecific derivatives showed resistance levels better than the cultivated check, ICCV 10 (4). Wild relatives of chickpea are an important source of resistance to leaf miner, *Liriomyza ciceri* and the bruchid, *Collasobruchus chinensis.*Two accessions of *Cicer cuneatum* (ILWC 40 and ILWC 187) and 10 accessions of *C. judaicum* have been found to be highly resistant to leafminer damage.Accessions belonging to *C. bijugum, C. pinnatifidum* and*C. echinospermum* have shown resistance to the bruchid, *Collasobruchus chinensis.*

Table 1. Population dynamics of *Helicoverpa armigera* on a susceptible (ICCC 37), a moderately-resistant (ICCV 2), and a resistant (ICC 506) chickpea cultivars - A hypothetical example based on the model proposed by Knipling (1979)

Generation		No. of *Helicoverpa armigera* moths ha^{-1}		
		ICCC 37	ICCV 2	ICC 506
Parent generation	P_1	10	10	10
First generation	F_1	4250	3250	3000
Second generation	F_2	903125	528125	450000
Third generation	F_3	191914063	85820313	67500000
Population ratio in relation to the resistant check (ICC 506)		2.84	1.27	1.00

It has been assumed that each female moth lays an average of 500 eggs, and the sex ratio is 1:1. There are three generations in a cropping season. The *Helicoverpa armigera* population at the beginning of the season is assumed to be 10 female moths ha^{-1}. In each generation, the larval mortality is 15% in ICCC 37, 35% on ICCV 2, and 40% on ICC 506.

Transgenic chickpea for resistance to *Helicoverpa armigera*

Genetic transformation as a means to enhance crop resistance or tolerance to biotic constraints has shown considerable potential to achieve a more effective control of target insect pests for sustainable food production (5). The δ-endotoxin genes from the bacterium, *Bt* have been deployed in several crops for pest management. Transgenic plants expressing *cryIIa* have shown high levels of resistance to *H. armigera,* and are currently under testing in confined field trial at ICRISAT (1). Once released for commercialization, these will prove to an effective weapon for management of pod borers in chickpea.

Marker assisted selection for resistance to *Helicoverpa armigera*

Mapping complex traits such as resistance to pod borer, *H. armigera* in chickpea is only just beginning. A mapping population of 126 F_{13} RILs of ICCV 2 x JG 62, has been evaluated for resistance to *H. armigera*. The overall resistance score (1 = < 10 leaf area and/or pods damaged, and 9 = > 80% leaf area and/or pods damaged) varied from 1.7 to 6.0 in the RIL population compared to 1.7 in the resistant check, ICC 506EB, and 5.0 in the susceptible check, ICCV 96029. The results indicated that there is considerable variation in this mapping population for susceptibility to *H. armigera*. Another RIL mapping population from the cross between Vijay (susceptible) × ICC 506EB (resistant) has also been evaluated for resistance to *H. armigera*. Efforts are also underway to develop interspecific mapping populations based on the crosses between ICC 3137 (*C. arietinum*) × IG 72933 (*C. reticulatum*) and ICC 3137 × IG 72953 (*C. reticulatum*) for resistance to pod borer and to identify QTLs linked to various components of resistance to *H. armigera* (8).

Host plant resistance in IPM

Chickpea cultivars with resistance to insects can play major role in integrated pest management, particularly under subsistence farming (Table 1). Varieties such as Vijay, Vishal, ICCV 10, ICPL 88034, and ICCL 86103 with low to moderate levels of resistance to pod borers can be cultivated in India. Varieties with resistance to leaf miner and aphids have also been identified for use in West Asia. High levels of resistance have been observed in desi type chickpeas to bruchids, *Callosobruchus* spp. Early plantings generally suffer low damage due to leaf miner, and *Sitona* species in West Asia. Early sowing leads to early canopy closure, which also helps to reduce virus spread in chickpea. Therefore, early sowing and optimum planting densities can be used to minimize aphid infestation. Ploughing the fields before sowing and after crop harvest and flooding reduces the infestation and population carryover of pod borers and soil dwelling insects. Intercropping or stripped cropping of chickpea with marigold, sunflower, mustard, and coriander can minimize the extent of *H. armigera* damage to the main crop (6).

Parasitism by the egg parasitoid, *Trichogramma* spp. is very low on chickpea because of acidic glandular exudates. The ichneumonid parasitoid, *Campoletic chlorideae* Uchidaisthe most important larval parasitoid on *H. armigera*, while *Chrysoperla, Nabis, Geocoris, Orius,* and *Polistes* are the common predators attacking *Helicoverpa* on chickpea and other crops. Provision of bird perches or planting of tall crops such a sorghum and sunflower that serve as resting sites for insectivorous birds such as Myna and Drongo helps to reduce the numbers of caterpillars. A number of natural enemies have been reported on case of cutworms, *Sitona*, aphids, and other foliage feeders. However, except for aphids, natural enemies are not very effective in reducing insect damage under field conditions. HaNPV (nuclear polyhedrosis virus) and *Bacillus thuringiensis* can be used forminimizing the damage by *Helicoverpa*, and possibly other lepidopteran insects (*Spodoptera* spp.). Neem oil (1%) and neem seed kernel extract (NSKE, 10 kg/ha) are also effective against lepidopteran insects, leaf miner and the aphids. However, because of lower bioefficacy and nonpersistent nature, their use has not been widely adopted by the farmers. Cypermethrin, fenvalerate, methomyl, thiodicarb, profenophos, spinosad, and indoxacarb are effective against pod borers and other leaf feeding insects, particularly on cultivars with some degree of resistance/tolerance to pod borers.

Conclusions

Insect-resistant cultivars will form the backbone of integrated pest management in future. The development and deployment of cultivars with resistance to insects would offer the advantage of allowing some degree of selection for specificity effects, so that pests, but not the beneficial organisms are targeted. For pest management programs to be effective in future, there is a need for in-depth understanding of the population dynamics of insect pests to develop appropriate control strategies, combine resistance to insects with resistance to important diseases and cold tolerance, utilization of wild relatives to diversify the genetic basis, and thus, increase the levels of resistance to the target insect pests, identification of quantitative trait loci (QTLs) associated with resistance to insects, develop insect-resistant varieties through genetic transformation using genes with diverse modes of action, and insecticide resistance management. Development of bio-pesticides with stable formulations, and strategies for conservation of natural enemies is essential for integrated pest management. ■

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Chickpea production technology

by Kadambot H.M. SIDDIQUE[1]* and Lakshmanan KRISHNAMURTHY[2]

Abstract: Chickpea ranks third among pulses in global production with its area expanding in Turkey, Canada and Australia. This crop is broad in adaptation and is widely distributed with its production limited by several biotic and abiotic stresses. It fixes atmospheric nitrogen via a symbiotic relationship with *Rhizobium* which benefits both chickpea and its following crops. Moisture availability, temperature and photoperiod suitability determine the sowing time for the best yield. Sowing rates range from 40 to 200 kg/ha and sowing depth from 5 to 8 cm for the best yield. Application of mineral fertilizers results in marginal yield increases as chickpea is equipped for acquisition of several minerals from non-traditional soil sources. Weed management is critical favoring the search for improved control measures and genetic sources of herbicide tolerance.. Future genetic enhancements with greater resistance to key biotic, abiotic stresses and herbicides can further improve the sustainability in chickpea production.

Key words: chickpea agronomy, disease and pest management, production constraints, sowing time, sowing depth, weed control

Introduction

Chickpea (*Cicer arietinum* L.) plays an important role in agricultural systems today ranking third in the world among pulses in production, behind dry bean and field pea. Recent years have witnessed improvements in global productivity and extensions in areas sown to chickpea after 40 years of no change. Improvements in varieties, agronomy and production technology, and new export market opportunities have seen the expansion of chickpea production in countries such as Turkey, Canada and Australia. This chapter summarizes key agronomic practices of chickpea cultivation and improvements that could help improve its production.

Adaptation and production constraints

Chickpea has broad adaptation and is widely distributed It is the most drought resistant cool-season grain legume that is commonly grown rain-fed on stored soil moisture (5), but responds well to supplemental irrigation in many environments. Chickpea exhibits a considerable degree of heat tolerance, provided there is sufficient soil moisture. Chickpea production is limited by several biotic and abiotic stresses, depending on growing environments: drought, cold, transient waterlogging, soil salinity/sodicity and high boron in the subsoil are the main abiotic stresses, and a number of diseases, pests and weeds are the key biotic stresses. In recent years, improved varieties and specific agronomic practices have been developed as genetic options to manage some of the above constraints.

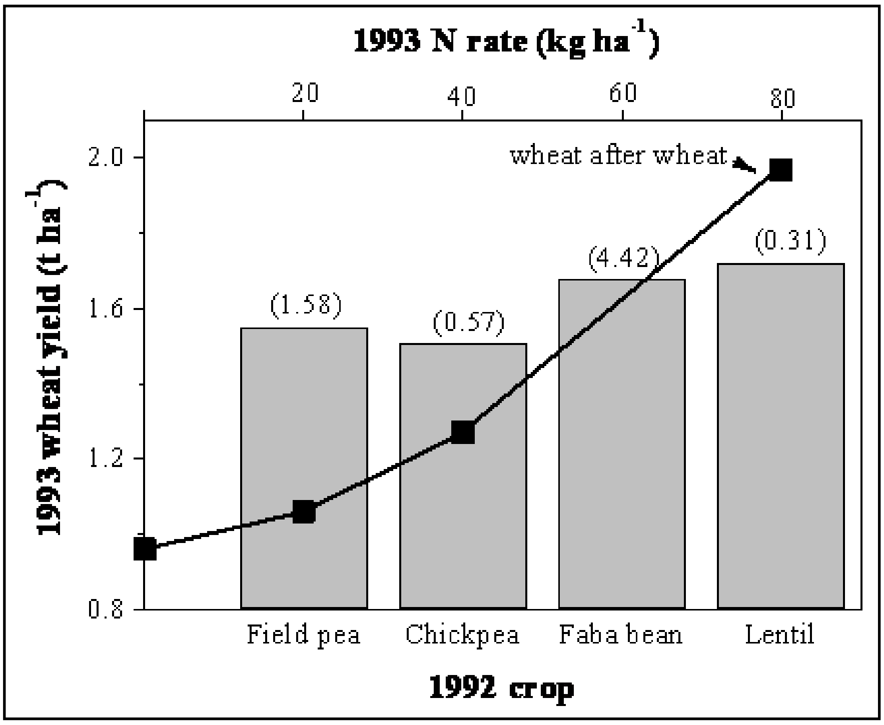

Figure 1. Grain yield of wheat grown in 1993 without nitrogen (N) fertilizer after various grain legume crops at Pingaring, Western Australia. Figures (bars) in parentheses are grain legume yields in 1992. Squares show the yield of wheat in 1993 when grown after wheat with various rates of N fertilizer (top axis). Reproduced from Loss, Brandon and Siddique (1998) with permission.

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Table 1. Time of sowing and harvest of chickpea in various regions

Country	Season	Sowing time	Harvest
Morocco	spring	mid-Feb to mid-Mar	Jun to early Jul
Tunisia	spring	mid-Mar to mid-Apr small areas of winter sowing	Jun to early Jul
Iraq	spring	mid-Feb to mid-Mar	Jun
Iran	spring	mid-Mar to mid-Apr small areas of winter sowing	Jul/Aug
Israel	winter	Dec to Feb	Jun
Jordan	spring winter	Mar Nov/Dec	Jul mid-Jun
Turkey	spring	Feb/Mar Highlands sown later to avoid Ascochyta blight	Jun
Algeria	spring	mid-Feb to end-Mar	Jun to early Jul
Egypt	winter	Nov (under irrigation)	Apr
Ethiopia	spring-autumn	Sept/Nov	Jan/Feb
Sudan	winter	Oct/Nov	Jun
Syria	spring winter	late Feb to early May Dec	Jun to early Jul
Indian subcontinent	winter	late Sept to Nov	Mar/Apr
Canada	spring	Apr/May	Jul to early Aug
USA	spring	Apr/May	Jul to early Aug
Australia southern ORIA* north eastern	 autumn autumn autumn	 May/June May May/June	 Oct/Dec Sep Oct/Dec

Chickpea agronomy

Rotational benefits. Chickpea is often grown in crop rotation, mainly with cereals, as it reduces the risk of pests and diseases associated with mono-cropping. An additional benefit is nitrogen fixation of atmospheric nitrogen via a symbiotic relationship with *Rhizobium*. For example, in southern Australia, it is estimated that chickpea crops get 37–86% of their total nitrogen through fixation leaving from 41 to 56 kg ha^{-1} residual nitrogen in the soil. Legumes prefer soil nitrogen, when available, over biologically fixed nitrogen. In many instances more soil nitrogen is removed than the crop actually fixes. In these situations, the subsequent cereal crop will still need additional nitrogen fertilizer. However, the non-nitrogen benefits of a chickpea crop in the rotation may still contribute to increased grain yield and protein contents in wheat (Fig. 1).

Soil type and land preparation. Chickpea is successfully grown on a wide range of soil types throughout the world, ranging from coarse-textured sands to fine-textured black soils. Ideally, chickpea is most suited to deep, neutral to alkaline fine-textured soils (sandy loams, clay loams and well-drained clays) with a pH of 5.5–9.0 and good water holding capacity. It is sensitive to waterlogging, sodicity/salinity, and boron toxicity.

Time of sowing. Moisture availability, temperature and photoperiod suitability are the main environmental concerns that determine the right sowing time for the best growth and yield. Flowering is advanced by temperature more than by day length (8). As a result, the optimal time of sowing varies based on the geographical region (Table 1) and in the cool season. Sowing too early or too late will reduce grain yields.

In the West Asia and North Africa region, chickpea is traditionally sown in spring and grown on stored soil moisture (except in Pakistan, Egypt and Sudan where chickpea is sown in winter). The productivity of this cropping system is constrained by terminal drought and heat stress, partly because a large amount of stored soil moisture is lost before sowing (6). Availability of drought-tolerant genotypes, shifting sowing from spring to winter with appropriate disease-resistant and winter hardy genotypes, and adopting conservation agriculture are a few approaches to increase productivity (6). Advancing the chickpea sowing date has increased yields more than 100% in some regions due to extended crop growth periods and increased water use. In the Mediterranean-type environments of southern Australia, best chickpea yields are obtained when sown after the first autumn rains and grow on winter rainfall (4). In the semi-arid Canadian prairies, chickpea is sown early in the spring growing season when soil moisture is still high (1).

In South Asia, Africa and Central America, the best crop performance is realized when sown in the cooler part of the year after the rainy season on stored soil moisture. In the north eastern part of Australia, chickpea is sown in May or June on stored soil moisture from summer rainfall.

Sowing rate, depth and method. Inadequate or patchy plant stands often limit yields in many production areas in the world, highlighting the importance of sowing rate and germination percentage. Chickpea sowing rates vary between 40 and 200 kg ha^{-1}, depending on genotype, seed size, seed type and environmental conditions (Table 2). On average, a plant density of 33 plants m^{-2} produces optimum seed yields across a range of environments although variations in row spacing are practiced for the convenience of weed control.. Generally, a close row spacing of 18–35 cm is the most productive.

The optimum sowing depth for irrigated chickpea or chickpea grown in high soil moisture conditions varies from 5 to 8 cm but can increase to 10–15 cm in moisture deficient soils without affecting emergence and yield. Deep sowing is beneficial for crops grown on stored soil moisture and to escape pre-emergence herbicide damage, frost, wind and insect attacks, and to improve survival of *Rhizobium* and nodulation. Use of two-wheel power tiller mounted seeders in developing countries is a good example of modifying technologies to suit developing country needs and to allow the required seeding depth with minimum disturbance to surface soil (6).

Table 2. Sowing rate, plant density and row spacing of chickpea in various regions

Country	Plant densities (plants m^{-2})	Sowing rate (kg ha^{-1})	Row spacing (cm)
Algeria	20–30	<100	50–300
Jordan	25–33	80–100	30–40
Morocco	25–35	80–120	40–70
Southern Australia	25–50	80–120	18–36
North eastern Australia	30–40	80–120	18–70
Syria	40–50	120–180	17.5–35
Indian subcontinent	33	40–65	30–45
Canada	45	120–150	25
USA	40	90–125	30
Turkey	35	90–120	25
Tunisia	20	70–90	70–100

Inoculation and nitrogen

Chickpea can fix atmospheric nitrogen through its nodules with the nitrogen-fixing *Rhizobium* bacteria and survive in low nitrogen soils. These bacteria, however, are species-specific and survive poorly on coarse-textured acid soils. Therefore, inoculation of seed with *Rhizobium* is needed for normal growth of chickpea in marginal soils and on fields that have not grown chickpea in the past. In nitrogen poor soils, therefore, a small starter dose of nitrogen (10 to 25 kg N ha^{-1}) can stimulate root and shoot growth during early crop development and lead to increased seed yields.

Other nutrient requirements

Grain legumes need a continuous supply of phosphorus throughout their growing season. Phosphorus deficiency is a widespread problem in South Asia and Africa and application of 60 kg P_2O_5 ha^{-1} has increased chickpea yield. However, the response to phosphorus tends to be less in chickpea than in other cool season food legumes and cereals because chickpeas are able to exploit other sources of phosphorus unavailable to most plants with the help of root exudates. Root exudates with organic acids also dissolve insoluble copper, zinc, iron and manganese, thereby avoiding deficiency. Iron deficiency, however, is common on high pH calcareous soils in South Asia and chickpeas respond positively to foliar spray of 0.5 % - 2% $FeSO_4$ solution. Zinc, sulphur and boron deficiencies have been observed in India, southern Australia and Nepal which can be corrected chemically.

Weed management

Chickpea competes poorly with weeds and therefore good weed management is critical for high yields. As post-emergence chemical weed control in chickpea is not possible, it is essential to check weeds in the previous crop and before sowing. In developing countries, weed control is mainly through manual and mechanical techniques. Chemical weed control methods are mainly used in North America, Canada and Australia through pre- and post-sowing pre-emergence applications of herbicides. The most effective and commonly used pre-sowing herbicides are Simazine and Cyanazine at rates of 1–2 l ha^{-1}, while Metribuzin and Spinnaker® at 200 ml ha^{-1} are used after sowing and before emergence. Therefore, identification of greater herbicide-tolerant varieties is a pressing need.

Water use

Chickpea is considered the most drought-tolerant cool-season grain legume able to tolerate intermittent drought due to its deep root system (Fig. 2) and its more indeterminate growth habit responds well to subsequent rainfall. However, seed yield loss due to terminal drought can be as high as 60%. Recent studies in southern Australia have shown water use efficiencies for dry matter production to reach between 11 kg ha^{-1} mm^{-1} to 18 kg ha^{-1} mm^{-1} and for grain yield between 2.6 kg ha^{-1} mm^{-1} and 7.7 kg ha^{-1} mm^{-1}. This study also showed chickpea to be less water use efficient than the high yielding faba bean and field pea (WUE_{dm}: 19 kg ha^{-1} mm^{-1} - 39 kg ha^{-1} mm^{-1}, WUE_{gr}: 6 kg ha^{-1} mm^{-1} - 16 kg ha^{-1} mm^{-1}).

Increasing early growth for rapid ground cover and reduced soil evaporation, and tolerance to cold temperatures during flowering and pod setting are essential to improve water use efficiency of chickpea in Mediterranean-type environments. Selecting genotypes with larger root systems, early flowering and pod setting, increased osmoregulation or greater translocation of biomass from stems and leaves to seed are other strategies explored by chickpea breeders for improving yield potential (7). In areas where annual rainfall is less than 400 mm or where there is a risk of drought during late vegetative and reproductive stages, chickpea responds positively to supplemental irrigation.

Harvesting, storage and marketing

Chickpea is ready to harvest when seed moisture reaches about 15%, which improves seed quality. Harvesting chickpea at physiological maturity can increase yield by 30% but needs suitable drying facilities.

Most harvesting is manual in developing countries and completely mechanized in developed countries. Pre-harvest crop desiccation at 90% crop maturity is necessary for easier mechanized harvests. Seed quality deteriorates rapidly with storage and reduced moisture and temperature increases longevity of the seed. Storing seed at less than 13% moisture, however, has adverse effects on viability. Therefore, reducing the storage temperature to 20 °C is the best option for increasing seed longevity.

Figure 2. Rooting depth of chickpea at early podding grown in a deep Vertisol at optimal spacing (30 × 10 cm) in Patancheru, India. Note the color change of roots from deep brown in the soil surface to ash white at maximum depth. Roots were traced to 135 cm soil depth.

Chickpea as a good source of carbohydrate and protein is traded for human consumption in both developing and developed countries (2). Most chickpea produced in India is consumed there, with a large production-demand gap requiring import. The main exporters of chickpea are Australia, Turkey, Canada, and Mexico with main markets in India, Pakistan, Bangladesh, Europe, USA, Middle East and the former USSR.

Future prospects

Improved chickpea varieties with greater resistance to key biotic and abiotic stresses are currently being developed to suit existing and emerging cropping systems by various national and international agricultural research organizations. Development of variety-specific agronomy packages, adoption of conservation agriculture and availability of herbicide-tolerant varieties are expected to further increase chickpea production worldwide. ■

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Chickpea – nutritional quality and role in alleviation of global malnourishment

by Manu P. GANGOLA[1], Monica BÅGA[1], Pooran M. GAUR[2] and Ravindra N. CHIBBAR[1]*

Abstract: Chickpea (*Cicer arietinum* L.) constitute a well-balanced source of carbohydrates, proteins, vitamins and minerals essential to combat malnourishment in human populations. The various seed constituents show large variations in abundance between genotypes, which allow selection of lines for both calorie-rich and calorie-reduced diets. Chickpea with a high protein content combined with high digestibility is preferred in diets where food is scarce. In diets of affluent cultures, chickpeas with good vitamin, fatty acid and mineral balance combined with low digestibility would have a preference. The major challenges in chickpea improvement are development of region-specific genotypes with reduced content of anti-nutritional constituents such as the raffinose family of oligosaccharides. This improvement would encourage a wider use of chickpea-based diets around the world.

Key words: carbohydrates, proteins, minor components, carbohydrate digestibility, malnourishment

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Introduction

Food security can be defined as a state when all the people at all times have physical, social and economic access to adequate amounts of safe and nutritious food to satisfy dietary needs and food preferences (5). However, food security is complex and has both temporal and spatial dimensions. During hunger epidemics, people do not have access to adequate amount of food to provide the necessary energy (9.2 MJ or 2,200 kCal) for normal human functions, and consequently, an increased risk of diseases caused by malnutrition emerges. However, overconsumption of food (11.3 MJ day^{-1} - 12.5 MJ day^{-1}) occurs primarily in the developed world and leads to obesity in persons with sedentary lifestyle (3). Many diseases related to diabetes and coronary health conditions are caused by bad food choices and overeating. Thus, food security, production and consumption of well-balanced diets are major challenges currently facing human well being around the world.

Globally, about 12.5% of world population can be considered undernourished with only a slightly higher incidence (14.9%) in developing countries (4). As one of the consequences of long-term consumption of foods with poor nutritional value are aberrant growth and development in humans, the need for improved diets is urgent. These diets should be nutritionally balanced and within the economic accessibility of all consumers in the world. Chickpea (*Cicer arietinum* L.) is one food ingredients that can add important nutritional value to diets. Here we will outline some of the seed components affecting nutritional value and digestibility of chickpeas and for a more detailed description of chickpea nutritional and health benefits, we refer to a recent review (6).

Chickpea is broadly classified into two types based on seed size and colour of flowers and seeds. The kabuli types produce white flowers and large cream-coloured seeds, whereas desi flowers are purple and seeds are small, dark-coloured and angular. Kabuli types are mainly produced in temperate regions, whereas desi types are grown in the warmer and dryer semi-arid tropical regions. Both kabuli and desi seeds are energy-rich with gross energy and calorific values varying from 15–18.7 MJ/kg and 334–391 kcal/100 g, respectively. The mature seeds are dominated by the large cotyledons accounting for 83% and 92% of seed weight of desi and kabuli types, respectively (7). Due to the difference in seed size, desi have a larger seed coat fraction (15%) than kabuli (6.5%). Only a small fraction of chickpea seeds is occupied by the embryo (1.5%). Chickpea is a good source of carbohydrates and protein, which are predominantly stored in the cotyledons. The embryo is rich in lipids and vitamins, whereas valuable dietary fibers and minerals are concentrated to the seed coat. The amount of each seed constituent is largely dependent on genotype, environment and their interactions; thus, large variations in seed composition occur between cultivars and production areas.

