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Global Lentil Production : Constraints and Strategies

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ABSTRACT

Lentil (*Lens culinaris* ssp. *culinaris*) is an important food legume crop with global production of 3.59 million tonnes. The crop suffers substantial yield losses from various biotic and abiotic stresses. Past efforts have been directed towards developing improved varieties with resistance to one or the other biotic stress, improving the seed size and shortening the crop duration to fit lentil in various cropping systems. In the past one decade, production and productivity of lentil have stagnated in the traditional base of South Asia. In order to break the current yield plateau in lentil, there is a need to develop extra short duration varieties for rice-based systems for South Asia, drought and heat tolerant varieties with multiple disease resistance for all the regions, and herbicide-tolerant and machine harvestable varieties for West Asia and North Africa (WANA) region. This requires a comprehensive research for developing strategy involving both the conventional and genomics tools.

Key words : Lentil germplasm, Production constraints, Research Progress, Strategies.

Introduction :

Lentil (*Lens culinaris* ssp. *culinaris*) is an important food legume with various uses as food and feed because of its protein-rich grains and straw. Globally, it is cultivated as a rainfed crop on 3.85 million hectares (m ha) area with 3.59 million tonnes (mt) production (Erskine *et al.*, 2011). The major geographical regions of lentil production are South Asia and China (44.3%), North America (41%), Central and West Asia and North Africa i.e. CWANA (6.7%), Sub-Saharan Africa (3.5%) and Australia (2.5%). South Asia grows lentil on 1.8 m ha area with 1.1 mt production exclusively as a post-rainy season crop on residual moisture whereas CWANA region with Turkey, Syria, Iran and

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Morocco as main producers grow winter and spring planted lentil on 0.59 m ha area with 0.48 mt production. In the Sub-Saharan Africa, Ethiopia is the major producer with 0.11 mt lentil. India is the second largest producer of lentil in the world after Canada with a total production of 1.03 mt. World lentil production has risen steadily by nearly four times (375 %) from an average of 0.92 mt in 1961-63 to 3.59 mt in 2008-10. This growth is primarily from an expanding harvested area from 1.64 m ha in 1961-63 to 3.85 m ha in 2008-10. Additionally, it also reflects an improvement in productivity from an average yield of 560 kg ha^{-1} in 1961-63 to 930 kg ha^{-1} by 2008-10. Its consumption is primarily in Asia, where seven of the top 10 lentil producing countries lie. Most production (56%) is consumed locally with only 44 % of the global production exported. The global import and export of lentil are 1.71 mt worth 1.55 million USD and 1.79 mt worth 1.48 million USD, respectively. Lentil remains in short supply in South Asia and CWANA regions due to mismatch in the levels of present production (1.19 and 0.48 mt) and consumption (1.83 and 0.88 mt). The demands for lentil in these two regions are expected to rise further due to population growth and rising income. By 2030, the world lentil consumption is estimated at 5.5 mt, being an increase of almost 2 mt from the present level (Clancey, 2009).

Production Constraints :

Average productivity of lentil in South Asia and CWANA region is less than the world average mainly due to prevalence of different biotic and abiotic stresses. Improved varieties have shown yield up to 5 t ha^{-1} on research fields and up to 3 t ha^{-1} on farmers' fields in Ethiopia (Schneider and Anderson, 2010). Yield gaps of 30-105% with an average of 42% have been reported from different production zones in India (Reddy and Reddy, 2010; Ali and Gupta, 2012). In CWANA region, the average productivity is 840 kg ha^{-1} with regional variation from 342 kg ha^{-1} in Tunisia to 1,338 kg ha^{-1} in Turkey as compared to the potential yield of 3,500 kg ha^{-1}. South Asia grows lentil exclusively as a post-rainy season crop on residual moisture and therefore, early withdrawal of rains adversely affects its establishment. The crop also confronts sudden rise in temperature and depleting soil moisture at grain filling stage, causing forced maturity. Fusarium wilt, root rot and rust diseases inflict heavy losses to the crop. Stemphylium blight also causes economic losses in certain pockets. The crop is relatively free from any serious infestation of insect pests except occasionally pod borer (*Etiella zinkenella*) and aphids (*Aphis craccivora*). Ultimately, all these contribute to poor yields of lentil in the region. In CWANA region, amount and distribution of rainfall during the crop season determine the lentil yield. Low temperature at seedling and flowering stages, intermittent drought throughout the crop season, and terminal drought and heat are common events (Silim *et al*., 1993; Wery *et al*., 1994). Spring planted crop frequently experiences terminal drought, heat stress and high incidence of root diseases whereas the winter planted crop encounters cold temperature, frost injuries and high incidence of Ascochyta blight. Weeds are rampant, more so in winter sown crop, causing very high damage to the crop. The crop is also infested with Sitona weevils (*Sitona crinitus*) in the region. In Sub-Saharan Africa, the crop is grown rainfed and suffers significant yield losses due to water stress at critical growth stages and a wide spectrum of diseases. Rust is a serious constraint followed by Fusarium wilt, root rot, Ascochyta blight, aphids and bruchids. However, the major biotic and abiotic constraints in lentil, based on extent of losses (%) in different regions, are given in Table 1.