Carbohydrates

The main energy provided by chickpeas in human diet and animal feed is derived from carbohydrates, which constitute 51% - 65% of desi and 54% - 71% of kabuli seed weight. Some of the carbohydrate energy is provided by the water-soluble sugars varying from 2.2% - 10.7% in desi, and 5.5% - 10.85% in kabuli types. The oval to spherical starch granules (9-10 µm wide, 14-30 µm wide) represent the major energy source of chickpeas and comprise 30-57% of seed weight (9). Two large glucan polymers, amylose and amylopectin, combined with minute amounts of proteins and minerals make up the granules. The amylose molecules are linear α(1,4)-linked glucan polymers that are sparsely branched through α(1,6) linkages. Amylopectin polymers, in contrast, are heavily branched as a result of α(1,6) linkages positioned at every 20-30 glucose residue on the α(1,4) glucan backbone. For desi and kabuli chickpeas, the amylose concentration varies from 20-42% and 20.7% - 46.5%, respectively; thus, many chickpea genotypes have considerable higher amylose concentration than cereal starches, which are in the 25% - 28% range (2).

The seed coat consists mainly of non-starch complex polysaccharides such as cellulose, pectic polysaccharides and hemicellulose giving rigidity to cell walls. These structural polysaccharides can be loosely grouped as dietary fiber and constitutes 15% - 22 % of seed carbohydrate content in chickpea. This is a relatively high concentration of dietary fiber when compared to cereals such as wheat (12%), rice (2 - 4%) and other pulse crops such as peas (5.1%) and beans (2.7%).

In humans, carbohydrates when consumed are acted on by enzymes which degrade the complex molecules in to progressively smaller molecules and finally into glucose to be absorbed by the blood stream. The ease by which food carbohydrates are broken down and delivered into blood stream is of great importance for human health (2). For starches, the ratio of amylose to amylopectin concentration in grains and seeds affects digestibility, where the less branched amylose molecules are more resistant to degradation in the digestive tract than the heavily branched amylopectin. Based on *in vitro* enzymatic hydrolysis assays, starch can be classified as readily digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS). The RDS fraction is broken down to constituent glucose molecules within 20 minutes, whereas it takes 100 min to break down the SDS and the amylose-rich RS fraction remains undigested after 120 minutes. In the human body, RDS and SDS are completely digested within the small intestine by enzymatic digestion, whereas RS need to reach the large intestine before degradation is initiated by bacterial fermentation. Similar to RS, dietary fibers of the cell wall are largely resistant to digestion in the small intestine, but undergo fermentation in the large intestine. Insoluble dietary fiber (e.g. cellulose and hemicelluloses) is important for the overall health of the digestive system as it supports gastrointestinal movement.

Protein and amino acid composition

The protein concentration in chickpeas ranges from 16.7% - 30.6% and 12.6% - 29% for desi and kabuli types, respectively, and are 2-3-fold higher than in cereal grains (8% - 16%). Chickpea proteins have a relatively high content of the essential amino acid lysine (4.9 g $100g^{-1}$ - 6.9 g $100g^{-1}$) as compared to cereal grains (2.8 g $100g^{-1}$). However, sulphur-containing amino acids methionine and cysteine are in lower concentration in chickpea as compared to cereals.. Protein digestibility, very important for human nutrition, is affected by various factors such as inhibitors of enzymatic breakdown of proteins. The enzyme inhibitors can be inactivated during processing or cooking but chickpea type and genotype also affect protein digestibility and in chickpea it varies from 34% - 79.4%.

Fatty acids

The fat concentration in chickpeas varies from 2.9-7.4% in desi and 3.4-8.8% for kabuli types and can be considered high when compared to other pulse crops. Polyunsaturated, monounsaturated and saturated fatty acids share about 66, 19 and 15% of the total fat content in chickpea seeds. The polyunsaturated linoleic acid is the most prevalent fatty acid in chickpea seed (46-62/16-56% in desi/kabuli types) followed by oleic acid (18-23/19-32%) and palmitic acid (9.1/9.4%). Linoleic acid is considered as hypocholesterolemic agent; thus it reduces the risk of atherosclerosis and coronary heart disease.

Minerals

On average, 100 g of raw chickpea seeds contains 4.6 – 6.7, 3.7 – 7.4, 93 – 197, 125 – 159, 732 – 1126, 0.7 – 1.1 mg of iron (Fe,) zinc (Zn), calcium (Ca), magnesium (Mg), potassium (K) and copper (Cu), respectively. A 100g serving of chickpea can meet significant requirement of daily allowances of Fe (75/33% in males/females), Zn (48/66%), Ca (13/13%), Mg (34/45%), K (21/21%) Cu (90/90%) and P (48/48%) (8). However, the mineral concentration can show large variations depending on genotype and growth conditions, and in particular soil environment. For example, chickpea grown in North America have a high selenium concentration (15.3-56.3 µg 100 g^{-1}) that is adequate to fulfill 61% of the recommended daily allowance in humans.

Vitamins and other bioactive compounds

Chickpea has a good complement of vitamins; the predominant being folic acid (~300 mg 100 g^{-1}) and tocopherol (~13 mg 100 g^{-1}). Chickpea seeds also contain antioxidants/pigments such as carotenoids, which give bright colors to plant tissues. The important carotenoids in chickpea are β-carotene, lutein, zeaxanthin, beta-cryptoxanthin, lycopene and alpha-carotene. With the exception of lycopene, wild accessions of chickpea contain higher concentrations of carotenoids than cultivated varieties. In the plants, the most prevalent carotenoid is β-carotene, which can easily be converted in to vitamin A. Chickpea seeds are rich in β-carotene and on a dry weight basis contain more than Golden rice or red-colored wheats (6).

Anti-nutritional compounds

The acceptability of chickpea in daily diets is often impeded by the presence of certain anti-nutritional factors in the seeds. Raffinose family oligosaccharides (RFO), phytic acid, saponins and enzyme inhibitors are generally included in this group of undesirable seed components. RFO play an important role for seed desiccation, germination, photosynthate translocation and stress tolerance in plants and are particularly prevalent in pulse seeds. For chickpea, the RFO content varies from 2 to 8%, and if consumed in large quantities, causes flatulence in humans. The stomach discomfort is a result of RFO fermentation in large intestine releasing carbon dioxide, hydrogen and in smaller quantities, methane gases. Phytic acid constitutes about 0.4 to 1.1 % of chickpeas and has an important cellular function for plant and seed development. The component has a negative effect on nutrition by chelating mineral nutrients, thereby lowering their bioavailability. Thus, about 60% - 90 % of all phosphorous present in legume seeds is unavailable for uptake and high presence of phytic acid in the western diet is thought to exacerbate iron, calcium and zinc malnutrition in developing countries. The saponins (56 g kg^{-1}) and inhibitors of trypsin (1 mg g^{-1} - 16 mg g^{-1}), chymotrypsin (2 mg g^{-1} - 13 mg g^{-1}) and α-amylase (5 unit g^{-1} - 11 unit g^{-1}) have been reported to reduce the bioavailability of other nutrients in chickpea seeds.

Use of chickpeas to combat nutritional deficiencies in diets

One step towards combating malnourishment in both developed and undeveloped countries could be an increased utilization of pulses such as chickpeas in the daily diet. As chickpeas have a large variation in carbohydrate and protein composition and functionality, the strategy would involve selection of genotypes with suitable digestion profile and nutrition value for each end-user group.

In developed countries with excess food supply, the focus is on optimizing vitamin, mineral and fatty acid content and simultaneously reducing digestibility and calorie uptake. For this purpose, chickpeas with a high amylose concentration and producing high content of RS or SDS upon cooking would be preferred. As RS behaves like dietary fiber in the digestive tract, it will release less calories than normal starch and the high-amylose diet would also have beneficial effects on the health of the digestive tract. Upon fermentation of RS and other dietary fibers, growth of remedial microflora, *viz.* lactic acid bacteria and bifidobacterium, is stimulated and production of short chain fatty acids like propionic and butyric acids is increased. Propionates can inhibit cholesterol and fatty acid biosynthesis and thereby lower the risk of coronary heart diseases, whereas butyrate can prevent colorectal cancer by reducing cell proliferation and inducing apoptosis.

In diets of food deprived regions, high-protein food products rich in essential amino acids and high energy content are needed to meet the daily nutritional requirements. Preferably, the pulse diet would be consumed with cereals to combine the high protein and lysine content with sulphur-rich amino acids of cereals. Chickpea genotypes with a starch structure promoting RDS, e.g. low amylose, would be preferred for complete digestion and thus full utilization of the calorific value of the food product (1).

In conclusion, chickpea is a very versatile pulse crop with large seed size, rich in dietary fiber, protein and a starch component with diversity in concentration and digestibility. Chickpea has the potential to be an integral part of human diet around the world by full utilization of its diversity. For developed world, it has potential to reduce obesity and related metabolic disorders as it can be used in calorie-reduced foods. However, for its full acceptance in developed countries, the concentration of antinutritional factors needs to be reduced to overcome stomach disorders associated with consumption of chickpea based foods. ■

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Chickpea crop in Argentina: An opportunity to diversify the national production

by Julia CARRERAS[1]*, María José ALLENDE[1], Alberto SALUZZO[3], Susana AVALOS[1], Vilma MAZZUFERI[1], Norma ATECA[1], Susana GARCIA MEDINA[2] and Claudio PANADERO PASTRANA[2]

Abstract: In Argentina the chickpea is cultivated from 20 ° to 33 ° S lat, from the north to the Midwest of the country. Planting starts from April to July, depending on the variety. The cultivated area has increased in recent years, reaching 40,000 hectares. It is grown kabuli types with large seed sizes (7-10 mm) which are sent almost entirely for export to neighboring countries. The chickpea breeding program developed in Argentina has been focused on the knowledge of this crop and the development of new cultivars with different attributes, including searching for new technology at various stages of production and the interaction with the productive sector. The future perspective involves the development of new cultivars and to meet different chickpea productive regions in Argentina, in order to cover a wider chickpea demand for export. In addition, to address plant health through the work of breeding and plant pathology programs.

Key words: chickpea cultivars, direct seeding, weed controls.

Current status of chickpea production

In Argentina chickpea area has increased in recent years, reaching 40,000 hectares in 2009-10 (7). Kabuli type chickpea is grown with large seed sizes (7-10 mm) and sent almost entirely for export to neighboring countries. However the production and export are negligible in the global market.

Worldwide chickpea average yield has improved in recent decades increasing from 504 kg ha^{-1} in 1980 to 760 kg ha^{-1} in 2008, but still remains low despite its agronomic importance. In addition to biotic and abiotic stresses to which it is subjected the crop, it must take into account that in many regions the growing season is too short not reaching a high developing biomass. In the case of Argentina the most important stress factor is the low temperature at the vegetative and flowering initiation stages.

Chickpea producers used to find difficult to maintain cropping areas due to low prices in the market, resulting in a drastic decrease in the years 80-90 (Fig. 1). However, trials with specific seed inoculants application, planting date, and crop management practices (density, direct seeding, herbicides, mechanical harvesting, etc.) generated relevant information that allowed analyzing skills of cvs. Chañaritos S-156 and Norteño against local populations. As a result, yields of Chañaritos S-156 and Norteño were raised above 2000 kg ha^{-1}. In 2005 it was started the exports to neighboring countries and later to different destinations which were nearly 50 countries in 2011 (4, 6).

Breeding programs

Chickpea is cropped from 20° to 33° S lat, in semi-arid or arid areas, from the north to the Midwest of the country. Sowing starts from April to July, depending on the variety. Most important constraints to production are: low yields of genotypes with high quality in seed size, intolerance to major abiotic stresses such as cold, susceptibility to biotic stresses such us fusarium wilt and lack of adoption of specific technology for growing.

The chickpea breeding program developed in Argentina has been focused in the knowledge of this crop and the development of new cultivars with different attributes, including searching for new technologies at various stages of production and interaction with the productive sector. This program began in 1972, at the Faculty of Agricultural Sciences, National University of Cordoba. Different aspects on local materials were studied, including the response of different seed size in relation to the production. The crop in the arid region (west of Córdoba, Catamarca and Salta) is performed with surface irrigation, favoring the manifestation of fusarium wilt. Causal agents of infection mechanisms were determined.

Each of the aforementioned contributions provided the criteria for starting selection with ´Sauco´ population, used by producers. In this variety selection was made from plants, breeds and evaluations in comparative testing of performance in Cordoba, Salta and Tucuman. The first cv. Chañaritos chickpea S-156 (Argentina No. 374, USDA N° 236, PI 636327) was obtained from these studies. Since his release to date, this cultivar is used for sowing of chickpea in different provinces of Argentina, showing a wide adaptation, good yield and grain quality .

Moreover crosses were made between genotypes which were locally adapted and uppermost commercial quality, to make rising of segregating material and selection of new lines, with assessments of performance. By these means it was obtained cv. ´Norteño´ (Argentina N° 1193). This cultivar is characterized by high yield potential, tolerance to cold in a vegetative state and commercial seed size larger than Chañaritos S-156. The cultivar ´Norteño´ resulted from the joint efforts of experts from the National Universities of Salta, Cordoba and the National Institute of Agricultural Technology (3) (Fig. 2).

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In 2012 two new cultivars were achieved: ´Kiara´ and ´Philip´ UNC-FCA. These genotypes are kabuli type with high performance, larger than Chañaritos S-156 and Norteño in seed size, and suitable for direct mechanical harvesting (9). Nevertheless, chickpea genetic basis in Argentina is very narrow. For this reason, we started to evaluate genotypes from crosses between kabuli × desi types including genetic variability for crop architecture, disease resistance and yield stability provided by the Univ. of Cordoba (Spain) (4, 5). Another investigation has been the study of major insect species associated with the crop. The most important groups of insects belong to Lepidoptera, Hemiptera, Diptera and Thysanoptera (2, 7).

As mentioned before, Kabuli type chickpeas are the preferred materials for producers because of excellent commercial size and grain quality. For this purpose an individual selection began into a local population and the lines are evaluated in Cordoba and Salta, with excellent prospects (1). Studies related with quality components (proteins, fatty acids, carbohydrates and minerals) are underway of a set of genotypes.

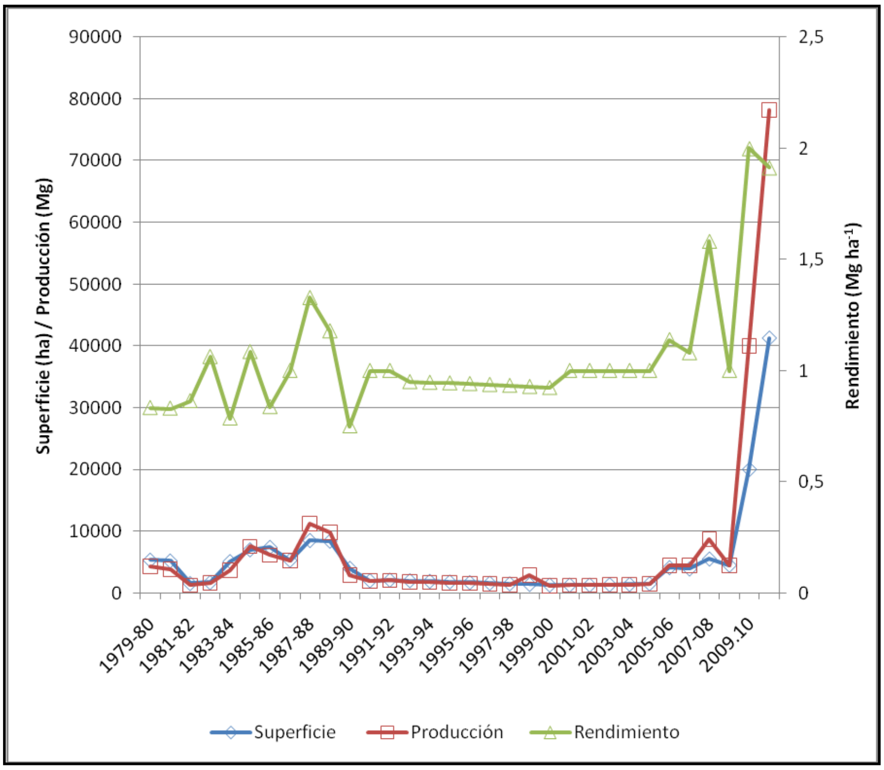

Figure 1. Trends in area, production and yield of chickpea in Argentina

Future prospects

In the year 2011 the first crop with symptoms of *Ascochyta rabiei* was detected (9), an important worldwide disease that had not yet been recorded in Argentina. The future perspective is to address this disease through breeding and plant pathology studies. In this sense, it is necessary to determine the aggressiveness of the pathogen, resistant materials and introduction of new materials to tackle this serious problem. Another perspective involves new cultivars, to meet different chickpea production regions of Argentina, in order to cover a wider chickpea demand for export. It is needed to consolidate and restate crop management practices, to have a highly qualified Argentinean chickpea that can be identified by that attribute. ■

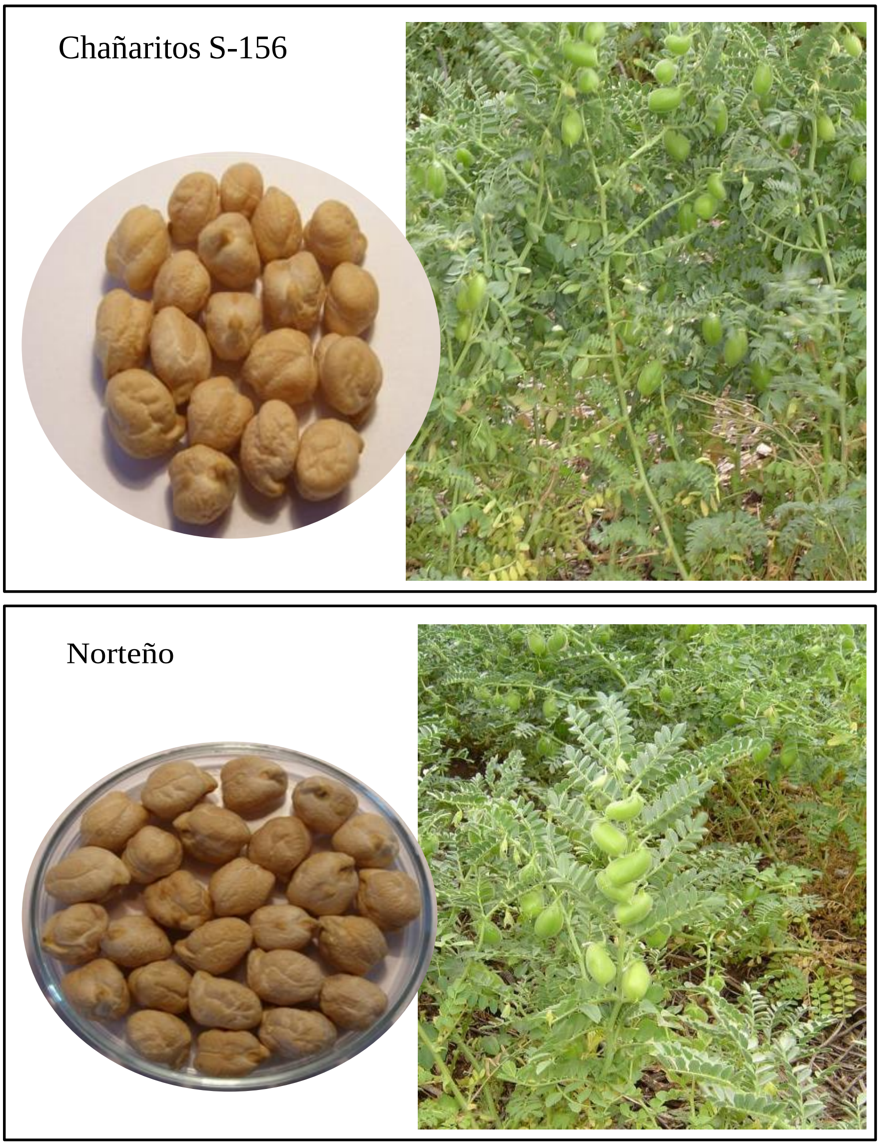

Figure 2. Comparisons of seeds and crops of Chañaritos S-156 (above) and Norteño (below)

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Chickpea: A crop of soon recovery in Chile

by Cecilia BAGINSKY G.

Abstract: Currently in Chile there are 1,334 ha of chickpea distributed in the central region mostly cultivated by small growers using low technology. Chile´s national average yield does not exceed 1 t ha^{-1}, which has led to low profitability and it has required to import grain to feed the 0.3 kg per capita per year of domestic consumption. In order to improve this crop, new genotypes with higher seed size have been developed to maximize export prices. Winter crop has been sown in ridges for greater water efficiency use and lower incidence of root diseases such as *Fusarium*. The technological level of the crop has been improved, especially regarding the harvest, the input use and diversification of exports through the introduction of new genotypes.

Key words: large caliber, Alfa-INIA, ridge

Current status of chickpea production

Thirty years ago Chile was one of major Latin America´s chickpea exporters, with a production area that exceeded 20,000 ha (Fig. 1). This situation changed dramatically since 2011 season, where only 1,334 ha were produced averaging around 1,700 t. Since then, Chile became an importer of chickpea (30 to 55% of national needs; Fig. 2) in order to cover Chilean consumption that is 0.3 kg per capita/ year. The reasons for this change are due to: i)economic disincentives due to low prices and poor grain quality (less than 9 mm caliber) that can´t be exported ii) low yields obtained by farmers with a limited technology integration, primarily related to mechanization and agricultural aspects such us weed control, fertilization and seed quality. These have meant that the average yield of the last 10 years has been 0.94 t ha^{-1} (3).

The production area is concentrated in the central Chile regions, known for its Mediterranean climate. The crop is established under rain fed conditions between August and November. Only a small part of the surface is irrigated, but it is done with low-tech. Most of the soil where is cultivated has clay or clay loam textures in rolling hills, marine terraces and/or flat areas. Major biotic stresses affecting the crop are root diseases such as *Fusarium solani* and *Rhizoctonia solani*.

Key constraints for chickpea production in Chile

One of the main limitations of the crop has been the low seed size, which frustrate any exporting possibility. Besides, Chile has a Mediterranean climate, characterized by slight to null rainfall during spring and summer months. Therefore the crop grows only with residual moisture left during winter rains, which normally turns into water deficiencies during the seed growth phase (7). In order to solve this problem, chickpea sowings have been moved towards soils that retain more moisture, such us clay loam or lake origin clay (rice soils). Nevertheless, these soils are difficult to manage in terms of preparing the seed bed (6), leading to low plant densities and higher weed incidence. In addition, in Chile this crop is cultivated by small growers, with low technology, and even in some places, using self obtained seeds, manual sowings and with little or no fertilizer application. Seed inoculation with nitrogen fixing bacteria is not common either, being rare to find plants with effective nodulation. Weed control is commonly performed mechanically, and the few herbicides that are applied are not always efficient due to low humidity or poor soil preparation (5).

Another limitation of the crop in Chile has been the presence of some pests (2) and root diseases, especially *Fusarium solani*, which occurs mainly in irrigated areas, with clay soils that retain too much moisture (1).

It should be noted further that another cause of low development of this crop has been the lack of government policies that encourage its sowing, research, especially related to plant breeding and sustainable resources management. In addition there is a lack of official organizations involved in promoting their use, qualities and advantages.

Main objectives of breeding programs

Among the breeding objectives are:

- Large grain materials that maintain or exceed the agronomic characteristics of the currently grown varieties in the country;
- Radical disease-resistant genotypes, especially for *Fusarium* which is the main disease in Chile;
- Genotypes with small plants and with few branches, thereby preventing lodging. This objective attempts to move to mechanical harvesting, due to the lack and high cost of labor, which has been on a steady increase in Chile.

Outstanding achievements

The Chilean Agricultural Research Institute (INIA) has conducting a breeding program for this species in Chile. National varieties have been developed looking for greater caliber. Among the produced varieties are 'Alfa-INIA' and 'Aurora-INIA' (4), where the former has larger grains (100 grains weight fluctuates between 56 g and 68 g) and its yields have exceeded 3 t ha^{-1} (7).

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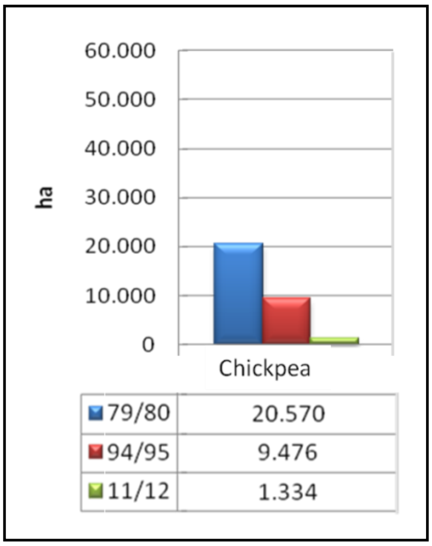

Figure 1. Chickpea harvesting area evolution in Chile (3)

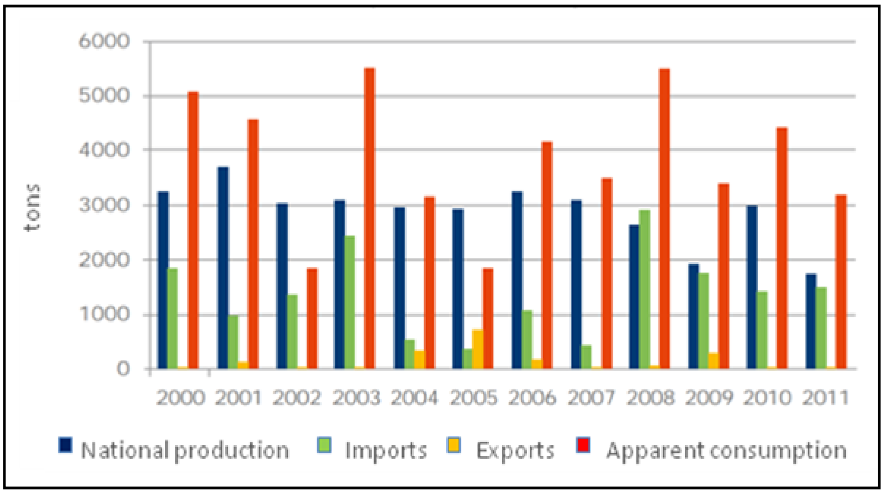

Figure 2. Status of chickpea production and trade in Chile (3)

One of the most outstanding achievements in management of this crop has been the establishment in winter crops on ridges, thus preventing moisture excess in the soil, which has meant a better plant establishment and larger caliber grain production. Associated with this, and no less important, it is that these same soils other crop species (grasses such as wheat and oats) have been evaluated, in order to achieve rotation system and avoid a higher incidence of root diseases such as *Fusarium* (6).

Future prospects

- The Chilean Office of Agricultural Studies and Policies (ODEPA), has initiated a series of studies to identify the main problems associated with this crop in different regions of the country, in order to execute an action plan or program that allows the recovery of the crop, according to growers requirements and specific situation from particular areas, involving public and private entities. In addition to that, consumption should be encouraged through nutrition campaigns.

- The economic feasibility evaluation of introduction of new genotypes to diversify the country's export demand must be done, in order to achieve new markets. In addition, breeding programs should focus their research in finding genotypes with shorter development cycles (80-90 days) to achieve greater water use efficiency. It should also aim to find radicals disease-resistant genotypes such as *Fusarium*, which would allow for the cultivation during winter, thereby increasing its efficiency.

- From the point of view of agricultural management, is expected to achieve most of the crop under ridges systems and, depending on the economic incentives that the crop achieve, the crop can be cultivated in other irrigated soils where will participate in crop rotation with more profitable crops. Research for more efficient nitrogen fixing native bacteria must be done, to lower production costs.

- The crop is intended to be collected by mechanical harvest through the generation of new genotypes suitable for. Besides the crop should have greater technological development, especially in regard to weed management, using appropriate products and machinery and applying in the appropriate opportunity. A similar situation should be done with irrigation, optimizing efficiency through modern irrigation systems. There should be different seed companies that ensure the maintenance of varietal purity and seed quality (health and physical), allowing more uniform crops since establishment and trough its development, thereby optimizing the harvest. ■

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An overview of chickpea breeding programs in Australia

by Kristy HOBSON[1]*, Ted KNIGHTS[1], Eric ARMSTRONG[1], Michael MATERNE[2], Larn MCMURRAY[3], Col DOUGLAS[4] and Ian PRITCHARD[5]

Abstract: Australian chickpea production has expanded from 7,000 ha in 1984 to peak at 560,000 ha in 2012. Although biotic and abiotic factors have at times hampered expansion, yield, quality and profitability have steadily improved over this period due to the development of disease resistant varieties in association with integrated agronomic and disease management packages. Crop management practices have been developed by a strong grower support network of agronomists, pathologists and industry representatives. The breeding program is nationally focused and coordinated through Pulse Breeding Australia (PBA). Outcomes are market driven with an emphasis on quality to ensure end user demands are met.

Keywords: chickpea varieties, pathology, disease, management packages

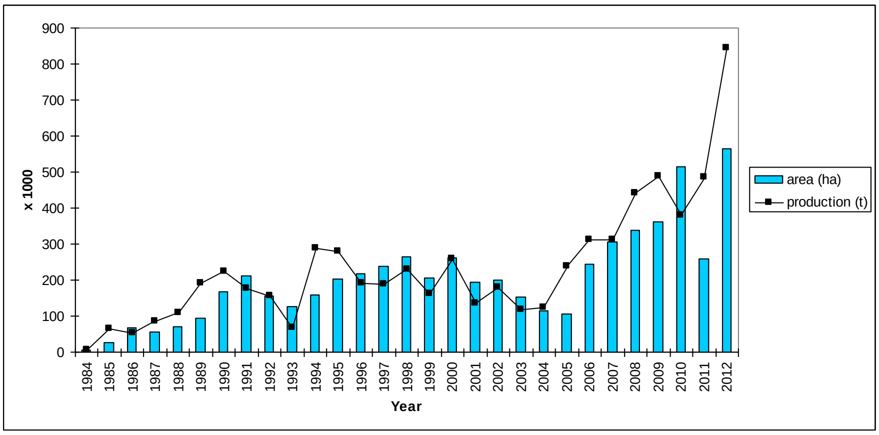

Figure 1. Trends in chickpea area (ha) and production in Australia from 1984 to 2012 (Source: Pulse Australia and ABARE. 2012 is a production estimate from Pulse Australia)

Current status of chickpea production

The area sown to chickpeas in Australia peaked in 2012 when an estimated 560,000 ha were planted (Fig. 1), the majority located in New South Wales and Queensland (462,000 ha). Historically the area and production of chickpea has been variable with an average yield around 1 t ha^{-1} but may range from 0.3 to 1.5 t/ha mainly dependant on seasonal conditions.

Desi chickpea is the dominant type grown accounting for approximately 85% of the total crop. It predominates in the northern portion of Australia's winter cropping belt in a temperate to sub-tropical environment. Kabuli production predominates in the south under a temperate to Mediterranean type environment. Across these areas large contrasts exist in rainfall, temperature, day length, soil type and a range of biotic and abiotic constraints (4).

Of the 72,000 ha of kabuli type sown in 2012, around 80 % (59,000 ha) were located in southern Australia. Small areas of desi production make up the remaining area through southern and Western Australia (Fig. 2).

The majority of Australia's chickpea production is dryland with very small areas grown on irrigation. Chickpea is a winter crop, normally sown into standing cereal stubble. In the northern Australia it can also be double cropped following a summer crop such as sorghum. Northern farming systems rely on exploitation of stored soil moisture. Wide row spacing (25 - 100 cm) is used and if topsoil moisture is not present at the desired planting time, seed may be 'moisture-seeked' by placing the seed 10 - 18 cm below the soil surface depending on moisture depth (Fig. 3). The area sown to chickpea has been increasing rapidly in Australia since the mid 2000's. This is due to a combination of improved varieties with increased disease resistance and associated management, along with an over-riding need for Australian growers to source cheaper more reliable forms of nitrogen and to introduce a break crop in cereal rotations. In more recent years, chickpeas have had a relative price advantage over cereals and this has provided a financial incentive for growers to include or expand their chickpea area. This is particularly the case in northern Australia where there are few alternative winter crop options.

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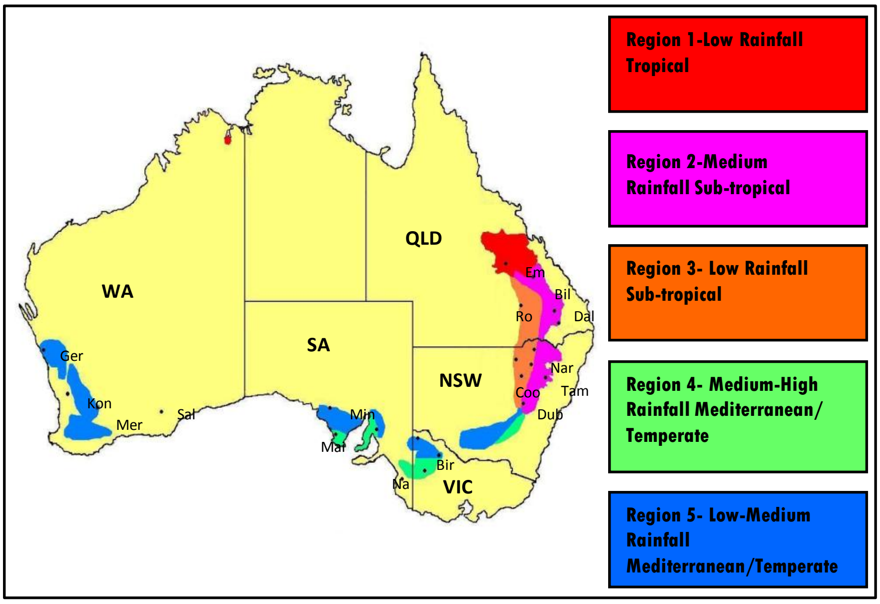

Figure 2. Chickpea growing areas in Australia with five eco-geographical regions

Australia's chickpea crop is exported to the Indian subcontinent and Middle East. Australian desi chickpea has a reputation of being a premium product in the Indian subcontinent market, but seasonal conditions, particularly in the lead up to harvest can result in variable grain quality.

Key constraints to chickpea production

Whilst weeds, insects (*Helicoverpa* spp.), abiotic constraints (drought, soil salinity, waterlogging, low temperatures during flowering/podding and frost) can all impact on chickpea production, the most significant issues are caused by disease. Phytophthora root rot (PRR) (*Phytophthora medicaginis*) was first detected in a commercial chickpea crop in 1979 and has consistently been a major production constraint in the main chickpea growing region of southern Queensland and northern New South Wales. With no practical chemical control options, paddock selection and host resistance are the only management options available to growers. The first variety to offer improvements in PRRR resistance was Barwon (1991), followed, more significantly, by Jimbour (2000). In 2005, the most resistant cultivar, Yorker, however yield losses of up to 50% could still be encountered under high disease pressure.

Ascochyta blight (AB) (*Ascochyta rabiei*) had a significant impact on national chickpea area in late 1990s. All Australian varieties at that time were highly susceptible and production in the most vulnerable region (southern Australia) became uneconomical and crop area fell dramatically (2). Following this, a major research effort was directed towards developing disease management packages and re-aligning the breeding program towards developing more resistant varieties. Both of these efforts were highly successful and expanded area in northern Australia and re-established significant area in southern Australia. More recently, the sub-tropical chickpea growing region of Central Queensland became threatened by ascochyta blight. As a result all chickpea growing regions in Australia now require varieties with high levels of ascochyta resistance.

Botrytis grey mould (BGM) (*Botrytis cinerea*) has been an infrequent but widespread disease and in some seasons has resulted in significant yield losses. Standard management practices now include a fungicide seed dressing to improve seedling establishment and control seedling rot from both BGM and AB. However, the occurrence of BGM during flower and pod set causes the greatest yield loss in Australia. This was particularly evident during the excessively wet winter and spring of 1998 and 2010, when northern crops accumulated high biomass levels and became susceptible to BGM resulting in severe crop losses.

Virus diseases can cause extensive crop losses in both northern and southern Australia. Certain management practices can reduce losses, but under very high aphid pressure large crop losses can result. Chickpea is susceptible to root-lesion nematode species (*Pratylenchus thornei* and *P. neglectus*) and yield reductions can occur. Furthermore, nematode numbers increase during chickpea production and has implications on producing following crops.

Weeds and herbicide damage from weed management are consistent production constraints. Control of broadleaf weeds has mainly relied on post-sowing, pre-emergent herbicides such as simazine and isoxaflutole. Of the abiotic stresses drought, soil salinity and low temperatures during the reproductive phase have the largest impact on production. Drought escape through early phenology is a critical strategy for chickpea in Australia and minimizing any delays in podset through improvements in chilling tolerance is a key component of this strategy (1).

Major aims of breeding programs

The national chickpea breeding program is a part of Pulse Breeding Australia (PBA) and breeds for all the major chickpea growing areas in Australia. The overall aim of the program is to produce varieties with yield reliability and stability whilst maintaining high seed quality. The program breeds both desi and kabuli type, with the major emphasis on desi type. The program maintains three desi germplasm pools to meet the three main regions of adaptation: sub-tropical, northern temperate and southern/western Mediterranean. The main objectives are: resistance to disease (AB, PRR, RLN); appropriate phenology (allied with chilling tolerance); salt tolerance; improved harvestability; and improved seed quality. The national breeding program is funded by the Grains Research and Development Corporation (GRDC) and mainland government state agencies. A regionally focused breeding program was initiated in 2005 for Western Australia (WA). The partnership involved a number of WA based entities and ICRISAT. An integration process is underway to further evaluate this germplasm in the PBA chickpea program.

Breeding achievements

The national breeding program has relied significantly on introduced germplasm. Many of the traits that are now well established in the program (e.g. plant type suited to mechanical harvesting, Phytophthora and Ascochyta resistance) have been introgressed from international germplasm. Although the most recently released desi varieties are derived from local hybridization programs (PBA HatTrick, PBA Slasher, PBA Boundary, PBA Pistol, PBA Striker, Ambar and Neelam), the most widely grown kabuli variety, Genesis™090 is a direct introduction (FLIP94-090C) from the International Centre for Agriculture in the Dry Areas (ICARDA). The first PBA kabuli release is expected next year and will provide a medium seed variety with improved adaptation and yield in short season environments.

In northern production regions, the desi variety PBA HatTrick dominates production (approximately 70% of the area) following its first commercial season in 2010. This variety offers a good combination of resistance to Phytophthora and Ascochyta, with seed quality equivalent to the well known Australian variety Jimbour. The rapid adoption of this variety was due to growers' desire for greater disease resistance and strong extension of a successful variety management package. The next proposed desi release for this region provides a greater level of Ascochyta and Phytophthora resistance, as well as an incremental improvement in yield.

Improvements in phenology (early flowering and early maturing), plant type, salt tolerance and yield are targeted for all regions in the next phase of desi and kabuli varieties developed by PBA.

There has been a concerted effort to improve seed quality of Australian chickpea varieties. As a result, seed size of current desi chickpea varieties have doubled in size compared to the foundation variety Tyson and improvements have been made in the milling efficiency (6).

Whilst current varieties offer moderate resistance to PRR, significantly improved Phytophthora resistance was detected in *C. echinospermum* (3), and this resistance has been successfully introgressed into adapted backgrounds using backcrossing. It is envisaged that a variety offering this level of resistance will be available in the next 7 years. A similar approach has been used for improvements of resistance to RLN with high levels identified in both *C. reticulatum* and *C. echinospermum* (5).

Figure 3. Chickpea crop in northern New South Wales, Australia, sown into standing cereal stubble on wide row spacings

Each variety released is supported by an integrated variety brochure which provides agronomic, disease and variety performance information. These brochures are produced with input from breeders, agronomists, pathologists, chemists and the industry body Pulse Australia. A commercial 'pipeline' for releasing PBA chickpea varieties was established with the national seed business Seednet.

Future prospects

The Australian chickpea industry is expected to continue to expand following a strong demand for chickpea in international markets, the need for a break crop in a cereal based rotation, and the release of improved chickpea varieties. The number of chickpea germplasm enhancement / pre-breeding projects being conducted in Australia has increased recently. These include research into Ascochyta, Phytophthora, Botrytis grey mould, Root-lesion nematodes, salinity, heat, drought, quality, herbicides, genomics and marker technology. All of the research programs have strong linkages to the breeding program ensuring that the outputs have a pathway for delivery to Australian chickpea growers. ■

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An overview of chickpea breeding program in Canada

by Bunyamin TAR'AN

Abstract: The chickpea breeding program at the Crop Development Centre (CDC), University of Saskatchewan is directed to make chickpea a less risky and easy to grow crop while maintains its high economic value in tandem with the general objectives in breeding to widen the genetic base and enhance the knowledge base of the genetics of the important traits. Modern technology and effective collaborations at regional, national and international levels are being put together to help achieving these objectives. Many important traits such as disease resistance, phenology and seed quality are complex and some are highly affected by the environments making breeding an incremental process.

Key words: breeding, kabuli, desi, ascochyta blight, seed quality, variety

Introduction

Chickpea (*Cicer arietinum* L.) is among the newest pulse crops introduced to western Canada but has contributed a significant role in western Canada's agriculture industry. The main type of chickpea grown in Canada is the kabuli type and the majority of the production occurs in the Province of Saskatchewan. In this province, chickpea is best adapted to the Brown and Dark Brown Soil Zones. Total acreage devoted to chickpea production in this province has increased from 2,400 ha in 1996 to around 100,000 ha in 2012. Production area peaked at over 400,000 ha in 2001, but has subsequently declined in the face of world price fluctuations and the high production risk caused by plant disease, mainly ascochyta blight and chickpea's long growing season requirement.

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The chickpea breeding program at the Crop Development Centre (CDC), University of Saskatchewan is the only breeding program that develops chickpea varieties for Canada. The breeding program has been directed to make chickpea a less risky and easy to grow crop while maintains its high economic value in tandem with the general objectives in breeding to widen the genetic base and enhance the knowledge base of the genetics of the important traits. Modern technology and effective collaborations at various levels are being put together to help achieving these objectives. It is important to note that many of the important traits such as disease resistance, phenology and seed quality are complex and are controlled by a few to several genes and some are highly affected by the environments making breeding an incremental process.

Production constraints and research progress

The major production constraints of chickpea production in Canada include vulnerability to ascochyta blight caused by the fungus *Ascochyta rabiei* Pass. Lab., late maturity and secondary growth, and weed management. Chickpea is well known to have inherently indeterminate growth habit. The plants will initiate secondary growth and/or will continue to flower when growing conditions remain favourable. Thus, some conditions such as moisture and/or nitrogen stress are required to encourage seed set and to hasten maturity. To overcome these constraints, the breeding program at the University of Saskatchewan is carried out to develop early maturing varieties with high yield potential, resistance to ascochyta blight, resistance to abiotic stress (cold tolerance); growth characteristics suitable for mechanized harvest and acceptable seed quality. In addition, research on development of appropriate agronomic practices, weed management and physiology are being carried out to support the breeding work.

The breeding program uses a breeding approach known as the F_2-derived family method. This procedure involves selecting desirable single plants in the F_2 generation, then advancing these as families into subsequent generations. The F_2 plants are space-planted to maximize seed production per plant. These populations are exposed to ascochyta blight that allow for selection of resistant plants. Seeds produced from selected F_2 single plants are evaluated visually. Selected F_2 plants were then planted as F_3 microplots. These microplots are combine harvested based on desirable agronomic characters including ascochyta blight disease resistance and early maturity. The selected F_4 families and the subsequent generations (F_5 to F_8) are tested for yield, seed quality and other traits, in replicated multi-location trials across the provinces of Saskatchewan and Alberta.

To date, 17 kabuli and desi varieties have been released in Canada. In addition, few varieties of specific market classes such as green and black desi and green cotyledon kabuli have been released. Steady gains in yield potential have been achieved together with the improvement in resistance to ascochyta blight over the past decade. Recently released varieties are rated as fair resistance to ascochyta blight compared to the older varieties which were rated as poor to very poor. Current actual chickpea yield in Saskatchewan ranged from 1.6 t ha^{-1} to 1.8 t ha^{-1} (Statistics Canada, 2012). Table 1 listed the latest registered varieties currently recommended for growers in Canada.

In ascochyta blight research, we have identified limited sources of resistance that are being intensively used in breeding to transfer the resistance into breeding lines. The breeding program has developed a number of populations to facilitate studying of ascochyta blight disease resistance. Table 2 lists examples of several populations used for allelism study for resistance to ascochyta blight.

Table 1. List of recommended chickpea varieties for western Canada for 2012-2013

Market class	Variety	Years Tested	Yield (% Amit)		Ascochyta blight**	Height (cm)	Days to Flower	Relative maturity	Seed weight (g1000 seeds^{-1})
			Area 1*	Area 2*					
Kabuli	Amit (B-90) ^	11	100	100	4.4	46	56	L	259
	CDC Alma	4	94	93	6.1	41	54	L	368
	CDC Frontier	11	106	104	4.3	45	56	L	350
	CDC Leader	7	111	107	4.5	41	55	M	389
	CDC Luna	10	99	99	5.7	39	53	ML	369
	CDC Orion	6	108	106	4.8	45	51	L	438
Desi	CDC Cabri	10	103	102	4.7	48	51	M	304
	CDC Corinne	10	114	111	4.1	44	55	M	245
	CDC Cory	4	112	105	4.3	48	57	M	273
	CDC Vanguard	10	108	109	4.7	42	53	ML	221

Source: 2013 Variety of Grain Crops. The Saskatchewan Ministry of Agriculture.
* Area 1: brown soil zone; Area 2: dark brown soil zone of western Canada
** Ascochyta Blight at pod filling period:0-9 scale; 0 = no symptom; 9 = plants are completely blighted. Scores 4 - 6 are considered fair resistance.
Relative Maturity: M = medium; ML = medium-late; L = late;

Recent advances in QTL and association analyses (3, 5, 8, 9) demonstrated that the genomic region on linkage group four is the most prevalent QTL associated with the resistance to ascochyta blight under Canadian conditions with some additional genomic regions in different linkage groups with additive gene action. Molecular approach is being developed to pyramid the genes for resistance (7), but much more research efforts is needed to strengthen the resistance. Other research areas that are being actively pursued include cellular characterization of the infection process and best control strategy for the ascochyta blight disease. Further characterization of chickpea genome has also been initiated in collaboration with the National Research Council of Canada. This includes 454 sequencing of various tissues (http://knowpulse2.usask.ca/portal/), SNP identification (7) and functional genomic. CDC Frontier (Fig. 1), a high yielding medium seeded kabuli with moderate resistance to ascochyta blight, has been used as the base line for these efforts.

Reduction of time to maturity and less indeterminate chickpea crop are important traits for successful chickpea production in western Canada. Few traits were found to strongly affect earliness in chickpea including early flowering, and double podding (1, 2). Introgression of the gene for double podding is being done using the markers linked to the '*s*' gene (9). Few germplasm sources (such as ICCV96029 and FLIP98-145C) with very early maturity have been identified (4) however, most of these germplasm are highly susceptible to ascochyta blight and have undesirable seed quality. Progress is underway to transfer the earliness trait into potential kabuli breeding lines with acceptable quality and improved ascochyta blight resistance.

Seed quality parameters in chickpea were focused on seed size, shape and seed coat colour. Several research initiatives are in progress to enhance chickpea utilization such as factors affecting canning quality. This information will be useful for breeders in selection of improved chickpea lines for future varieties.

Sequencing the whole genome of CDC Frontier by the international collaborative efforts has been completed. The availability of the whole genome sequence is a critical step that will enable chickpea geneticists and breeders to develop a full understanding of the variations found in each genotype. Its use will dramatically accelerate complete identification of genomic variations because it will be relatively easy to generate re-sequence data from different genotypes which can be aligned with the reference genome and then be linked with phenotypes to obtain biological insights. The availability of the reference sequence information will enable the elucidation of complex genetic interactions in chickpea.

Table 2. Mean and range disease score (0-9 scale) of five F_2 populations derived from susceptible (S) x moderately resistance (MR) and MR × MR crosses. The coefficients of variation and mid- parent values for each population are indicated

Cross	Total F_2 plants and clones	Mean (Sd)	Range	cv (%)	Mid parent
ICCV 96029 (S) / Amit (MR)	203 (592)	5.1 (1.4)	3.0 – 8.5	21.2	6.1
ICCV 96029 (S) / CDC Corinne (MR)	180 (522)	5.0 (1.5)	3.0 – 8.7	9.4	6.1
ICCV 96029 (S) / CDC Luna (MR)	160 (424)	7.1 (2.1)	4.3 – 9.0	12.1	6.6
ICCV 96029 (S) / CDC Frontier (MR)	187 (556)	5.2 (1.3)	3.3 – 9.0	18.1	6.1
CDC Frontier (MR) / Amit (MR)	163 (482)	4.9 (1.0)	3.0 – 5.5	16.2	4.5

Figure 1. Seed sample of CDC Frontier

Further analysis beyond this sequencing project may include finding candidate genes and its variation for traits related to disease resistance, early maturity, nutritional quality, bioactive compounds and bioavailable micronutrients in chickpea. Abiotic stress tolerance would also be suitable candidates for characterization in the longer term. The next logical steps from these efforts would be to integrate the outputs into the applied chickpea breeding activities, which include selection of parents for crossing, screening the early generations for the desired genotypes that contain all (or the majority of) favourable allele combinations and integration of the selected lines into elite variety development. ■

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An overview of chickpea improvement research program in Ethiopia

by Asnake FIKRE

Abstract: Chickpea accounts for more than 15% of the Ethiopian legume production. Ethiopia is the largest producer, consumer and exporter of chickpea in Africa. It has achieved a remarkable growth in productivity, production and export of chickpea during the past decade. Ethiopia is currently among the top ten countries for area, production, productivity and export of chickpea. It has the highest average yield of chickpea (1.7 t ha^{-1}) among the countries having chickpea area more than 200,000 ha. Over 20 improved varieties of chickpea have been released in Ethiopia and most of these were developed from the breeding material supplied by ICRISAT and ICARDA. The share of kabuli chickpea in the total chickpea area is growing and currently about one-third of the chickpea area is under kabuli chickpea.

Key words: breeding, chickpea, Ethiopia, production

Current status of chickpea production

Chickpea is among important legumes accounting for more than 15% of Ethiopian legume production and about one million households are engaged in chickpea production (1). The cost of chickpea production is lower than that of many other field crops as its production is towards the end of the cropping season and the crop has less weed pressure and less soil management cost (drainage). Chickpea is known for soil nitrogen enrichment and advantages in crop rotation with cereals. It is also an important source of diet and consumed in Ethiopia in different preparations like snacks, curry, blend to bread/Enjera powder, green pea, and salads.

Ethiopia is the largest producer, consumer and exporter of chickpea in Africa, and is among the top ten most important chickpea producers in the world (3). Ethiopian chickpea production is changing from traditional varieties to improved varieties and from desi type to the kabuli type. The farmers are increasingly using market-preferred varieties and adopting improved crop production practices recommended by researchers (7).

Chickpea production has shown steady increase during the past decade with currently reaching more than 400,000 t per year. The major contributor to this increase in production is the remarkable improvement in productivity than the expansion in area (Fig. 1). The average chickpea yield in Ethiopia is currently 1.7 t ha^{-1} (1), which is among the highest in the world and is almost double than the global average.

The advantages recognized by farmers in chickpea cultivation include: (a) low input requirements and production cost compared to other crops, (b) low requirement of synthetic fertilizers, (c) improvement and sustainability of soil fertility, (d) growing chickpea demand due to increasing domestic consumption and export, and (e) increasing market prices. An assessment of producers demand shows that they are opting more for kabuli chickpeas (2). The kabuli types had negligible share two decades ago, but now occupy about 1/3 of the total area. This trend will continue and kabuli chickpea area may be higher than desi chickpea area in the future. There is also a growing demand for extra-large seeded kabuli chickpea.

Chickpea is mainly grown in Amhara (52.5%), Oromia (40.5%), SNNP and Tigry states. Chickpea is largely grown rainfed on residual soil moisture. Trials on planting dates and associated crop husbandry practices have shown yield advantages up to 100%. Advancing planting date by at least one month increased productivity significantly as it avoids terminal drought stress. However, advancing the planting date may lead to excess soil moisture at the early growth phase which needs to be properly managed.

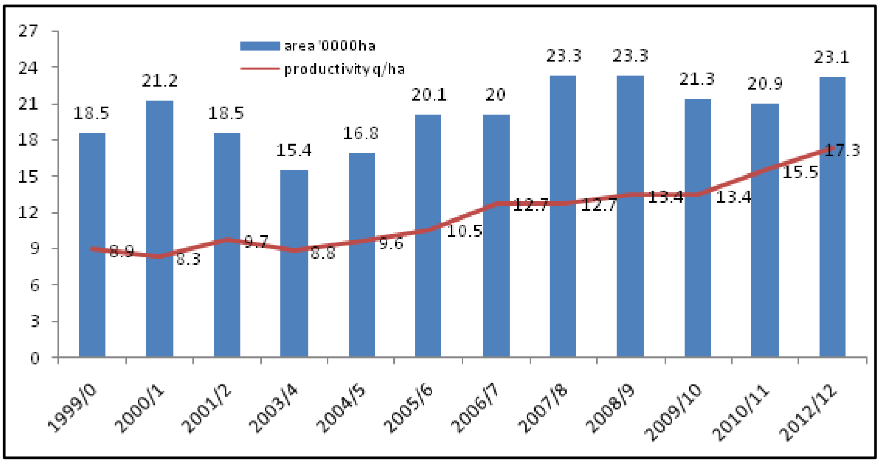

Figure 1. Trends in area and productivity of chickpea in Ethiopia (1999/00 to 2011/12)
Source: Central Statistics Authority (CSA) of Ethiopia 2000-2012

Ethiopian Institute of Agricultural Research (EIAR), Debre Zeit Agricultural Research Center (DZARC), Debre Zeit, Ethiopia

Table 1. Chickpea varieties released in Ethiopia (D = desi, K = kabuli)

Released name	Year	Source	Source material/pedigree	On-farm average yield (kg ha^{-1})	Key traits
Kobo	2012				Drought tolerance
Kassech	2011	ICARDA	FLIP 95-31C		Drought tolerance
Akuri (K)	2011	ICRISAT	ICCV 03402		Drought tolerance
Minjar (D)	2010	ICRISAT	ICCV 03107	1900	Ascochyta tolerance, drought tolerance
Acos dubie (K)	2009	PVT/ Mexico	Acos Dubie (Monino)	1800	Extra-large seed; high market value
Natoli (D)	2007	ICRISAT	ICCX-910112-6	3000	High productivity, good seed quality, root rot tolerance
Mastewal (D)	2006	ICRISAT	ICCV 92006	2000	High yield and good seed quality
Fetenech (K)	2006	ICRISAT	ICCV 92069	1750	High yield and good seed quality
Yelibe (K)	2006	ICRISAT		1750	High yield and good seed quality
Kutaye (D)	2005	ICRISAT	ICCV 92033	1640	High yield and good seed quality
Teji (K)	2005	ICARDA	FLIP-97-266c	1750	High yield, good seed quality, root rot tolerance
Ejere (K)	2005	ICARDA	FLIP-97-263c	2250	High yield, ascochyta tolerance, earliness
Habru (K)	2004	ICARDA	FLIP-88-42c	2700	High yield, earliness, ascochyta and root rot tolerance
Chefe (K)	2004	ICRISAT	ICCV 92318	2450	High yield and adaption, ascochyta and root rot tolerance
Shasho (K)	1999	ICRISAT	ICCV 93512	2300	High yield and adaption and root rot tolerance
Arerti (K)	1999	ICARDA	FLIP-89-84c	3350	High yield and adaption, ascochyta tolerance
Akaki (D)	1995	ICRISAT	ICCL 820016	2000	High yield, desired seed size, wilt and root rot tolerance
Worku (D)	1993	ICRISAT	ICCL 820104	2000	High yield, desired seed size, wilt and root rot tolerance
Marye (D)	1985	ICRISAT	K-850-3/27 x F378	1850	High yield, desired seed size, wilt and root rot tolerance
Dubie (D)	1978	Ethiopia	Selection from landrace	1500	High yield and adaptation, desired seed size
DZ-10-4 (K)	1970	Ethiopia	Selection from landrace	1300	High yield and adaptation
DZ-10-11(D)	1970	Ethiopia	Selection from landrace	1350	High yield and adaptation

Extensive efforts have been made in promoting the improved cultivars and associated crop production technologies to farmers through participatory evaluation approaches (5, 6). A large number of farmer-participatory varietal selection (FPVS) trials were conducted under Tropical Legumes II project. The adoption of improved varieties and technologies has been high in the recent years, which led to an increase in the productivity and production of chickpea.

Chickpea breeding in Ethiopia

The chickpea breeding program is aimed at development of varieties with higher yield potential, enhanced resistance/tolerance to key abiotic and biotic stresses and improved adaptation to different agro-ecologies and cropping systems. Drought is the major abiotic stress for chickpea. The major diseases include fusarium wilt (*Fusarium oxysporum* f. sp. *ciceris*), ascochyta blight (*Ascochyta rabiei*), and dry root rot (*Rhizoctonia bataticola*). Among insect-pests, pod borer (*Helicoverpa armigera*) is the most serious pest. Some losses may also occur due to cut worm (*Agrotis sp.*). Seed under storage is mainly damaged by bruchids (*Callosobruchus chinensis*).

Chickpea breeding program has been in place for over four decades at Debre Zeit Agricultural Research Center (DZARC), the then experimental station under University. The systematic efforts on collection, characterization and evaluation of local germplasm started in 1970s. The initial breeding efforts were mainly on desi type and thus most of the varieties released in the beginning were of desi type. Considering the increasing demand of kabuli chickpea in the domestic and international market, the current breeding program has a greater emphasis on kabuli type.

The Ethiopian chickpea breeding program has had a strong collaboration with CGIAR centers, namely ICRISAT and ICARDA, working on chickpea. For enhancing the efficiency and precision of the chickpea breeding program, molecular breeding approaches are being integrated in partnership with ICRISAT under the Tropical Legumes - I (TL-I) project of the Generation challenge Program (GCP). ICRISAT and GCP helped in development of human resources and infrastructure facilities for implementing molecular breeding. Currently, marker-assisted backcrossing (MABC) and marker-assisted recurrent selection (MARS) are being used for developing improved breeding lines. Breeding lines developed thorough MABC, improved for drought tolerance traits, are already under field testing.

Salient achievements

Twenty-two improved varieties of chickpea have been released in Ethiopia (Table 1). Twelve of these varieties were released from the breeding materials supplied by ICRISAT and five from the breeding material supplied by ICARDA.

Good progress has been made in development of varieties with moderate to high resistance to fusarium wilt and ascochyta blight. However, it has been a challenge to develop varieties with resistance to pod borer because of the lack of sources of resistance. The pod borer is mainly being managed by insecticides and to some extent by following integrated pest management (IPM) approach.

The demonstrations on the complete package of recommended chickpea production technologies (improved varieties along with associated crop production technologies) showed a yield advantage of 100% at the national level and up to 4-fold in some areas. The chickpea yield of 4 t ha^{-1} is being obtained by following recommend production practices in favorable environments. The yield advantages at various levels of the adoption of improved technologies are presented in Fig. 2.

Ethiopia has a share of more than 60% in chickpea marketing from Africa. About 80% of chickpea is marketed locally while some 20% is exported mainly to the Asian and Middle East countries. There is a need of further improving chickpea marketing and the value addition chain as to provide maximum benefit to the farmers (7, 8). Nevertheless, there has been a steady increase in market price of chickpea that has benefited the farmers. The household income from chickpea cultivation has been found to be between 1,500 USD to 2000 USD ha^{-1}. With regard to the seed system, crrently, about 90% of the seed demand is being met by informal seed system in which the farmers were organized as seed growers in a seed business model. The rest of the demand (about 10%) is met by the public and private seed enterprises, like Ethiopian Seed Enterprises, Oromia Seed Enterprises and Amhara Seed Enterprises. The informal seed system now has about 15 seed producers' associations, each with 30 to 50 members. These associations have strong backstopping from the research system and are recognized nationwide as entities with product of at least Quality Declared Seed (QDS). These associations have the capacity to produce about 5000 t QDS per year and distributes to farmers all over the country. The informal seed system is playing an important role in enhancing adoption of improved chickpea cultivars, particularly kabuli types.

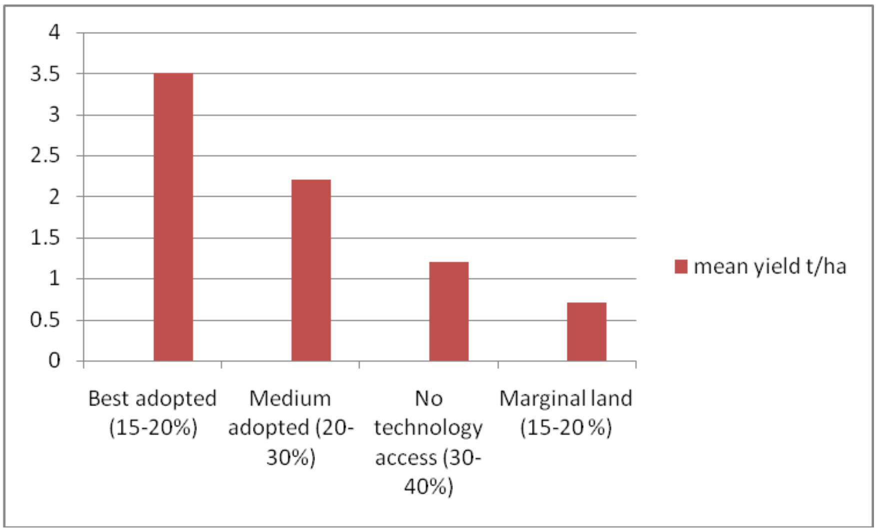

Figure 2. Current Ethiopian chickpea productivity (mean yield t ha^{-1}) estimates at different levels of technology adoption

Future prospects

Based on representative survey and secondary data source from respective agricultural offices, the crop ecology in Ethiopia has recently been characterized and the potentials at district (wereda) level were established (4). This would be an important road map for research and development of chickpea in Ethiopia.

The chickpea research and developments efforts in Ethiopia need to focus on the following areas for further increasing and sustaining chickpea production and further increasing income of farmers from chickpea production and value addition:

- Development of varieties with enhanced resistance/tolerance to stresses and wider ecological adaptation;
- Development of extra-large seeded kabuli varieties which attract premium price in the market;
- Development of varieties preferred by agro-processing industries;
- Development of competitive market products from chickpea. ■

Acknowledgments

The author would like to acknowledge Ethiopian Government, Generation Challenge Program (GCP), Tropical Legumes – I (TL-I) and Tropical Legumes – II (TL-II) projects, ICRISAT, ICARDA and others who contributed to a green revolution in Ethiopian chickpea sector.

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An overview of chickpea breeding programs in India

by Sushil K. CHATURVEDI[1]*, Neelu MISHRA[1] and Pooran M. GAUR[2]

Abstract: India currently accounts for nearly 70% of the global chickpea production and consumption. There has been a large shift in chickpea area from north to south over the past four decades. The chickpea production has increased substantially in the recent years. Over 200 improved varieties have been released from different parts of India. The major constraints to chickpea production include moisture stress, temperature extremities, root diseases, pod borer, and weeds. Transgenics are being developed for enhancing pod-borer resistance. Integrated breeding efforts are being made to develop varieties with improved resistance/tolerance to key abiotic and biotic stresses, suitability to mechanical harvesting and tolerance to herbicides.

Key words: abiotic stresses, biotic stresses, chickpea breeding, breeding achievements, chickpea varieties

Current status of chickpea production

Chickpea, locally known as Bengal gram, Gram or Chhola, has been under cultivation in India from ancient times. It is the most important pulse crop of India contributing to about 40% of domestic pulse production. It is mainly gown rainfed (68% area) and highly valued for its ability to improve and sustain soil fertility. Being a rich source of protein, it plays an important role in ensuring nutritional security to the common agrarian people. The decreasing per capita availability of pulses in India from 69.0 g in 1961 to 31.6 g in 2011 has created an alarming situation calling for concerted and expeditious efforts in improving productivity of pulse crops.

India is the largest producer of chickpea accounting for about 70% of the global share. During 2011-12, India produced 7.58 million tons chickpea from 8.87 million ha area with an average yield of 912 kg ha^{-1}.During the past five decades (1960-2010), chickpea production in India has increased from 6.25 to 8.25 million tons despite a slight decline in the area from 9.28 to 8.75 million ha (4). The trends in area, production and yield of chickpea during the past 40 years are presented in Fig. 1.

Growing chickpea in rotation with cereals was a general practice in India and particularly in northern India (2).With the advent of input intensive *Green Revolution* technologies, a dramatic shift in major cropping systems took place in northern India. The area of pulse crops like chickpea was largely replaced by cereals. During 1964-1965 to 2008-2009, the chickpea area in northern India (Punjab, Haryana, Uttar Pradesh and Bihar states) declined by 4.4 million ha, while increased in central and southern India (Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka) by 3.5 million ha (5).

India is a major producer as well as consumer of chickpea. Despite large domestic production, India has to import chickpea to bridge the gap between demand and production. In recent years, India has also started exporting chickpea, mainly large and extra-large seeded kabuli types to Middle East and other neighboring countries. However, the import invariably exceeds export. For example, during 2006 to 2010, India has an average export of 173,000 tons and export of 132,000 tons per year (4).

Key constraints to chickpea production

Abiotic stresses. Over 68% of the chickpea area is rainfed and soils of rainfed area are generally with low organic carbon content, poor fertility level and water holding capacity. As chickpea is largely grown on conserved soil moisture as a rainfed crop during post-rainy season, the crop often experiences moisture stress towards the end of the season. In addition, heat stress at the reproductive stage has become a major constraint to chickpea production because of a large shift in chickpea area from cooler long-season environments (northern India) to warmer short-season environments (central and southern India), increased area under late sown conditions due to increased cropping intensity, and an expected overall increase in temperatures due to climate change (5). Frost or low temperatures during flowering sometimes result in substantial reduction in yield in northern and central India. Chickpea in northern India sometimes show excessive vegetative growth and lodging when it is sown under irrigated conditions or when there are frequent winter rains. Chickpea is a poor competitor to weeds at early growth phase and may incur heavy yield losses if weeds are not managed. Soil salinity, alkalinity and acidity also affect chickpea productivity in some areas.

Biotic stresses. Fusarium wilt (*Fusarium oxysporum* f. sp. *ciceris* Matuo & K. Sato) and collar rot (*Sclerotium rolfsii* Sacc.) are the important root diseases of chickpea throughout India. Dry root rot (*Rhizoctonia bataticola* (Taubenh.) E.J. Butler) has emerged as a major disease in central and southern India where chickpea growing season is dry and warm. Ascochyta blight (*Ascochyta rabiei* (Pass.) Labr.) and botrytis grey mold (*Botrytis cinerea* Pres.) are the important foliar diseases of chickpea in northern India where chickpea growing season is cool and humid.

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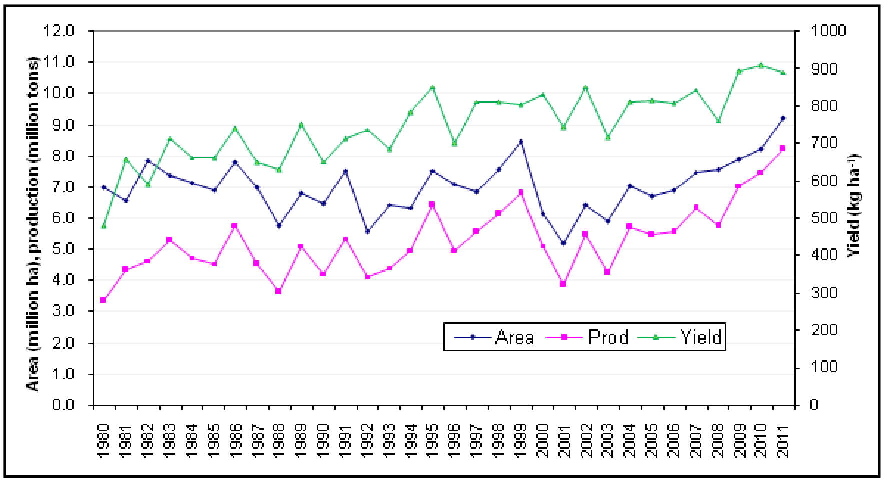

Figure 1. Trends in chickpea area, production and yield in India from 1980 to 2011

The viral diseases, rust (*Uromyces ciceris-arietini*) Grognot, root nematodes (*Meloidogyne* sp.) can also cause substantial yield losses in some areas. Among insect pests, pod borer (*Helicoverpa armigera* Hubner) is the most important pest of chickpea throughout India. Termites (*Odontotermes* spp.), cutworm (*Agrotis* sp.) and leaf miner (*Liriomyza cicerina* Rondani) are also important in some chickpea growing areas. As in other pulses, bruchid (*Callosobruchus chinensis* L.) is the major pest during storage of chickpea.

Socioeconomic factors. A large number of farmers in India have small land holdings. They have limited input resources available and tend to give first priority to staple cereals (rice, wheat, maize) and high value crops (potato, sugarcane) for allocation of resources. The benefits of available improved cultivars and crop production technologies have not been fully realized at farmers' fields as their adoption, particularly crop management practices, remained low in several states of India.

Chickpea breeding in India

Chickpea breeding work was initiated in India as early as in 1930 and an All India Coordinated Pulses Improvement Project (AICPIP) was launched in 1967 to ensure sharing and multi-location evaluation of breeding lines. The Directorate of Pulses Research (DPR) was established in 1984 at Kanpur (India) which was further upgraded to the level of Indian Institute of Pulses Research (IIPR) in 1993 with a mandate of basic, strategic and applied research on a group of pulse crops including chickpea. AICPIP was also trifurcated and All India Coordinated Research Project on Chickpea (AICRPC) came into existence in same year.

Chickpea cultivation is wide spread as it is grown from 32^{0} N in northern India in cool and long season (> 140-170 days crop duration) to 10^{0} N in southern India under warm and short season (90-100 days crop duration). For the convenience of evaluation and release of locally adapted varieties, India has been divided intofive agro-ecological zones (Fig. 2) namely, north hill zone (NHZ), north west plain zone (NWPZ), north east plain zone (NEPZ), central zone (CZ) and south zone (SZ). The best performing genotypes developed at various research institutions are pooled and evaluated in multi-location trials in all five agro-ecological zones. A variety can be released for one or more zones by a Central Variety Release Committee or for a state or part of the state by a State Variety Release Committee.

The chickpea breeding is aimed at developing locally adapted cultivars with high yield potential, acceptable grain quality and resistance/tolerance to key abiotic and biotic stresses prevalent in the target area.

Salient achievements

India has a long history in chickpea breeding and the world's largest network of chickpea breeding programs. Over 20 research stations located in various parts of India have active chickpea breeding program. These belong to State Agricultural Universities (SAUs), Indian Institute of Pulses Research (IIPR) and Indian Agricultural Research Institute (IARI) and are linked to AICRPC (Fig. 2). Excellent progress has been made in chickpea breeding in India (3, 8). The Indian chickpea breeding program has a strong collaboration with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and greatly benefited by its presence in India. A total of 206 chickpea varieties have been released in India during 1921 to 2011 (4 during 1921-1940, 17 during 1941-1960, 33 during 1961-1980, 85 during 1981-2000 and 67 during 2001-2011), with 38 from the materials supplied by ICRISAT. Some old varieties, such as Dahod yellow, Chaffa, Radhey and Annegiri, are still cultived. Currently, > 90 varieties are in seed production chain. About 43% of the indent of breeder seed during 2011-2012 was for the varieties developed with ICRISAT.

One of the most significant achievements of chickpea breeding is the development of varieties with high resistance to fusarium wilt, now mandatory for release of a new chickpea variety in India. Excellent progress has been made in developing early maturing varieties (e.g. ICCV 2, ICCC 37, JG 11, JG 14, KAK 2, DCP 92-3, BGD 72) with high yield potential. The early maturing varieties escape terminal drought and heat stresses and helped in expansion of chickpea area to southern India, where growing season is short (90-100 days) and warm (6).

The development of kabuli chickpea varieties, which remained a low priority for decades, has received high attention during the recent years. Few kabuli varieties (L551, ICCV 2, BG 1003, BG 1053) with medium seed size (< 30 g 100 seed^{-1}) were released in India, before the release of the first large-seeded kabuli variety, PKV Kabuli 2 (popularly known as KAK 2), in 2001. KAK is an early maturing fusarium wilt resistant variety with a seed size of about 38g 100 seed^{-1}. This is currently the most popular chickpea variety in India. Several large-seeded (31 - 45 g 100 seed^{-1}; e.g. JGK 1, IPCK 2002-29, IPCK 2004-29, JGK 2, Vihar, LBeG 7 andVirat) and also extra-large seeded (46-60 g 100 seed^{-1}; e.g. JGK 3, KRIPA, PKV Kabuli 4-1, IPCK 02 and MNK 1) kabuli varieties have been released in India during the past decade. They have contributed to expansion of kabuli chickpea area in India and their recent export.

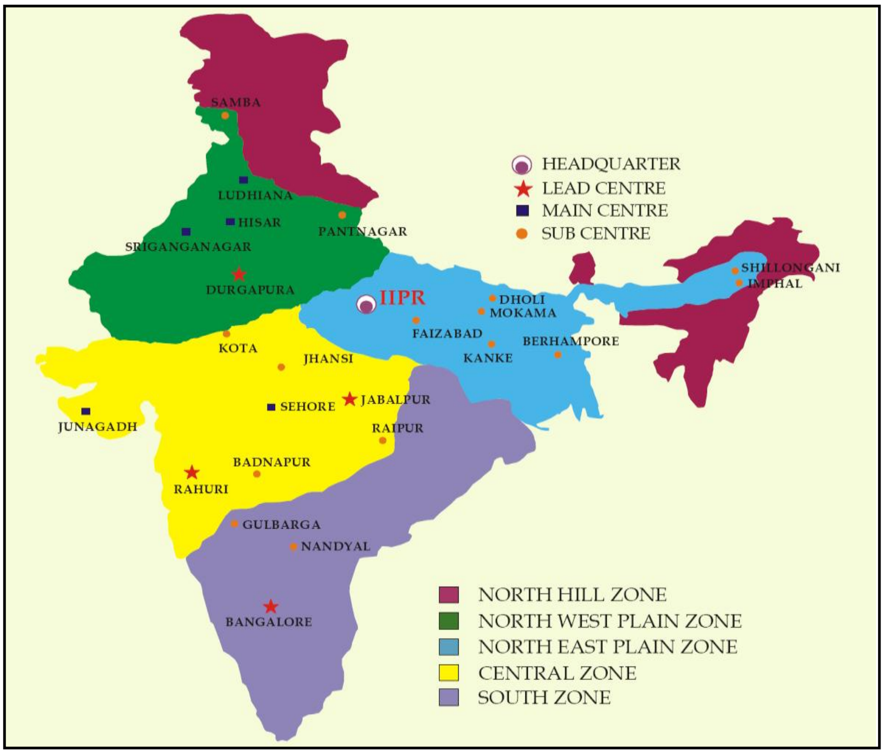

Figure 2. Chickpea research network in India (Adpoted from AICRP on Chickpea Report)

Chickpea varieties (RSG 888, Vijay) tolerant to terminal moisture stress became popular in drought prone areas of the country. Recently, a heat tolerant chickpea variety JG 14 (ICCV 92944) has been released and several sources for heat tolerance have been identified (1, 7). In northern India, where chickpea crop attain more vegetative growth and subsequently show lodging leading to huge yield loss or sometimes failure of crop, variety DCP 92-3 can be grown successfully. Similarly, variety Karnal Chana 1 (CSG 8962) can be grown in areas of mild level of soil salinity.

Development of varieties resistant to pod borer remained a challenge as the level of resistance available in the germplasm are very low. Therefore, transgenic approach is being used for development of pod borer resistant cultivars.

The new priority traits where chickpea breeding efforts have recently started include heat tolerance, herbicide tolerance and suitability to mechanical harvesting.

Future prospects

- There is a need to develop varieties with tall and erect or semi erect growth habit which will be suitable for mechanical harvesting. In addition, higher amount of solar light interception on these varieties will help in enhancing photosynthetic activities and in reducing humidity inside crop canopy which will help in minimizing losses due to foliar diseases.
- Broadening of the genetic base by bringing genes from wild *Cicer* species and primitive landracesto develop suitable plant types with durable resistance to major biotic and abiotic stresses.
- Integration of molecular markers in chickpea breeding programs for improving efficiency and precision.
- Development of herbicide tolerant varieties for promoting resource conservation (zero or minimum tillage) technologies and reducing cost of cultivation as manual weeding is becoming very expensive.
- Germplasm of cultivated and wild species need to be evaluated systematically for identification and utilization of sources of resistance to emerging diseases like collar rot and dry root rot.
- In view of climate change, development of varieties tolerant to terminal drought and heat stresses needs special attention. Breeders should join hands with physiologists and molecular biologists to tackle these problems effectively.
- Development of extra-large seeded (100-seed weight > 50 g) kabuli chickpea varieties with resistance to major diseases and tolerance to frost and low temperatures at flowering.
- Development of early to extra-early maturing varieties for late sown conditions i.e. harvest of rice or other rainy season crops to increase cropping intensity.
- Development of transgenic for resistance to *Helicoverpa* pod borer.
- Development of varieties with improved nutrient use efficiency, particularly phosphorus use efficiency. ■

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An overview of chickpea breeding programs in Iran

by Sayyed H. SABAGHPOUR

Abstract: Chickpea is the most important pulse crops in Iran accounting for nearly 64% of the food legume area in Iran; and 4.2 % of the area and 2.2 % of the production of chickpea globally. Chickpea is mostly grown rain-fed (98%) in the spring season and largely on marginal lands. Terminal drought stress reduce productivity of chickpea considerably in spring planting in comparison to autumn and entezari (late autumn) sowing. Improved chickpea varieties with suitable characters have been released and crop management recommendations developed for different areas. Winter planting of chickpea in milder environments and Entezari planting in harsh (sever cold) environments have been found promising. In some areas, farmers obtained 50% or more yields with adoption of improved varieties to winter- or Entezari - sowing. Efforts are being made on enhancing adoption of these technologies.
Key words: agronomy, breeding, abiotic stresses, biotic stresses

Current status of chickpea production

Legumes are important in sustainable production of food and feed in the Islamic Republic of Iran. They are important source of good quality protein in the diets of people and are valuable as animal feed. Legumes also increase and sustain the productivity of the soil and in rotation with cereal and reduce chances of build-up of diseases, insect pests and obnoxious weeds for the following cereals crops.

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Food legumes (*Cicer arietinum*, *Lens culinaris*, *Phaseolus vulgaris*, *Vigna radiata*, *Vigna unguiculata* and *Vicia faba*) occupied 790,437 ha in 2010 which is 6.2% of the country's cultivated area (1). Iran has a share of 1.56% of the area and 1.35% of the production of pulses in the world. Iran accounts for nearly 4.2 % of the world chickpea area (508,000 ha) and 2.2% of the world production (2). It is the most important legume of the country growing on more than 64% of the total food legume area. Chickpea (98%) is mainly planted under rainfed condition grown in rotation with cereals mainly wheat and barely.

Key constraints to chickpea production

Drought is the common abiotic stress limiting chickpea production in different parts of Iran. Chickpea frequently suffers from drought stress towards the end of growing season after flowering, during pod setting and seed formation, drought is accompanied by heat stress in rain-fed conditions. Terminal drought stress reduces productivity of chickpea considerably in spring planting in comparison to autumn and entezari sowing. In spite of superiority of autumn and entezari planting to spring planting in respect of high water use efficiency and less occurrance of terminal drought stress (3), some farmers prefer to plant chickpea in spring due to weed problem. The chickpea yields are low in some farmers' fields because of poor agronomic practices, such as soil moisture loss during field preparation, low plant density, late sowing, poor weed control and also use of local varieties. The local chickpea varieties are harvested by hand because of spreading growth habit, resulting in enhanced harvesting cost. Local varieties of chickpea are susceptible to ascochyta blight (*Ascochyta rabiei*), fusarium wilt (*Fusarium oxysporum* f. sp. *ciceris*) and virus diseases. Ascochyta blight is a major yield reducer for chickpea in semi-warm areas of north, northwest, west and southern Iran. Though ascochyta blight occurs both in winter and spring planted chickpea, it is more severe in winter sown crop (4). Occurrence and severity of this disease depend largely on the cultivar and weather condition in a given year. Ascochyta blight incidence was 100% in the epidemic years in farmer's fields on local varieties in the Mediterranean, warm and moderate region of Iran. Hashem chickpea variety was released in 1997 has erect growth habit and resistance to ascochyta blight and (5). A survey on aschochyta blight disease conducted in different areas in northwest of Iran showed that farmers who planted local chickpea varieties had ascochyta blight incidence of 35% in the range of 30-80% (4). Fusarium wilt is another important disease mainly in spring chickpea in the northwest of Iran. A survey conducted on Fusarium wilt disease in north and northwest of Iran showed that 19% of the chickpea fields have Fusarium wilt incidence in the range of 5-60% (4).

Pod borers are the most important insect pest that cause substantial yield losses in chickpea in Iran. Two pod borer *Helicoverpa armigera* and *Helicoverpa viriplaca* species are the most frequent. Cutworms (*Agrotis* spp.), are also important pests for chickpea in spring planting. Bruchid is the major pest in seed storage.

Research on chickpea has not been extensive in the past decades. Chickpea yield was low (400 kg ha^{-1}) as farmers continued to grow local varieties and did nor follow improved agronomic practices (4). However, recent efforts in chickpea research have been fruitful. Three improved chickpea varieties have been released in 1997, 2004 and 2008 for semi-warm and moderate areas and are gradually being adopted by farmers. Trends in chickpea yield from 1996 to 2010 is given in Fig. 1. The lower yields in 2007-2008 and 2008-2009 are due to sever drought stress in these years. Recently, the farmers have an increased productivity of 511 kg ha^{-1}.

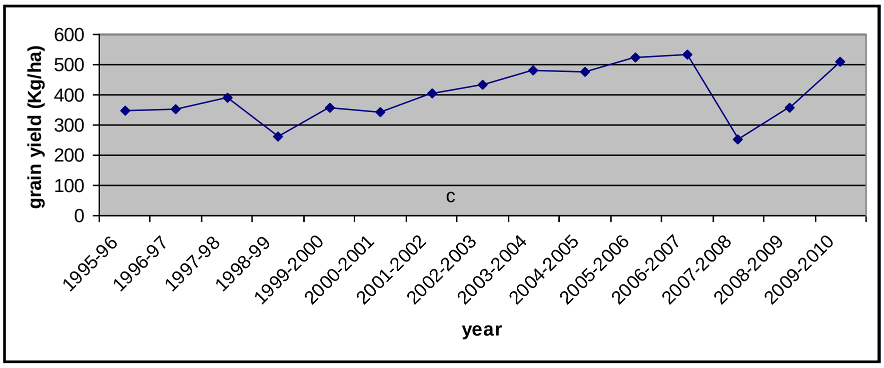

Figure 1. Trends in chickpea yield in Iran from 1996 to 2010

Major aims in breeding programs

Chickpea hybridization program in Iran started in 1989 with an aim of creating genetic variation and improving local varieties. The chickpea research is being carried out by Dryland Agricultural Research Institute (DARI) in collaboration with other research organizations in Iran and the International Institutes ICARDA and ICRISAT. The major aims in breeding programs are following:

- Development of varieties with wide adaptability;
- Development of varieties with enhanced resistance/tolerance to biotic (ascochyta blight, fusarium wilt, viruses, pod borer and leaf miner) and abiotic stresses (cold, heat, drought and salinity);
- Development of varieties with large seed and high yield potential;
- Development of biological control methods for insect pests such as pod borer, cutworms and leaf miner;
- Identification of effective rhizobia and rhizobial inoculation techniques;
- Identification of physiological aspect of yield variation under different environmental conditions, which might be helpful for agronomic manipulations.

Salient achievements

Three kabuli varieties, namely Hasham (5), Arman (6) and Azad (7) were released in 1997, 2004 and 2008, respectivly. These varieties were developed from the breeding lines received from ICARDA through Iran-ICARDA collaboration. These varieties are tolerant to ascochyta blight and have high yield potential and erect growth habit, therefore are suitable for mechanical harvest. Some promising lines, such as ILC 1799 (tolerant to drought and fusarium wilt, large seed size and high stable yield), ILC 482 (high stable yield and with high adaptation for autumn and spring planting), SEL93TH24460 (cold tolerant and high potential yield) and FLIP 99-66c (resistant to ascochyta blight), are under pre-release evaluation trials.

The agronomy of chickpea cultivation including date of sowing, seed rate, method of sowing, plant population, weed control, and method of harvesting, has been researched and recommendations developed for different areas. The efforts are being made to transfer these recommendations to farmers with the help of Extension Specialists. Research on exploration of possibility of winter planting of chickpea in milder environments and entezari planting in harsh (severe cold) environments has given fruitful results with good successes (Fig. 2). Transfer of these technologies to farmers is in progress and in some areas farmers are getting almost 50% or more productivity with adoption of winter- or entezari sowing. For increasing chickpea yield, the following strategies have been standardized by the chickpea research programs of the country and recommended for transfer to farmers:

- Minimum tillage should be done for preparing chickpea field which will minimize soil moisture loss during field preparation;
- Optimum date of sowing recommended for different regions and seasons should be followed;
- Optimum quantities of suitable fertilizers recommended for each variety and area may be used;
- Improved varieties, such as Hasham, Arman and Azad should be used.

The results of experiment show that autumn planting had 72% higher yield than spring planting for chickpea in moderate and semi-warm areas (3). Chickpea variety which has resistance or tolerance to aschochyta blight should be planted in the moderate and Mediterranean climate and semi-warm areas in autumn. For cold area, entezari planting (December) in winter may be done or planting in spring should be as early as possible when the soil is in field capacity in February or March. Optimum plant population should be used for local and improved varieties.

Future prospects

The average yield of chickpea obtained by farmers in Iran is very low. A huge potential exists for increasing yield levels of chickpea in Iran. At present, the average chickpea yield obtained by farmers is around 511 kg ha^{-1}, while it is 1200 kg ha^{-1} in on-farm yield trials. The farmers can obtain high chickpea yields if they follow the recommendations of improved varieties and crop production technologies for their area. Increase in chickpea productivity will improve income of farmers and contribute to improving food and nutritional security. ■

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An overview of chickpea breeding programs in Kenya

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Abstract: Chickpea is a new crop in Kenya and its potential has not been fully utilized. The chickpea grain yields generally range between 1.2 to 3.5 tons/ha at farmers' fields, indicating that chickpea has a potential of becoming an important export crop in Kenya. The chickpea breeding program in Kenya is still at infant stage and being established with support from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). Four chickpea varieties have been recently released from the breeding material supplied by ICRISAT. Efforts are being made on evaluation of germplasm and breeding lines, application of modern molecular breeding tools and techniques in chickpea breeding and establishment of effective seed system for establishing a sustainable chickpea production system in the country.

Key words: abiotic stress, biotic stress, drought tolerance, Aschochyta blight, *Helicoverpa armigera*

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Current status of chickpea production and distribution in Kenya

Chickpea is a relatively new crop grown in Eastern and Rift valley provinces of Kenya, though the landraces have been under cultivation in coastal and Eastern parts of Kenya for over 40 years. The current chickpea area in Kenya is about 55,000 ha and production is approximately 15,000 t to 18,500 t (2). Chickpea is widely consumed in Kenya, mainly by the large population of Asian origin living in urban cities (Nairobi, Kisumu, Mombasa, etc) and for whom chickpea is an important source of protein. Kenya also has highly developed processing industries for chickpea. Kenya imports approximately 100,000 t of chickpea annually mainly from Tanzania, Sudan and Ethiopia (5) which is processed (dehulled) and then either consumed locally or exported to Asian markets (mainly India and Pakistan).

In large cities, chickpea is now considered as functional food with low fat, cholesterol free and ideal cheap source of protein and energy to the affluent and vegetarian populations with major food-related health problems like diabetes, cancer or coronary heart diseases. For the rural poor populations mainly in the arid and semi-arid lands (ASALs) of Kenya, chickpea is considered as an alternative drought tolerant legume which can replace bean, which is known to be more susceptible to heat and drought stresses than chickpea. Chickpea is considered as a cheap source of protein and also recognized as appetite suppressant because it is digested slowly and hence delay the reappearance of hunger for several hours, a characteristic highly valued by poor communities who leave on one meal per day.

Chickpea has become attractive to cereal farmers (maize, finger milet and wheat) due to its ability to improve soil fertility and yield of following cereal crops by 24-68% in a cereal-legume relay cropping system (1). As a green manure crop, chickpea improves soil structure of acidic soil (8). Chickpea is also known to reduce incidence of fusarium wilt in passion fruit it preceded passion fruit in the rotation (7). Currently over 270,000 households derive their livelihoods from the from chickpea both in dry highlands and ASALs of Kenya. The government of Kenya currently recognizes chickpea as mitigation strategy for climate change effects (5) and has embarked on a campaign to promote the crop countrywide. The crop also has potential of reducing crop losses caused by the new devastating Maize Lethal Necrotic Disease (MLND) when sown in rotation with maize in major maize producing areas affected by the disease in parts of Kenyas' Rift valley region like Bomet, Kilgoris, Naivasha, Narok and Nakuru.

Key constraints to chickpea production

Several biotic and abiotic constraints limit chickpea production in Kenya. Amongst the biotic factors, pod borers (*Helicoverpa armigera*), ascochyta blight (caused by *Ascochyta rabiei*) and fusarium wilt (caused by soil borne fungus, *Fusarium oxysporum* f. sp. *ciceris*) are major causes of yield losses. Pod borer causes yield losses of up to 80% especially in ASALs areas where insect severity is high, but can be as low as 30% - 50% in cooler areas (6). Due to limited sources of resistance, application of insecticides remains the only option for controlling this pest. Aschochyta blight is a widespread major foliar disease that causes extensive grain yield losses (up to 100%) and reduces grain quality especially in dry highlands of Kenya. High chickpea yields can be achieved if chickpea is sown in long rains in the highlands, but this is rarely adopted by the farmers because the cool and wet weather favors the development of Aschochyta blight epidemics. Intergraded disease management (IDM) protocol, which include use of tolerant cultivars adapted to early sowing, seed dressing with fungicides, and foliar application at different growth stages (seedling or early vegetative growth stages), is being standardized for management of ascochyta blight.

Terminal drought is a major abiotic constraint limiting chickpea production in most growing areas since the crop is largely sown on residual soil moisture after long rains (in relay cropping with cereals) and experiences moisture stress towards the end of the crop season (summer in the dry season. In ASALs where crop is sown during long rains, the crop can still experience drought if the rains are low in amounts (250 - 450 mm), poorly distributed, and short (40 - 60 days). Several other socio-economic constraints, like access of farmers to credit, agricultural inputs (seed, fertlizers, fungicides, pesticides, etc.) and market affect adoption and production of chickpea by farmers.

Major aims in breeding programs

Chickpea breeding program in Kenya was non-existent until recently (last 10 years ago) when collaborative efforts between Egerton University (EU), Kenya Agricultural Research Institute (KARI) and ICRISAT through funding support from Generation Challenge Program (GCP), Tropical Legumes I (TL-I) and Tropical Legumes II (TL-II) projects, and other donors resulted in establishment of a functional breeding program. ICRISAT has been the major source of advanced breeding lines for release as commercial varieties or germplasm for crop improvement in Kenya and within the Eastern and Southern Africa Region (ESA). The major target of chickpea improvement includes high yield potential, adaptability to different agro-eco zones, early maturity, large seed size (100 seed weight of 30 - 55 g) in kabuli type, and resistance/tolerance to key abiotic (terminal drought) and biotic (pod borer, ascochyta blight and fusarium wilt) stresses. Germplasm nurseries for these attributes have been sourced from ICRISAT and multi-location evaluation trials carried out to identify potential candidates for release or use in breeding program. Under TL-I project, novel breeding approaches, like marker-assisted backcrossing (MABC) and marker-assisted recurrent selection (MARS), are being used for improving drought tolerance (4).

Salient achievements

A functional chickpea breeding program is currently being developed in Kenya at Egerton University and KARI. However, recent efforts on evaluating breeding lines received from ICRISAT have led to release of four varieties for commercial production in Kenya. These include Chania Desi 1 (ICCV 97105) and LDT 068 (ICCV 00108) in desi type and Saina K1 (ICCV 95423) and LDT 065 (ICCV 00305) in kabuli type. LDT 065 and LDT 068 were released in 2009, while the remaining two varieties were released in 2011. These varieties are early maturing and have moderate to high resistance to fusarium wilt. LDT 065 and Chania Desi 1 have moderate resistant to ascochyta blight. The desi varieties are suitable for making splits (*dhal*) and *Githeri*, while kabuli varieties are suitable for salads and harvest of green pods. LTD 068 has upright growth habit and can be harvested by combine harvesters. There are several other desi (e.g. ICCV 92944, ICCV 94954, ICCV 01507) and kabuli advanced breeding lines (ICCV 97306, ICCV 96329) being evaluated under national performance trials and some of these may be released in near future. Concerted efforts are being made under TL-II project to enhance seed availability of the recently released improved varieties by bringing together several seed companies and local seed traders.

Pod borer causes yield losses ranging between 20-40% and sometimes up to 80% (6). Field evaluations and laboratory screening have shown that no genotype is completely resistant to its infestation. This suggests that integrated pest management (IPM) is the only option for management of pod borer.

Chickpea yield losses of up to 100% has been reported due to ascochyta blight in the crop grown during the rainy, wet and cool long rain season (May-August) (3). Farmers often use very expensive fungicides to contain this disease, which increases cost of production. Thus, use of resistant varieties is the most sustainable solution for managing asochyta blight. Sources of resistance to ascochyta blight have been identified and need to be introgressed in the current commercial varieties.

Among abiotic factors, drought stress is the single most important constraint to yield of chickpea in Kenya. Efforts are being made to develop varieties with deeper and vigorous root system. A genomic region controlling root traits has been introgressed from ICC 4958 or ICC 8261 into several varieties (Chania Desi 1, Saina K1, LDT 068, ICCV 10, ICCV 92944 and LDT 065) using MABC. In addition, MARS is being used in two crosses (ICCV ICCV 04112 × ICCV 93954 and ICCV 005107 × ICCV 94954) for developing improved lines (4).

The ongoing research and developmental efforts on chickpea are expected to enhance area and productivity of chickpea in Kenya and improve income and food and nutritional security to the farmers.

Future prospects

The foundations of future prospects of breeding program in Kenya have been laid with strong support from ICRISAT, Generation Challenge program (GCP), national partners and other international partners. The ongoing work on large scale germplasm characterization and evaluation, modernization of facilities, application of modern molecular breeding tools and techniques, establishment of effective seed system and capacity building efforts will ensure that a a sustainable chickpea production system is established in the country. The breeding program will continue to make efforts on improving resistance tolerance to terminal drought, pod borer, ascochyta blight and fusarium wilt. ■

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Chickpea cropping and breeding program: An overview on the Tunisian situation

by Moez AMRI[1]*, Mariem BOUHADIDA[2], Mohamed H. HALILA[2] and Mohamed KHARRAT[1, 3]

Abstract: Chickpea in Tunisia faces several biotic and abiotic stresses which affect seriously the productivity and cause a lack of interest from farmers to cultivate this crop. Since 1980s, the chickpea breeding program had as objectives, the selection and the development of new varieties tolerant/resistant to the major biotic constraints mainly the most damaging fungal diseases Ascochyta blight and Fusarium wilt. Many winter chickpea varieties were released mainly from germoplasm received from ICARDA and were tested in different environments. The results obtained in the breeding program and concerning the new selected varieties of chickpea, indicated good prospects for this crop in terms of tolerance/resistance to major diseases and high yield. The winter sowing chickpea growing with appropriate integrated management package involving variety choice, fungicide application could also have good economic returns in term of productivity.

Key words: *Cicier arietinum*, breeding program, genetic resistance, Tunisia

Introduction

Chickpea (*Cicer arietinum* L.) plays an important agronomic role in the agriculture system of many countries through its contribution in the improvement of Nitrogen soil fertility by fixing atmospheric Nitrogen and constitutes a cheap and healthy source of protein for human consumption in many poor countries.

In Tunisia, the development of chickpea in the agricultural field crop system is facing several constraints such as biotic particularly ascochyta blight and root diseases and abiotic stresses (drought in spring sowing and water logging in some areas in winter sowing). These constraints become more and more pronounced especially with the climate changes affecting both the development of the crop, and its enemies (development of new pathogens/pests and changing in the aggressiveness and virulence of others). Among the main serious diseases that can completely destroy the crop in some fields are *Ascochyta rabiei,* Fusarium wilt and an emerging problem which is the root rot especially during the wet seasons.

The creation of the food legume laboratory at National Institute for Agricultural Research of Tunisia (INRAT) in early 1980 enhanced researches on food legume covering breeding and agronomic aspects. The research program conducted in collaboration with International of Center for Agricultural Research of Dry Areas (ICARDA) concerns faba bean, chickpea and lentil mainly and was focused on the development of new varieties adapted to different environments and tolerant/resistant to the main biotic stresses. This program which constitutes part of the Field Crop Laboratory of INRAT programs since 2000 is executed in collaboration with the Regional Research Center of Field Crop of Beja (CRRGC) since 2010. The chickpea breeding research program has generated eight chickpea varieties (seven of them are for winter sowing) selected mainly from germplasm introduced from ICARDA and with some widely cultivated (ie. cv. Béja 1).

The chickpea cropping situation: grown areas, production and yield

In 1980s and early 1990s, chickpea was grown in relatively considerable cropping areas (more than 35,000 ha) mainly as spring crop, At present time the grown area decreased tremendously to less than 10,000 ha (Fig. 1) This important decrease is due to the lack of highly resistant varieties and the complexity to control the main fungal diseases such as Ascochyta blight and root disease complex. Also, the increase of chickpea price combined with spring drought, observed frequently during 1990s, explain the decrease of spring sown chickpea. For this reason the chickpea research breeding program has focused on the development and selection of winter chickpea new high yielding varieties with better level of tolerance / resistance to major diseases and better adapted to climatic conditions.

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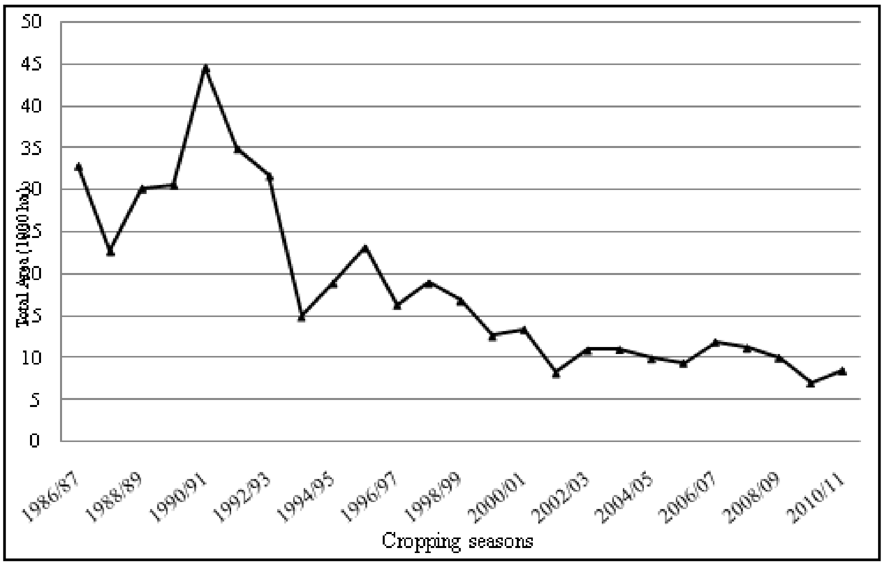

Figure 1. Chickpea total cultivated areas in Tunisia (1,000 ha) for the last 25 years (DGPA, Ministry of agriculture)

Table 1. The winter chickpea varieties list (Kabuli type) released by the breeding program

Variety	Pedigree	Date of registration	Caracteristics
Chetoui	ILC3279	1987	- Small seed size, erect type - Tolerant to *A. rabiei* - Recommended for winter sowing
Kasseb	FLIP83-46C	1987	- Small seed size - Tolerant to *A. rabiei* - Recommended for winter sowing
Amdoun 1	-	1987	Large seed size, Resistant to race 0 of Foc Recommended for spring sowing
Bouchra	FLIP84-79C (X80TH176/ILC72xILC215)	2003	- Small seed size - Tolerant to *A. rabiei*
Nayer	FLIP84-92C (X80TH176/ILC72xILC215)	2003	- Small seed size - Tolerant to *A. rabiei* - Recommended for winter sowing
Beja1	(Amdoun1xILC3279)xILC200	2003	- Small seed size - Tolerant to *A. rabiei* - Resistant to race 0 of Foc - Recommended for winter sowing
Nour	X96TH61-A3-W1-A2-W1-A1-W1-W1	2011	- Medium seed size - Tolerant to *A. rabiei* - Resistant to race 0 of Foc - Recommended for winter sowing

Many winter chickpea varieties were selected, released and registered by the breeding program in the early 2000s (Table 1). These new high yielding varieties are tolerant/resistant to the most damaging diseases of this crop. Cultivars Bouchra and Neyer have relatively high level of tolerance to Ascochyta blight (*Ascochyta rabiei*). Béja 1 combined resistance to ascochyta blight and Fusarium wilt (*Fusarium oxysporum* f. sp. *ciceris*) and contributed significantly to the yield increase (Fig. 2) and consequently the stabilization of the chickpea production.

Selection for dual resistance to Ascochyta blight and Fusarium wilt

Many serious diseases have the potential to destroy chickpea crop (4). *Ascochyta rabiei* and Fusarium wilt complex caused by various fungi were reported to be the most damaging of this crop in Tunisia (1, 2, 3). Recently an emeging problem of root rot caused by *Rhizoctonia solani* (anstomosis group AG2-3) was reported (5). The main objectif of the chickpea breeding program is to develop winter varieties combining many resistance sources including a dual resistance to both *A. rabiei* and Fusarium wilt. The same material is evaluated every year in differents environmental conditions and exposed to different disease pathotypes as well as for agronomic traits (Fig. 3). This evaluation occurs in different experimental research stations (Table 2). The field evaluation is completed and confirmed by laboratory test to confirm their reaction.

Selection for resistance to Ascochyta blight

Every year many nurseries and trials including material in $F_{3:4}$ generation or advanced lines in specific trials are received mainly from ICARDA (more than 700 lines) are tested for resistance to *A. rabiei* under field conditions. At the seedling stage the materiel is innoculated by infeted debris collected in previous year and then scored using the 1-9 scale, where 9 the most susceptible when the repeated susceptible check is almost destroyed (Fig. 4). The most resistant genotypes with good agronomic traits is selected.

Selection for resistance to Fusarium wilt

The screening for resistance to Fusarium wilt complex is done at the same cropping season in a wilt sick field in the Oued Beja experimental station (Fig. 5). The main fungi are *Fusarium oxysporum* f. sp. *ciceris, Verticillium alboutrum* and other *Fusarium* species. Using the 0-100% scale for dead plants per plot we identify the resistant lines. Only genotypes, showing also resistance to *A. rabiei,* are kept and progressed to next generation in order to select for dual resistance. This field evaluation is confirmed by laboratory screening and molecular study.

Use of modern technologies: Marker Assisted Selection (MAS)

During the last years the research strategy within the Field Crop Laboratory, in collaboration with national and international institutions, introduced the use of modern technologies in the chickpea breeding program. These tools will contribute efficiently in the identification and exploitation of genetic resources as well as specific genes related to the resistance to *A. rabiei* and Fusarium wilt. In addition, DNA molecular marker techniques allow construction of linkage maps for the crop which could be used to locate and estimate phenotypic effects of quantitative trait loci (QTLs) and the genes responsible for the resistance expression to these diseases. ■

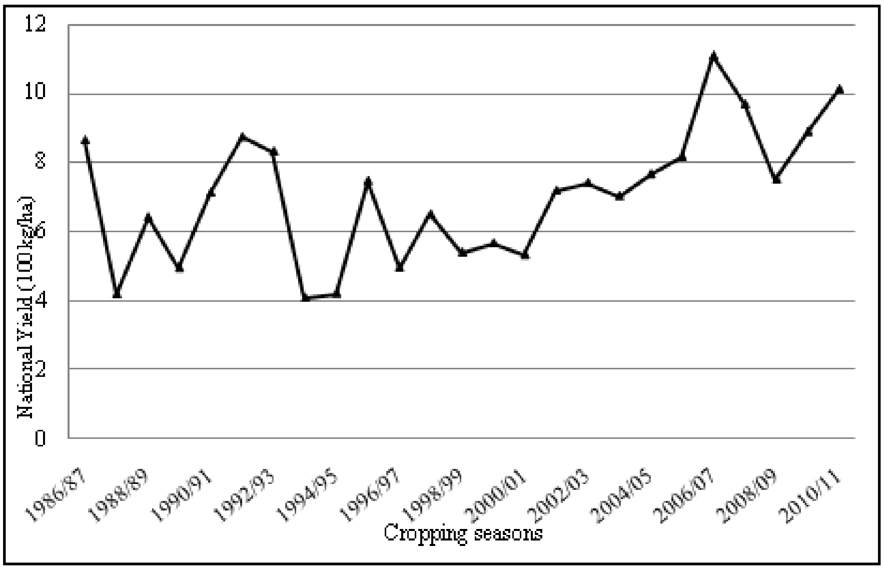

Figure 2. Chickpea national yield (100 kg ha^{-1}) recorded during the last 25 years (DGPA, Ministry of Agriculture)

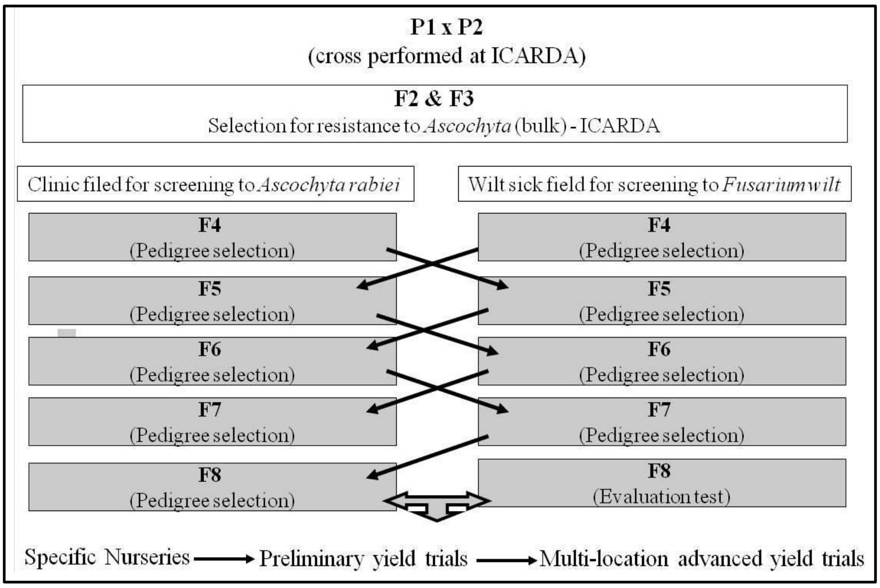

Figure 3. Schematic representation of the different steps of selection of chickpea varieties

Table 2. The different experimental stations were conducted the chickpea breeding program

Experimental station	Bioclimatic data	Evaluation and screening
Oued Beja (36 44'03.53"N; 9 13'37.73"E)	Sub-humid (580-600 mm)	*Ascochyta rabiei* *F. oxysporum* f.sp. *ciceris and root rot* Agronomic traits
Oued Meliz (36 28'44.58"N; 8 29'37.87"E)	Semi-arid (450 mm)	*Ascochyta rabiei* Agronomic traits
Kef (36 07'31.26"N; 8 43'19.61"E)	Semi-arid (350-400 mm)	*Ascochyta rabiei* Abiotic stresses Agronomic traits

Figure 4. Screening for resistance to *A. rabiei* after innoculation by infested debris at Oued Beja experimental station

Figure 5. Screening for resistance to *Fusarium oxysporum* f.sp. *ciceris* in a highly infested field at Oued Beja experimental station

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An overview of chickpea breeding programs in Myanmar

by Mar Mar WIN[1]*, Tun SHWE[1] and Pooran M. GAUR[2]

Abstract: Chickpea is an important legume in Myanmar, not only for local consumption but also for export earnings. Major chickpea-producing area is the central dry zone which contributes 96% of the chickpea production. Kabuli chickpea is mainly grown for export, while desi chickpea is for local consumption. Eight improved varieties of chickpea (5 desi and 3 kabuli) have been released in Myanmar. The adoption of improved varieties and improved crop production practices has led to remarkable increase in chickpea yields and production.

Key words: central dry zone, export, improved varieties, intercropping, varietal improvement

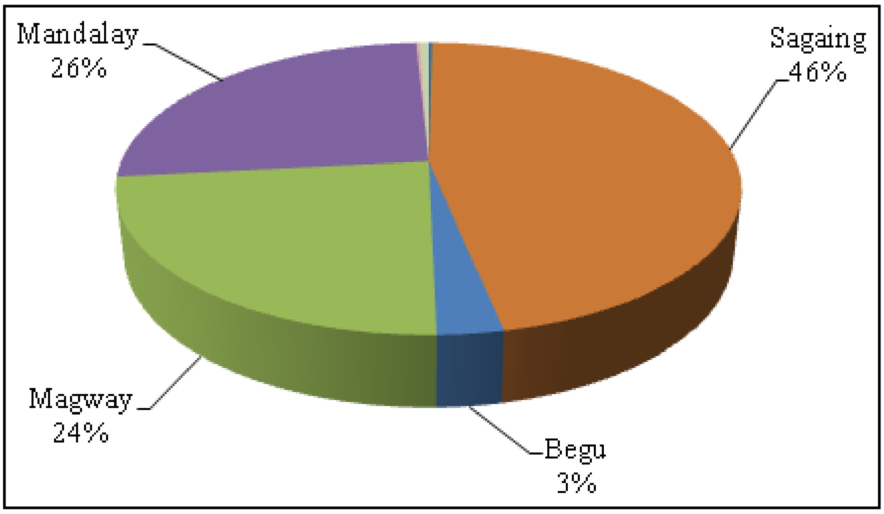

Figure 1. Share of different regions of Myanmar in chickpea production during 2011-2012

Current status of chickpea production

Chickpea is currently grown on 333,195 ha with a total production of 473,020 MT and the average productivity of 1423 kg ha^{-1} (MOAI 2012). The majority of this area is concentrated in the central dry zone which includes Sagaing (46%), Mandalay (26%) and Magway (24%) region. These regions together contribute 96% of the chickpea production (Fig. 1).

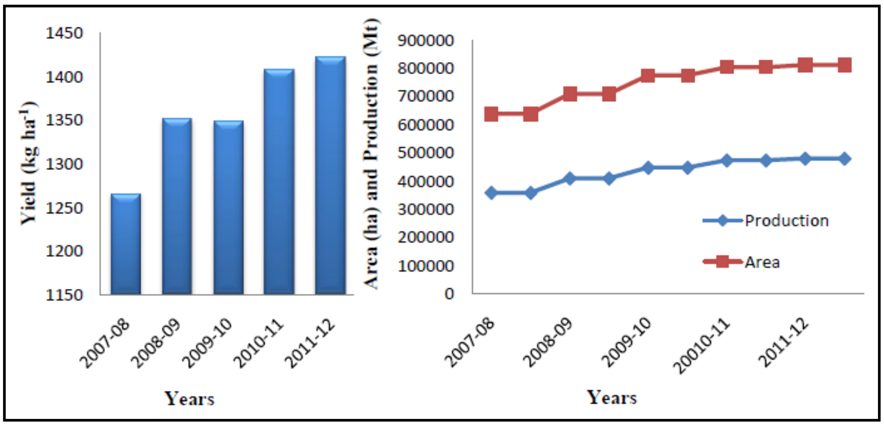

Figure 2. Yield, sown area and production of chickpea in Myanmar during 2007-2008 to 2011-2012

Production and productivity of chickpea has registered an increasing trend from 2007-08 to 2011-12 (Fig. 2). The increase in area is partly due to promotion of export markets and favorable price in the local market and partly due to the research and development efforts of Department of Agricultural Research (DAR). During 2011-2012, Myanmar exported 78,702 MT chickpea (1). There is high demand for chickpea in India, Singapore and Pakistan.

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In Myanmar, the climate of the central dry zone is very hot and arid. This region largely has sandy loam or floodplain clayey soils and the annual precipitation varies from 500 mm to 1000 mm (3). During the chickpea crop season the maximum temperature ranges from 25 °C to 38 °C and minimum temperature from 8 °C to 20 °C. Chickpea is grown under residual soil moisture in both low land and upland conditions. In lowland areas, it is grown as a relay or sequential crop after rice, while in upland areas it is grown mostly on fertile soil with a good water holding capacity after sesame, maize, mugbean or fallow. In upland area of Sagaing region, farmers are now keen to grow kabuli chickpea as it fetches a higher market price. Desi type is more dominant in rice-chickpea sequential cropping system. Chickpea is sometimes intercropped with wheat or sunflower without any definite spatial arrangement as a trap crop to reduce pod borer infestation. Chickpea is also grown along the banks of Chindwin and Ayeyarwaddy Rivers after the flood water recedes (4).

Table 1. Sown area, yield and production of chickpea varieties in central Myanmar during 2011-2012

Region/Variety	Sown area (ha)	Yield (kg ha^{-1})	Production (Mt)
Sagaing			
Yezin 3 (ICCV 2)	75065	1585	118953
Yezin 4(ICCV 88202)	3941	1612	6353
Yezin 6 (ICCV 92944)	39797	1622	64555
Yezin 7(ICCV 95311)	2071	1594	3301
Yezin 8(ICCV 97314)	33938	1623	55101
Yezin 9(ICCV 97306)	230	1661	383
ICCV 01309	6	1630	10
Mandalay			
Yezin 3 (ICCV 2)	45303	1219	55208
Yezin 4 (ICCV 88202)	13118	1479	19396
Yezin 5 (ICCV 3)	139	1141	158
Yezin 6 (ICCV 92944)	164	1240	205
Yezin 8 (ICCV 97314)	4	1223	5
Local	27558	804	22147
Magway			
Yezin 3 (ICCV 2)	5594	1416	7920
Yezin 4 (ICCV 88202)	56390	1440	81215
Yezin 5 (ICCV 3)	937	1243	1185
Yezin 6 (ICCV 92944)	6433	1554	9997
Yezin 8 (ICCV 97314)	38	1594	61
ICCV 37	549	1175	645
ICCV 93031	12	1493	18
Local	8859	1318	11672
(Source: Department of Agriculture) (2)			

Key constraints to chickpea production

Poor agronomic management. Chickpea is a cool season crop and normally grown after the harvest of monsoon rice. Soil physical conditions often are not conducive for planting chickpea immediately after rice harvest that eventually extends turnaround time. Planting of chickpea also suffers from occasional late rains that make the land unworkable particularly in heavy textured soils.

Abiotic constraints. Chickpea is grown mainly on the residual soil moisture and a very little rainfall occurs during the winter. Moisture stress occurs at later growth stage of the crop. In late sowing area, chickpea yield is very low due to high temperature stress during flowering time. Thus early maturing, heat and drought tolerant varieties are needed for Myanmar.

Biotic constraints. Pod borer (*Helicoverpa armigera*) infestation occurs every year throughout the growing season. Root diseases include collar rot (*Sclerotium rolfsii*) at seedling stage, fusarium wilt (*Fusarium oxysporum*) at either early or late growth stage, and dry root rot (*Rhizoctonia bataticola*) at late growth stage.

Socioeconomic constraints. Despite the importance of chickpea in Myanmar farming systems, farmers give least preference to applying agricultural inputs, such as fertilizers or plant protection measures. Such inputs are relatively high priced and often limited, and thus reserved for rice or high value crops. Lack of storage knowhow and capability for chickpea grain also result in a low farm gate price at the time of harvest with high seasonal fluctuations. There are no organized marketing channels or Government support prices for chickpea. Low-income farmers bear most of the risks associated with chickpea production.

Major aims in breeding programs

Chickpea research program of Myanmar is under DAR and it is aimed at development of improved varieties and crop production technologies for different ecosystems. DAR has a strong collaboration with ICRISAT. ICRISAT supplies breeding materials, provides training to researchers and provides technical guidance in the research program and conduct of conduct of farmer-participatory varietal selection trials for identification of suitable chickpea cultivars.

Current research priorities include development/identification of high yielding desi and kabuli varieties with early maturity, grain quality preferred by export market, tolerance to drought and heat stresses, and resistance to root diseases (mainly fusarium wilt, collar rot and dry root rot) and pod borer for upland and rice-based ecosystem. Agronomic research is being carried out on sowing time, spacing (seed rate and plant population), nutrient management and cropping systems. On-farm evaluations of improved varieties and technologies are carried out with participation of farmers and under supervision of researchers, government officials and extension workers.

Figure 3. Intercropping with chickpea and sunflower in upland condition

Salient achievements

Eight improved varieties of chickpea, 5 Desi types (Yezin 1, Yezin 2, Yezin 4, Yezin 6 and Shwenilonegyi) and 3 kabuli types (Yezin 3, Yezin 5 and Yezin 8), have been released in Myanmar through DAR. These varieties have high yield potential, short to medium duration, wide adaptation and export quality grain. All these varieties, except Shwenilonegi, were developed from the breeding materials supplied by ICRISAT. ICRISAT supplied over 4,700 chickpea breeding lines to Myanmar during 1975 to 2012. The varieties developed through DAR-ICRISAT partnerships cover about 88% of the chickpea sown area in the central dry zone. The extra-early kabuli variety Yezin 3 (ICCV 2) is the most popular variety in Sagaing and Mandalay region, while desi variety Yezin 4 (ICCV 88202) is the most popular variety in Magway region (Table 1). The cultivation of heat tolerant variety Yezin 6 (ICCV 92944) and recently released kabuli variety Yezin 8 (ICCV 97314) in now increasing in Sagaing and Magway regions. Shwenilonegyi, the first chickpea variety developed from the hybridization program of DAR, has attractive grains with high recovery of split grains (4) and is becoming popular among farmers.

The adoption of improved varieties and improved production practices has led to remarkable increase in chickpea yields and production in Myanmar. The improved crop production technologies have also been adopted widely. For example, chickpea-sunflower intercropping (Fig. 3) found beneficial in pod borer management and crop diversification is widely adopted by farmers.

Future prospects

There are good prospects of further increasing chickpea production in Myanmar. The additional production can be achieved by (i) increasing productivity through adoption of improved varieties and cultural practices; and (ii) increasing area through utilization of fallow lands and introduction of new cropping patterns. There is need of replacing old varieties with recently released varieties. Several new breeding lines, such as Sinshweni, Yezin 7 (ICCV 95311), Yezin 9 (ICCV 97306), ICCV 01308 and ICCV 01309 are under pre-released stage evaluation (Table 1). These lines produced higher yields compared to the existing varieties at research stations and farmers' fields. Thus, we expect to have more choices of improved varieties to the farmers in the near future. The greatest challenge in adoption of a new variety is the shortage of seed. Thus, seed system needs to be strengthened for improving the availability of quality seeds of improved varieties.

Conclusion

The area, production and yield of chickpea in Myanmar during the past five years (from 2007/2008 to 2011/2012) have increased by 19%, 34% and 12%, respectively. This is mainly because of the adoption of improved cultivars and production technologies by the farmers. Terminal drought and heat stresses, root diseases and pod borer are the major constraints to chickpea production. There is a need to address these constraints by development and adoption of improved cultivars and farmer-friendly management practices. Minimizing losses from these constraints would result in higher and more stable yields. This is important not only for farmers for increasing income, providing food and nutritional security, but also for the country for getting foreign exchange through export. ■

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An overview of chickpea breeding program in Pakistan

by Asghar ALI* and Shahid R. MALIK

Abstract: Chickpea is a major food legume crop of Pakistan. The production of chickpea has been fluctuating which may be attributed to biotic and abiotic stresses, non-availability of quality seed of improved varieties and non-availability of post-emergence herbicides for weed control. Chickpea breeding is being focused on development of high yielding *desi* and large seeded *kabuli* varieties having resistance/tolerance to major biotic and abiotic stresses. Twenty-six improved varieties of chickpea have been released through National Coordinated Research Program on Pulses (NCRPP). High emphasis is now being given on *kabuli* chickpea improvement to meet the demand of the country and reduce the import.

Key words: chickpea, *Cicer arietinum*, production constraints, *Ascochyta* blight, *Fusarium* wilt

Current status of chickpea production

The total area under major pulse crops in Pakistan is about 1.5 million hectares. Chickpea is the major winter food legume crop occupying 73% of the total pulses area with 76% contribution towards the total pulses production in Pakistan. Most of the chickpea production comes from d*esi* type and k*abuli* type occupies a small proportion of total chickpea area. Chickpea is well known for its ability to withstand moisture stress and atmospheric nitrogen fixation. Therefore, it is grown in rainfed agriculture system. The major supply of grain legumes depends upon the production of chickpea and failure of this crop results in pulses debacle in the country.

In Pakistan, chickpea is grown under a wide range of agro-ecological zones. However, nearly 90% of the crop is cultivated under rainfed conditions mostly on receding soil moisture. Punjab province alone contributes about 80% to chickpea production of the country. In Punjab, 90% of chickpea crop is planted in rainfed area, out of which 75% is concentrated in Thal area comprising districts of Bhakkar, Khushab, Layyah, Mianwali and a part of Jhang. It is also grown in Pothwar area mainly in the districts of Attock, Chakwal and Rawalpindi. The irrigated area of chickpea is scattered throughout the Punjab, which is dropped from 26% in 1970-1971 to as low as 10% in 2008-2009 (2). In Khyber Pakhtunkhawa, chickpea is mainly grown in Karak, Lucky Marwat and D.I. Khan districts. The crop is grown on residual moisture after rice in Sindh, (Sukkur, Jacobabad, Larkana and Shikarpur districts) and Balochistan (Naseerabad and Jaffarabad districts).

During the last five years, the area of chickpea in the country remained stagnant with little fluctuations. However, on the other hand, the production profile revealed severe fluctuations highlighting the problem of instability (Fig. 1). As the chickpea is grown on more than 80% of the area falling under dry land agriculture system, it remains under high influence of change of natural environmental conditions. For example, the crop season 2011-2012 was not favorable for crop due to severe prolonged frost at flowering stage in major chickpea growing areas. This event was rare and exhibited once in ten years.

Pakistan's per capita consumption of pulses has been increasing and now touched to the figure of more than 1 million ton per annum. During the financial year 2010, desi chickpea accounted for 51% and kabuli chickpea 12% of the total pulses consumption. Pakistan imported 150,000 t of kabuli and 51,000 t of desi chickpea during that year. The chickpea production has decreased to 291,000 tons in 2011-2012, from 496,000 t in 2010-2011 showing a decrease of 41.3% (5).

Key constraints to chickpea production and their solutions

The study of the production trends reveals high fluctuations highlighting the problem of instability, which may be attributed to biotic and abiotic stresses, lack of quality seed and inadequate mechanization.

Biotic stresses. The main fungal diseases affecting chickpea productivity in Pakistan are *Ascochyta* blight (*Ascochyta rabiei*), *Fusarium* wilt (*Fusarium oxysporum*) and *Rhizoctonia* dry root rot. The major threat was found to be *Ascochyta* blight. It was specifically targeted after epidemic breakout of this disease in 1980s. The gene source for resistance was explored from exotic germplasm and incorporated into desired background. Now a number of lines and varieties in the country are carrying those genes responsible for resistance against this deadly disease. Among insect pests, pod borer (*Helicoverpa armirgera*) is the major pest. The work was initiated to develop *bt* based bio-pesticide but it was left in half way and now the control is achieved through chemical insecticides. is a poor competitor to weeds because of slow growth rate and limited leaf area development at early stages of crop growth and establishment. The chemicals are identified for narrow leaf weeds which are safe for chickpea. Haloxyfop-R-Methyl of Aryloxy-propionate group in 10.8 EC is safe for post-emergence application. However, control of broad-leaf weeds is still under investigation and the research work is under progress.

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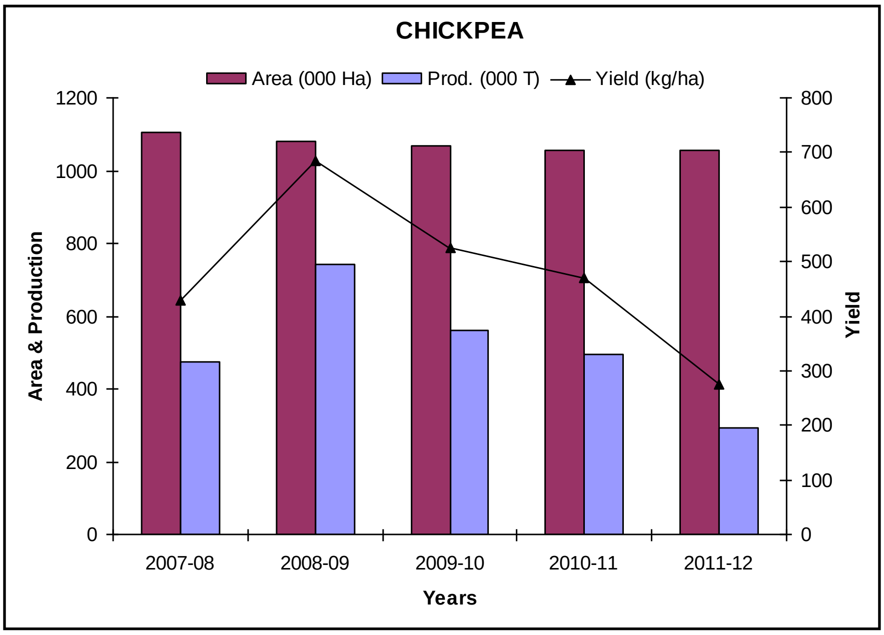

Figure 1. Trends in the area, production and yield of chickpea from 2007 to 2012 in Pakistan. Source: Agricultural Statistics of Pakistan

Abiotic stresses. The abiotic stresses identified are drought and cold. Both constraints are not easy to tackle. During 2011/2012 cropping season, severe and prolonged low air temperatures badly affected the chickpea production. So far, almost no effort has been initiated to overcome this problem. On the other hand, increase in the drought tolerance comes at the cost of yield. The work in this regard is also not showing any significant improvement in the breeding material available in the country. A research project was initiated for the improvement of low temperature tolerance some five years ago at National Agricultural Research Council (NARC) but it was stopped after one year.

Lack of quality seed. There is limited amount of improved varieties' seed available from the seed corporations and companies each year. Growers also retain seed but that may be of poor quality with reduced germination and vigour, as well as being infected with seed-borne pathogens. Non-availability of quality seed in adequate quantity is one of the major constraints in chickpea production. NARC initiated a self-sustainable seed production system of pulse crops. The involvement of private sector and government seed corporations will further help in meeting the seed demand of farmers in the country.

Inadequate mechanization. Machinery is available for land preparation, ploughing, sowing and threshing. However, locally made combine harvesters that can be afforded by the farmers are not available. Thus, the sample machine needs to be imported and modified according to local conditions. Some service providers from government or private sector may come up to help in this. The machines are expensive and not affordable by poor and small farmers. At least some affordable machines must be available in the country. At the same time, combine machines must be available at Tehsil level on rent basis. It will make the crop easy for handling and the losses will be minimized.

Chickpea breeding in Pakistan

Due to epidemic of *Ascochyta* blight, chickpea crop in Pakistan was completely devastated for three years consecutively from 1979-1982. This situation compelled the policy makers and researchers to devise some strategies to strengthen and coordinate research efforts for improvement of the crop. Therefore, NCRPP was initiated at Pakistan Agricultural Research Council (PARC) with the appointment of a National Coordinator to achieve the following objectives:

- Mobilize available scientific resources towards national issue of achieving self-sufficiency in food legumes;
- Develop multidisciplinary research groups on pulses with a coordinated approach to ascertain researchable issues and strategies to tackle them;
- Strengthen the provincial research setups financially and technically;
- Avoid duplicity in research, if exists anywhere.

Since then, the development of high yielding *desi* and large seeded *kabuli* varieties having resistance/tolerance to major biotic and abiotic stresses is the main objective of chickpea breeding programs in Pakistan. Chickpea breeding is one of the components of NCRPP in the country. Major breeding work is being carried out at NARC, Nuclear Institute for Agriculture and Biology (NIAB), and Ayub Agricultural Research Institute (AARI). The rest of the institutes in the provincial or federal set-up are mainly working on germplasm evaluation and/or as a yield testing sites.

National Coordinated Research Program on Pulses (NCRPP) at NARC, Islamabad. The chickpea breeding program at NARC is aimed at the utilization of genetic diversity of chickpea for development of varieties with increased seed yield as well as stability; resistance to biotic (Ascochyta blight, stem and root rot) and abiotic (cold) stresses; plant type for mechanized harvesting and acceptable or improved nutritive value and cooking quality of seed. In addition, research on development of appropriate production technologies involving agronomy, pest management and other related scientific disciplines is being carried out to support the breeding work.

For effective utilization of germplasm collections in breeding programs, genetic characterization in terms of measure of the extent and pattern of genetic diversity within and between populations is essential not only to unveil the magnitude of genetic diversity available in the germplasm for conservation purposes but also to determine genes useful for possible progress in future breeding programs (3, 7). Evaluation and characterization of chickpea indigenous and exotic germplasm from ICARDA and ICRISAT is a continuous activity to identify diverse genotypes for desirable traits. Crossing is also likely to produce higher heterosis, desirable genetic recombination and segregation in progenies when it is made between genetically diverse parents, therefore, selected germplasm is used in the development of new recombinants through hybridization and the segregating populations are advanced. Off-season advancement is also practiced to get two generations in one year. The desirable plants are selected and evaluated in on-farm trials for desired traits. Germplasm and segregating populations are also provided to provincial institutes on their demand. Multi-location trials are also carried out to evaluate genotypes in different agro-ecological zones.

So far, two varieties, with blight resistance and high yield, of desi chickpea 'Dasht' and 'Parbat' have been released and are being successfully grown in the blight prone areas. Work on kabuli chickpea has been accelerated during last five years and new germplasm with blight resistance and large seed size have been identified from exotic sources. The selected lines are being used in breeding kabuli chickpea varieties.

Nuclear Institute of Agriculture and Biology (NIAB), Faisalabad. The objectives of this institute are to create genetic variability through gamma radiation; marker assisted breeding and other techniques to evolve chickpea varieties having high yield potential, disease (blight and wilt) resistance and better plant type. Information about the chickpea germplasm with resistance to wilt and blight is available and utilized in marker assisted breeding for these characters. Utilizing specific linked markers two genotypes namely CH 70/02 and CH 73/02 have been identified that are resistant to both blight and wilt diseases of chickpea and provide a good resistant source for utilization in breeding program. Five chickpea varieties have been developed and released by this institute.

Table 1. Chickpea varieties developed through NARS up to 2011

Variety name	Institute	Year of release	Salient characteristics
CM-72	NIAB, Faisalabad	1982	Desi, high yielding, small seeded, tolerant to Ascochyta blight.
C-44	AARI, Faisalabad	1982	Desi, high yielding, bold seeded, tolerant to A. blight, susceptible to iron chlorosis.
Noor-91	AARI, Faisalabad	1992	Kabuli, high yielding, bold seeded, tolerant to A. blight.
Punjab-91	AARI, Faisalabad	1992	Desi, high yielding, bold seeded, tolerant to A. blight, in case of delayed maturity susceptible to shattering.
Paidar-91	AARI, Faisalabad	1992	Desi, high yielding, medium seeded, tolerant to ascochyta blight.
NIFA-88	NIFA, Peshawar	1992	Desi, high yielding, small seeded, tolerant to ascochyta blight.
DG-89	RRI, Dokri, Sindh	1989	Desi, medium bold seeded, high yielding, suitable for rice based system of Sindh, tolerant to root diseases.
DG-92	RRI, Dokri, Sindh	1989	Kabuli, high yielding and suitable for rice based system of Sindh, province.
Karak-1	GRS, Karak	1992	Desi, small seeded, drought tolerant, tolerant to blight.
Bittle-98	AARI, Faisalabad	1998	Desi, high yielding, bold seeded, tolerant to A blight resistant to iron chlorosis.
KC-98	GRS, Karak	1998	Kabuli, tolerant to blight and drought, high yielding
Sheenghar	GRS, Karak	2000	Drought and blight tolerant, bold seeded, high yielding
Lawagar	GRS, Karak	2000	Kabuli, medium bold-seeded, drought and wilt tolerant.
Punjab-2000	AARI, Faisalabad	2000	Desi, high yielding, bold seeded, A. blight tolerant, resistant to shattering.
CM-2000	NIAB, Faisalabad	2000	Kabuli, high yielding, med seeded, tolerant to A. blight, suitable for in irrigated and rice growing areas.
Balkasar	BARI, Chakwal	2000	Desi, high yielding, medium seeded, tolerant to A. blight, suitable for cultivation in Pothwar region.
Venhar	BARI, Chakwal	2000	Desi, high yielding, medium seeded, tolerant to A. blight, suitable for cultivation in Pothwar region.
Dashat	NARC, Islamabad	2003	Desi, high yielding, medium seeded, resistant to ascochyta blight, suitable for cultivation in Pothwar region.
Parbat	NARC, Islamabad	2003	Desi, high yielder than Dasht medium seeded, resistant to A. blight, suitable for cultivation in Pothwar region.
KK-2	GRS, Karak	2003	Desi, drought tolerant, med. seed size
KK-3	GRS, Karak	2003	Desi, drought tolerant, med. seed size
Thal-2006	AZRI, Bhakkar	2006	Bold seeded, drought and blight tolerant, highly responsive to irrigation.
CM-2008	NIAB, Faisalabad	2008	Kabuli, high yielding, mutant
Punjab-2008	AARI, Faisalabad	2008	Desi, high yielding
Noor-2009	AARI, Faisalabad	2009	Kabuli, high-yielding, tolerant to *Fusarium* wilt, suitable for cultivation in irrigated areas.
Bhakkar-2011	AZRI, Bhakkar	2011	Desi, High yielding, wilt resistant, suitable for rainfed and irrigated areas

Ayub Agricultural Research Institute (AARI), Faisalabad. This provincial institute is working on chickpea breeding with the main focus on development of varieties with high yield potential, resistance/tolerance to biotic (Fusarium wilt) and abiotic stresses (drought and heat), earliness in maturity and good cooking quality. Eight varieties of desi chickpea and three of kabuli chickpea have been developed by this institute.

Salient achievements

Through the coordinated research efforts, 26 chickpea varieties have been developed by various research institutes which are adapted to different agro-ecological zones and have resistance/tolerance against key biotic and abiotic stresses prevalent in the chickpea growing area of Pakistan (Table 1).

Future prospects

Chickpea like other food legume has narrow genetic base. Genetic variations for many biotic and abiotic stresses are not available in the functioning gene pool. However, some of these traits are available in wild *Cicer* species. Therefore, there is a need to start a massive pre-breeding program at selected centers with already available facilities and expertise. Significant scientific interventions are needed for major breakthrough in chickpea yield levels through morpho-physiological changes in plant type. Chickpea future research demands to develop an ideotype in this crop plant like in lentil which resulted in release of variety Markaz-09 at NARC (1). There is a need to develop chickpea varieties suitable for mechanical harvesting. Horizontal expansion of area under kabuli chickpea could be achieved through the development of high input responsive varieties for those areas.

The new advances in genomics provide opportunities to breeders to utilize these technologies for improving and stabilizing chickpea yield (4). The integration of these technologies would improve the precision and efficiency of chickpea breeding in the development of improved varieties with enhanced resistance to biotic and abiotic stresses. *Helicoverpa* spp. is the dominant pest in most of the areas causing damage to about 30% - 40%. The use of chemical insecticides has traditionally been the primary management option for *Helicoverpa* control on chickpea (6). This problem can be very well addressed by genetic transformation which provides a complementary means for the betterment of crop. ■

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An overview of chickpea breeding programs in Spain

by Josefa RUBIO[1]*, Teresa MILLÁN[2] and Juan GIL[2]

Abstract: Chickpea is considered a traditional crop in Spain however, its cultivated area has significantly decreased in the last fifty years. The main objectives of Spanish breeding programmes are the development of new varieties with resistance to the two major fungal diseases caused by *Ascochyta rabiei* and *Fusarium oxysporum* f. sp. *ciceris* together with other agronomic traits such as large seeds, flowering time or growth habit. New cultivars developed from crosses between Spanish, ICARDA and ICRISAT lines are currently being obtained. At present in Spain there is a high demand of chickpea, thus it is expected that the chickpea growing area will be increased in the future.

Key words: chickpea, breeding, resistance, varieties, Spain

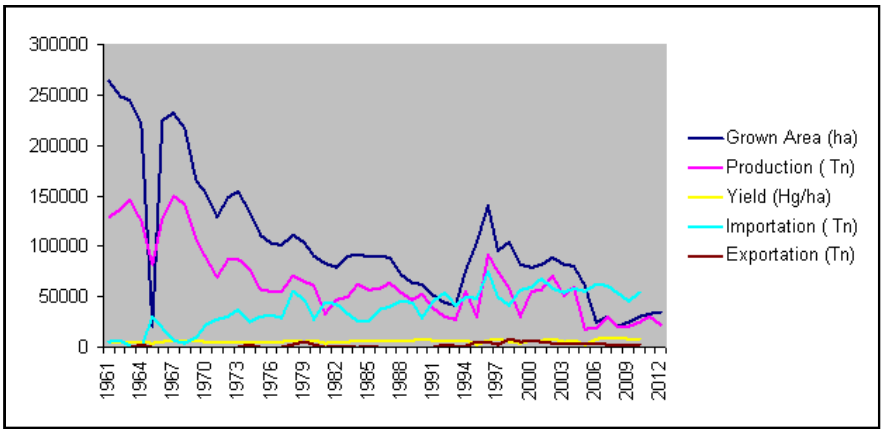

Figure 1. Evolution of grown area, production, yield, importation and exportation of chickpea in Spain

Current status of chickpea production

Spain is the major producer (42.8% of the total European production) and also the major consumer of chickpea in Europe (around 76,051 t). It has been a traditional crop in Spain for centuries; currently it ranks fourth in terms of area harvested after other legumes as pea, vetches and bitter vetch. The cultivated area in Spain has suffered tremendous fluctuation from 1961, decreasing in last years (Fig. 1) (1, 2). Apart from biotic and abiotic stresses, importations from Mexico maintained for political reason together with the low price of soybean and social aspects such as the migration of the population from rural to urban areas could explain this situation.

In Fig. 1 it can be appreciate an increase of chickpea cultivation during period 1995-1999 explained partly by the European Agricultural Policy and partly due to the high market prices for first-quality seeds. In the last years the growth area has decreased till around 34,000 ha in 2012 distributed across Extremadura, Andalucia, Castilla La Mancha and Castilla-León semiarid regions. Accordingly, total production has decreased to 22,500 t in 2012 (2). Nowadays Spain needs to import approximately double than its chickpea production. In 2010 around 53,800 t were imported principally from México, being Spain the fifth country in terms of word imports (1).

Key constraints to chickpea production

Biotic stresses. The main fungal affecting chickpea in Spain are both blight caused by *Ascochyta rabiei* and wilt caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *ciceris*. Both diseases are the most frequent, destructive and difficult to control. Development of resistant cultivars is the most effective, economical and environmentally friendly method of managing these diseases, as in Spain the research is being carried out on this subject.

Abiotic stresses. The most important abiotic stress in Spain is drought and the high temperature at the end of the cycle. As well, when spring is cooler than usual chilling tolerance at flowering must be taken into account since affects success in pod setting.

Major aims in breeding programs

In Spain chickpea is mainly kabuli type, essentially used for human consumption. Today the most cultivated varieties are still traditional landraces ('Blanco Lechoso', 'Castellano' and 'Pedrosillano') that are susceptible to both blight and wilt. It is a rainfed spring crop sowed at early March and harvested in the middle of July. Consequently, due to this short growing period, plants develop poor biomass implicating low yields (around 800 kg ha^{-1}).

At present, the development of resistant lines to mayor diseases (Fusarium and blight) is the main objective of chickpea breeding programs. Resistance to blight made possible the introduction of winter sowing with the prospect of increasing chickpea production that could be doubled (Fig. 2).

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However, the lack of stable production continues to be a major concern in this crop and other agronomic traits related to the adaptation to a cropping system are also considered. Thus, earliness, bushy growth habit and double podding seems to have a positive effect on yield and yield stability in chickpea crop under our environmental conditions (3, 4). Other traits such as chilling tolerance at flowering time (< 15 ºC), that can be occasionally a problem for pod setting, is also being introduced in our crossing program.

Seed size, determined by seed weight, is a key quality determinant in the Spanish market. In Andalucia regions (southern Spain) the farmers prefer chickpea 'Blanco Lechoso' type with big seed (around 60 g weight per 100 seeds) because it fetches three times higher prices than other chickpea cultivars (around 1,5 EUR kg^{-1} 'Blanco Lechoso' and 0,50 EUR kg^{-1} median or small seeds type). 'Blanco Lechoso' is susceptible to Ascochyta blight, so the development of new materials combining resistance and big seeds size is a major aim in our breeding programme and recently successful advanced lines combined these traits have been developed in collaboration with a farmer cooperative (www.campodetejada.es) (Fig. 3). Similarly, large 'Blanco Lechoso' cultivar resistant to Fusarium wilt are being developed by a backcrossing programme assisted by molecular markers

Figure 2. Winter and spring showing in chickpea

Figure 3. Chickpea advanced lines in the field

Salient achievements

Breeding efforts have contributed substantially to improve chickpea yield potential in Spain and 33 varieties have been released so far. Some of them derived of selection from ICARDA materials like 'Fardon' derived from ILC72, with resistance to blight, erect habit and good quality of seed. Other varieties derived from our crossing program are resistance to blight, to wilt or to both disease like 'Zoco' that combine resistance to Fusarium wilt (races 0 and 5) and resistance to Ascochyta blight or 'Cavir' with resistance to Fusarium wilt (races 0 and 5), early flowering and good seed size (around 45 g per 100 seeds). In spite of these efforts it is necessary to solve some problems with the commercialization of the new varieties. Seed companies are not very interested in an autogamous species because farmers only buy sowing seeds for the first season and later use their own harvested seeds for replanting.

Future prospects

Further breeding progress are necessary to include new sources of disease resistance in the new chickpea varieties; Marker Assisted Selection (MAS) would greatly accelerate the development of new chickpea cultivars. We have studied the utility of available markers for MAS in our breeding program and those are recommended to select in early generations (F_2). In addition, development of new plant materials as MAGIC (Multiparent Advanced Generation Intercross) populations using kabuli type as parental lines in order to generate new variability are in prospect. It will be also taken into account the use of anther culture in order to gain time in obtaining new cultivars. Freezing and chilling should be considered in chickpea breeding for winter sowing in Spain; both traits could affect chickpea at various stages of development from germination to maturation. However, in Spain, efforts in the release of new cultivars in order to increase cultivated area and chickpea yield should be accompanied by the increase of chickpea consumption contributing to a more healthy way of life. We expect that the chickpea growing area will increase in the future since this crop is well adapted to our conditions and nowadays it is growing the demand by the farmers. ■

Acknowledgments

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An overview of chickpea breeding programs in Tanzania

by Robert O. KILEO

Abstract: Chickpea is an important cash and food crop of small scale farmers in Tanzania. It is mainly grown on the vertisol flat plains of Lake Victoria basin and some patches in the North-east part of the country. The total chickpea area in Tanzania is about 110,000 ha and production is about 95,000 metric tons. The chickpea breeding program has started recently and is focusing on developing locally adapted cultivars with early to medium maturity, high yield potential, resistance to key diseases (fusarium wilt, collar rot and dry root rot) and tolerance to pod borer and soil salinity. Four chickpea varieties have been released in 2011. The adoption of these varieties is being enhanced by strengthening seed production and delivery systems.

Key words: chickpea, breeding, resistance, varieties, Tanzania

Introduction

Chickpea (*Cicer arietinum* L.) is among important legumes grown in Tanzania as both cash and food crop. The other legumes grown include common bean, groundnut, cowpea, pigeon pea, and mung bean. Chickpea is grown by small scale farmers owning 0.5 to 4.0 hectares of cultivated land. It is mainly grown in the Lake Zone of Tanzania (75% of country production) under residual moisture as relay cropping with cereals (maize, rice or sorghum). The Lake Zone occupies a vast land of vertisols (clay soils) locally called *mbuga* plains surrounding mainly the southern part of Lake Victoria. Relay cropping and good water holding capacity of vertisols make it possible to take two crops (cereals followed by legumes) per year under rainfed condition. Administrative regions where chickpea forms an important component of the farming system are Shinyanga, Mwanza, Tabora, Simiyu and Kigoma. The crop is also grown in the Northern zone of Tanzania in Arusha and Manyara regions.

Since Tanzania's independence (1961) to early 1990s, the chickpea area remained very low and ranged between 15,000 to 20,000 ha. The research and developmental efforts on crop management practices later contributed to expansion of chickpea area (3). The chickpea area is estimated to be around 110,000 ha. There is an increasing trend in chickpea area as the crop is fetching a good export market price in Asia. Similarly, the chickpea production has increased from less than 10 Mt during 1960s to 95,000 Mt. The partnership with International Crops Research Institutes for the Semi-Arid Tropics (ICRISAT) in Tropical Legumes II project has contributed significantly to this development (1). The average yield of chickpea in Tanzania is now about 950 kg ha^{-1}. This is mainly because of the promotion of research new varieties and good management practices. Famers who are using improved varieties are getting an average yield of 1,200 kg ha^{-1}.

Key constraints to chickpea production

Terminal drought. During the years of insufficient rainfall (less than 500 mm) or when rains cease too early (in May), the soils do not hold enough residual moisture to sustain the growth cycle, especially of the long maturing (more than 110 days to 75% maturity) varieties. The crop experiences drought towards the end of its season (terminal drought). The strategy has been to breed for short and medium maturing varieties that can complete their growth cycle before moisture is depleted from the root zone. Another one has been to develop varieties with deep and vigorous root system.

High temperatures. The chickpea crop, particularly if sown late, experiences high temperatures (> 30^{0}C), during the reproductive stage. Temperature stress at this stage adversely affects pod set and reduces grain yield.

Soil salinity or alkalinity. Water logging conditions in the clay soils build up the levels of soil salinity or make the soil alkaline (pH > 8). The capacity of roots to access and absorb nutrients is hampered, hence affecting the plant growth and its final yield (2).

Fusarium wilt (*Fusarium oxysporum*): Fusarium wilt is the most important disease affecting production of chickpea in Tanzania. All local varieties are susceptible to this pathogen, causing yield loss of over 55% under field conditions. It is a vascular disease that causes browning and blackening of xylem. Affected seedlings first show drooping of the leaves, then collapse. Though the roots look healthy, when split vertically the vascular tissues show brown to black discoloration. The fungus is seed and soil borne and can survive in the soil in the absence of the host.

Collar rot (*Sclerotium rolfsii*). This disease is becoming a serious problem in vertsols where high soil moisture, the presence of under decomposed organic matter on the soil surface and high temperature conditions prevail.

Dry root rot (*Rhizoctonia bataticola*). It is becoming an important disease under moisture stress conditions and when the crop is exposed to temperature above 30°C during the dry season. The disease generally appears around flowering and podding stage. The whole plant dries up and turns straw-colored. Roots become black and brittle and have only a few lateral roots or none at all.

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Pod borer (*Helicoverpa armigera*). It is the most important pest of chickpea in all the chickpea growing areas of Tanzania. It damages almost all the pods in case of severe damage, but on an average, causes nearly 40% - 60% annual yield losses. Larvae feed on leaves during the vegetative phase, on flowers and pods during the reproductive phase and on the developing seed at podding stage. Only few farmers are controlling it by spraying insecticides.

Ineffective seed production and delivery systems. There is no formal seed production and supply system established for chickpea in Tanzania. Most of the farmers rely on own-saved seed and access to seed of improved varieties is either through informal networks or assistance from research institutes or non-governmental organizations (NGOs). The farmers have limited access to the information about improved chickpea varieties and their seed. The private sector has also not shown interest in chickpea seed production.

Socio-economic constraints. Socio-economic constraints in the legumes sector in Tanzania include poor access to input and output markets, limited availability of improved seed varieties and other agricultural inputs (insecticides, fertilizers), inadequate agricultural extension services, and a general lack of market information. High transaction costs due to collection of farm produce from a large number of smallholder farmers and mixing of grains from different farmers and varieties resulting into poor market quality reduces the prices paid to the farmers.

Key objectives of chickpea breeding program

The chickpea breeding program started in Tanzania only after implementation of Tropical Legumes II project in 2007. The current priorities of this program includes development of locally adapted cultivars with early maturity, high yield potential, improved grain quality and resistance/tolerance to abiotic (terminal drought and heat stresses and soil salinity) and biotic (pod borer, fusarium wilt, collar rot and dry root rot) stresses (Fig. 1). In addition, efforts are being made to enhance adoption of recently released varieties by enhancing awareness of farmers about available improved varieties and production technologies and increasing availability of seed of new varieties through both formal and informal seed systems.

Figure 1. Field trials of the chickpea breeding program in Tanzania

Figure 2. Field days and training programs for the extension workers and farmers in Tanzania

Salient achievements

Establishment of a breeding program. Prior to 2007, the chickpea research was not a priority in the national agricultural research system (NARS) of Tanzania. With the implementation of Tropical Legumes II project, the Lake Zone Agricultural Research and Development Institute (LZARDI) of Ukiriguru initiated chickpea research and developmental activities in 2007. ICRISAT is leading the Tropical Legumes II project and helping LZARDI in strengthening the chickpea breeding programs by supplying germplasm and breeding materials, providing training to researchers and providing technical guidance in implementing research and developmental activities. Four Tanzanian researchers received one month training on "Chickpea Breeding and Seed Production" at ICRISAT, Patancheru, India.

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Figure 3. Field days and training programs for the extension workers and farmers in Tanzania

Figure 4. Field days and training programs for the extension workers and farmers in Tanzania

Release of 4 new varieties. The chickpea breeding lines received from ICRISAT were evaluated at multilocations and further selected lines were subjected to farmer-participatory varietal selection trials (FPVS). Four promising breeding lines were finally selected and proposed for release. These were formally released by the Tanzania National Variety Release and Seed Certification Committee in 2011. These include two desi (Ukiriguru 1 and Mwanza 1) and two kabuli varieties (Mwangaza and Mwanza 2). The important characteristics of these varieties include early maturity (90-100 days), high yield potential, resistance to fusarium wilt and the grain quality preferred by the domestic and international markets. These are the first chickpea varieties released in Tanzania.

Enhancing adoption of improved varieties. Extensive efforts have been made to strengthen the extension system and the seed production system so that the farmers have better access to information and inputs, including seed. Under the Tropical Legumes II project (TL II), a total of 68 FPVS trials were conducted. Several field days and training programs were organized for the extension workers and farmers for upgrading their knowledge on improved varieties and crop production practices (Fig. 2, 3 and 4).

Future prospects

Potentials exits for further expansion of chickpea area and increase in chickpea yield levels in Tanzania. The chickpea research and developments efforts need to pay high emphasis on the following:

- Increasing emphasis on addressing abiotic (temperatures, salinity) and biotic (Fusarium wilt) constraints using conventional and modern breeding tools;
- Establishing sustainable seed production strategy by linking with Tanzania Agricultural Seed Agency and other stakeholders in the zone;
- Improving the *Maize - Chickpeas* and *Rice - Chickpea* relay cropping systems by introducing suitable chickpea varieties into the system;
- Outsourcing resources to address capacity building needs (staff, infrastructure) and strengthening collaboration with other stakeholders by adopting new tools;
- Exploring market opportunities (linking, value addition, information) and inclusion of market and policy research into the program. ■

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An overview of chickpea breeding programs in Turkey

by Cengiz TOKER*, Fatma ONCU CEYLAN, Zeynep OZUGUR, Duygu SARI and Adem CETIN

Abstract: Turkey is not only one of the most important variation centers and cradle of thirteen wild *Cicer* species including endemic and endangered species, but also important producer and exporter countries in the world. Aims of this communication are to review (i) current status of the cultivated chickpea; (ii) stresses caused yield reduction, (iii) achievements of breeding programs, and (iv) future strategies of the chickpea breeding in Turkey. Although drought, heat, freezing, ascochyta blight and weeds are referred to as common and important stresses, macro and micronutrient deficiencies and toxicities including salinity are known as local stresses in Turkey. About 30 commercial varieties have been released via selection, hybridization and mutation breeding. MAS and novel biotechnological approaches for resistance to biotic and abiotic stresses should be considered for pyramiding of the valuable gene(s) or QTL(s) in ideotype breeding.

Key words: chickpea, *Cicer arietinum*, wild species, drought, cold, ascochyta blight

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Current status of chickpea production

With the cultivated chickpea (*C. arietinum* L.), thirteen *Cicer* species including *C. anatolicum* Alef., *C. bijugum* K.H. Rech., *C. echinospermum* P.H. Davis, *C. floribundum* Fenzl, *C. heterophyllum* Contandr *et al.*, *C. judaicum* Boissier, *C. insicum* (Willd.) K. Maly, *C. isauricum* P.H. Davis, *C. montbretti* Jaub. & Sp., *C. pinnatifidum* Jaub. & Sp. and *C. reticulatum* Ladiz. and *C. uluderensis* Donmez are naturally grown in Turkey. Turkey with these genetic resources is one of the most important variation centers and cradle of *Cicer* species including endemic, endangered and progenitor species as well.

The cultivated chickpea called 'nohut' in Turkish is traditionally grown in many provinces except for some provinces in the East Black Sea region of Turkey. Mersin, Kirsehir, Kutahya, Konya and Antalya are the top five provinces based on sowing areas in Turkey. Average seed yield in 2011 ranged from 750 kg ha^{-1} to 3000 kg ha^{-1} (8). According to Food and Agriculture Organization Statistics in 2010 (4), it is produced 530,634 t ha^{-1} from 446,218 ha areas with average seed yield of 1,189 kg ha^{-1}. Turkey is the fifth rank on the basis of chickpea sowing areas in the world after India, Pakistan, Iran and Australia. With 56 896 t export quantities in 2010, Turkey is still one of the most important chickpea exporter countries in the world, despite declined trend in its export quantities and values (4). Average seed yields, sowing areas and production quantities (8), export quantities and values (4) of the chickpea in Turkey were summarized in Table 1. Another one has been to develop varieties with deep and vigorous root system.

Key constraints to chickpea production

The cultivated chickpea is mainly grown as spring crop in cereal-dominated rotation from sea level to 3,000 m altitudes in Turkey (5) in spite of the fact that it has recently been sown in autumn at medium altitudes in some region of Anatolia.

It is generally sown from March to May (5) at the end of spring rainfall to escape devastating disease of chickpea, ascochyta blight caused by *Ascochyta rabiei* (Pass.) Labr. The crop therefore suffered from terminal and unpredictable or intermittent drought accompanying by high temperature (heat) stress during reproductive stage when it is sown in spring months.

If the chickpea is sown in autumn months to overcome drought and high temperature stresses, it faces cold (freezing) and ascochyta blight stresses during seedling and reproductive stages, respectively (6).

Fusarium wilt caused by *Fusarium oxysporum* f. sp. *ciceris* (Padwick) synd. and Hans (5) is the other disease of the cultivated chickpea from year to year and from location to location. Weeds are one of the most important yield constraints especially in autumn or winter-sown crop. The pod borer (*Helicoverpa armigera* (Hub.)) and leaf miner (*Liriomyza cicerina* Rondani) under field conditions and seed beetles (*Callosobruchus* sp.) under stored conditions are the common cosmopolitan insect pests of the chickpea in Turkey (5).

Table 1. Seed yield, sowing areas, production and export quantities of the chickpea in Turkey

Years	Area (ha)	Production (t)	Seed yield (kg ha^{-1})	Export quantities (t)	Export values (1,000 USD)
1988	778 000	777 500	999	527 361	155 803
1989	818 000	683 000	835	179 311	884 75
1990	890 000	860 000	966	276 927	135 434
1991	878 000	855 000	974	367 033	139 865
1992	856 000	770 000	900	267 819	106 836
1993	820 000	740 000	902	202 010	81 610
1994	760 000	650 000	855	102 510	58 539
1995	745 000	730 000	980	123 825	110 531
1996	780 000	732 000	939	192 710	112 104
1997	721 000	720 000	999	263 189	107 587
1998	665 000	625 000	940	157 890	771 72
1999	625 000	560 000	896	101 668	57 844
2000	636 000	548 000	862	50 137	33 132
2001	645 000	535 000	830	153 953	75 288
2002	660 000	650 000	985	104 671	48 101
2003	630 000	600 000	952	189 600	82 552
2004	606 000	620 000	1023	133 073	69 166
2005	557 800	600 000	1076	123 593	83 026
2006	524 367	551 746	1052	104 685	66 066
2007	503 675	505 366	1003	69 193	41 873
2008	505 165	518 026	1026	88 338	76 758
2009	455 934	562 564	1234	88 507	74 969
2010	455 690	530 634	1165	56 896	54 709
2011	446 413	487 477	1092	-	-

Table 2. Importance of biotic and abiotic stresses caused yield losses in the chickpea in Turkey

Abiotic	Drought	Heat	Freezing	Chilling	Salinity	N, P, Fe, Zn	B
Importance	***	**	**	*	*	*	*
Biotic	A. blight	F. wilt	Weeds	Pod borer	Leaf miner	Seed beetle	
Importance	***	*	***	**	**	*	

Macro and micronutrient deficiencies and also micronutrient toxicities including salinity in the chickpea growing areas in Turkey result in yield losses. Macro and micronutrients are nitrogen (N), phosphorous (P), iron (Fe) and zinc (Zn) deficiencies and boron (B) toxicity. Biotic and abiotic stresses caused yield losses in the chickpea in Turkey are given in Table 2.

Major aims in breeding programs

Chickpea breeding programs focus on seed yield in 'kabuli' or '*macrospema*' chickpeas because 'desi' or '*microsperma*' chickpea are not commercially grown in Turkey. According to Turkish Standards Institution (TSE), four different seed shapes are commercially traded in the domestic markets; (i) extra large seeds called ram-shaped or 'ispanyol', (ii) large seeds called owl-shaped or 'leblebilik', (iii) medium seeds called pea-shaped or 'yuvarlak' and (iv) mixture of these seeds. The first two standards with high seed yield are main goals in breeding programs. Also, drought and freezing tolerance are major aims for spring- and autumn-sown crop, respectively. All commercial varieties are tested for resistance to ascochyta blight and quality traits before release them. As a principal, varieties must be resistant at least one patotype or some races of ascochyta blight. Combine harvestable trait is one of the most important characteristics.

To increase yield of chickpea, three approaches are widely used with: (i) winter-sown chickpea at medium altitudes, (ii) early spring-sown, and (iii) traditionally spring-sown chickpea in spring months.

Salient achievements

Genetics and breeding studies were started to evaluate morphological traits and select for resistance to ascochyta blight from 1950s to 1980s after genetic resources had been collected in 1930s and later years (3, 5). Improvement of varieties has been triggered via transfer of breeding material by the International Center for Agricultural Research in the Dry Areas (ICARDA), established in 1977 in Aleppo, Syria. More than 30 commercial varieties have been released via selection, hybridization and mutation breeding so far. The following varieties; Akçin-91, Aksu, Aydın-92, Azkan, Cevdetbey 98, Çağatay, Dikbaş, Diyar-95, Er 99, Gökçe, Gülümser, Hisar, ILC-482, Işık-05, İnci, İzmir-92, Küsmen 99, Menemen-92, Sarı 98, TAEK-Sağel, Uzunlu 99, Yaşa-05, Hasanbey, Seçkin, Aziziye, Damla-89, Çakır, Ilgaz, Sezenbey, and Zuhal are currently and commercially grown in Turkey. Most of these varieties have high yield capacity, large or extra large seeds and they are suitable for combine harvest, and resistant at least one patotype of ascochyta blight (7). Also, all of these varieties are 'kabuli' or '*macrosperma*' chickpeas with single flower per axis. One of them have simple leaf shape. All research activities in food legumes including chickpea were chronologically reviewed by Ciftci (1, 2).

Future prospects

Collection, documentation, and evaluation of wild *Cicer* species have top priority since genetic resources are endanger in their habitats. Suitable gene(s) should be transferred from the primary gene pool to the cultivated chickpea or incorporated into some breeding lines. Mutation breeding can be strongly advised to increase genetic variation. Molecular markers could be used for identification of QTLs related with resistance to abiotic and biotic stresses. Marker assisting selection (MAS) and novel biotechnological approaches for resistance to biotic and abiotic stresses should be considered for pyramiding of the valuable gene(s) or QTL(s) in ideotype breeding. ■

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Chickpea production in the US

by George VANDEMARK

Abstract: In the United States, chickpeas are grown primarily in the Pacific Northwest (ID and WA). Chickpea production in the US over the past five crop seasons (2007-2011) has had an average annual production value of approximately 50 million USD. The initial epidemics of Ascochyta blight disease in the Pacific Northwest resulted in devastating crop losses, so developing varieties with resistance to blight remains a priority in the US. Two other important traits for chickpea improvement in the US are early maturity and large seed size. Early maturity will reduce the need for pre-harvest applications of dessicant herbicides. Larger seeds enjoy a price premium of over 50% more than small chickpeas. The increasing value of chickpeas in the US will likely result in an expansion of acreage in the near future.

Key words: chickpea, breeding, resistance, varieties, USA

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In the United States, approximately 70% of chickpeas are grown in the Pacific Northwest (ID and WA), with the other 30% being produced in the Northern Plains (MT and ND) and the Southwest (CA and AZ). Over the past five crop seasons (2007-2011) an average of more than 115,000 acres of chickpeas were planted with an annual production value of approximately $50 million (5). The USDA National Agricultural Statistics Service classifies chickpeas grown in the US as 'small' (< 8 mm seed diameter) and 'large' (> 8 mm). Small chickpeas are used almost exclusively for humus production. Large chickpeas are used for the fresh and canning markets. In 2011 large chickpeas represented approximately 73% of the total chickpea production in the US large beans, which likely reflected the higher prices offered for large chickpeas (≈ 39 USD per 100 cwt) compared to small chickpeas (≈ 24 USD per cwt) (5).

The relatively low production value per acre of chickpeas precludes the use of most chemical methods for controlling diseases and insect pests. Diseases still cause considerable losses to chickpea production in the US. The initial epidemics of Ascochyta blight disease in the Pacific Northwest resulted in devastating crop losses (3), so developing blight resistant varieties remains a priority for the US. The chickpea germplasm CA0490C025C, released by the USDA-ARS in 2011, is highly resistant to Ascochyta blight. Besides Ascochyta blight, chickpea production in the US is also impacted by several other diseases of generally minor significance, including Bean Leaf Roll Virus (4) and wilt caused by *Fusarium oxysporum* f. sp. *ciceris* (2).

Two other important traits to chickpea producers in the US, and consequently traits of interest to breeders, are early maturity and large seed size. Chickpeas are typically harvested in the US during August-September to avoid autumn precipitation. However, most chickpea varieties have not sufficiently senesced by this time to be harvested. Consequently, most chickpea growers in the US apply a desiccant herbicide, such as glyphosate, to the crop 7-10 days prior to harvesting. Earlier maturing chickpea varieties might allow growers to harvest their crop without having to apply desiccant herbicide prior to harvest. Early maturing varieties may also allow growers to delay sowing during the spring planting season, which is recommended as to manage losses to ascochyta blight (1). Large seed size is a critical trait for chickpeas intended for the fresh or canning markets, with larger seeds having a light cream to white color being more desirable than smaller and darker seeds. Over the past five years (2007-2011), producers in the US have received an average of 32.50 per cwt for large chickpeas, a 52% premium over the average price of small chickpeas (5).

The global importance of chickpeas to human nutrition results from additive effects of biological and cultural factors, of which raw production, consumer acceptance, and nutritional value are especially prominent. The concentration in seed of several essential minerals, including selenium (Se), magnesium (Mg), iron (Fe) and zinc (Zn) are relatively low in legumes (6). Work is in progress to characterize seed mineral concentrations of advanced chickpea breeding lines and commercial varieties commonly grown in the US. Significant effects have been observed for genotype, location, and genotype x location interactions for the majority of seed mineral concentrations (Table 1).

Table 1. F Ratios (Prob > F) for effects test of genotype and environment on seed mineral concentrations for 20 chickpea breeding lines and three check varieties examined at three locations in 2010 (Pullman, WA, Genesee, ID and Kendrick, ID)

Source	DF	Calcium	Potassium	Magnesium	Phosphorus
Genotype (G)	22	9.65 (< 0.0001)	12.8 (< 0.0001)	4.12 (< 0.0001)	20.6 (< 0.0001)
Environment (E)	2	0.64 (0.53)	52.2 (< 0.0001)	0.44 (0.64)	63.13 (< 0.0001)
G x E	44	1.05 (0.41)	1.12 (0.31)	1.11 (0.31)	3.14 (< 0.0001)

In conclusion, chickpea production in the US is experiencing an increase in the acreage under production, value per unit of production, and total production value. Objectives for breeding programs continue to be the development of new varieties that combine high yield with desirable agronomic traits, such as early maturity, and desirable market traits such as large seed size, light color, and high nutritional value.

The increasing value of chickpea production in the US will invariably lead to grower interest in producing chickpeas in regions where they have not been historically grown. The expansion of chickpea production into these new regions will likely result in the identification of emerging diseases and abiotic constraints that will require the attention of breeding programs. ■

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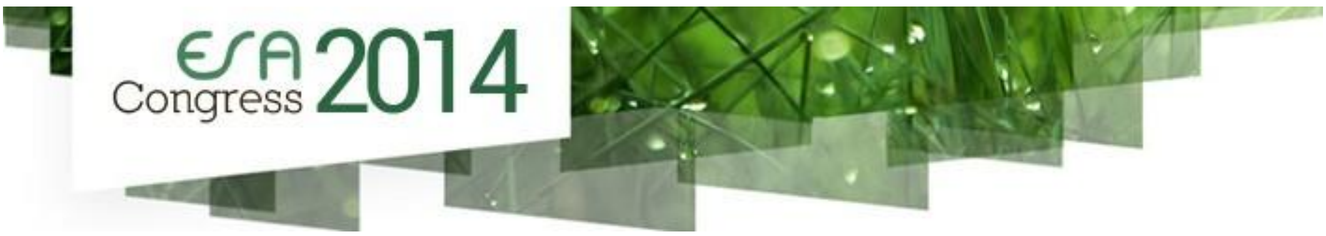

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