Table 1. Yield losses (%) due to major biotic and abiotic constraints in lentil

Stresses	South Asia	Sub-Saharan Africa	CWANA
Abiotic	**28.0**	**28.0**	**28.0**
Drought	15.0	20.0	15.0
Heat, cold and frost	13.0	8.0	13.0
Diseases	**40.0**	**27.0**	**22.0**
Wilt/root rot	20.0	12.0	10.0
Rust	10.0	8.0	7.0
Ascochyta/Stemphylium blights	10.0	7.0	5.0
Insect Pests	**12.0**	**15.0**	**20.0**
Sitona weevil/bruchids	5.0	10.0	15.0
Aphids	7.0	5.0	5.0
Parasitic weeds	**-**	**-**	**10.0**
Soil factors	**20.0**	**30.0**	**20.0**

Research Progress and Strategy :

International Center for Agricultural Research in the Dry Areas (ICARDA) has a global mandate for lentil improvement. It carries out basic and strategic research of applied nature to identify useful gene pool and generate improved germplasm for adaptation to CWANA region, South Asia and Sub-Saharan Africa. ICARDA holds one of the largest collections of lentil with 11,643 accessions. ICARDA has provided 1,03,197 seed samples to scientists in 52 countries since its establishment. However, only a small proportion of the lentil germplasm has been used in improvement programs. Plant breeders are often reluctant to use new germplasm resources due to lack of reliable information for specific traits, associated linkage drag, high genotype-environment interaction, assumed risks while dealing with unknown and wild germplasm lines, and restricted access due to limited seed availability and regulations governing international germplasm exchange. At ICARDA, a core collection consisting of 1,150 accessions has been developed to make comprehensive germplasm evaluation.

Recently, ICARDA has applied Focused Identification of Germplasm Strategy (FIGS) to improve the utilization of lentil germplasm and share the same with national partners. In the past, efforts were made to evaluate germplasm for biotic and abiotic stresses, grain quality and nutritional traits and their utilization in the breeding programmes, resulting in the improved elite breeding lines. Multi-environment evaluation of these elite lines has resulted in the release of 116 improved varieties of lentil in 33 countries. This includes 29 varieties for West Asia, 27 for South Asia, 4 for Central Asia, 35 for North Africa and Sub-Saharan Africa, 12 for Oceania, 4 for North America, 3 for Latin America and 2 for Europe. The major success has been achieved in terms of increasing per day productivity by improving seed size and reducing the crop duration to match the production environments in addition to insulating varieties against key pathogens such as Fusarium wilt and rust, and developing varieties amenable to machine harvest. This has also resulted in widening the genetic base of cultivated germplasm in South Asia. Some of the past successes of ICARDA's lentil program are as follows :

Short duration varieties for rice-based systems : South Asia's cereal-cereal systems are dominated by rice-wheat (9.77 m ha) and rice-rice (2.12 m ha) systems in the Indo-Gangetic Plains. Expansion of more productive wheat in northern India, and *boro* rice in Bangladesh and northeastern India has resulted in substantial reduction in area under legumes. This is primarily because of the unsuitability of traditional varieties in these cropping systems. With cereal yields projected to double over the next 30 years, this trend of pushing out legumes is likely to continue unless extra early varieties that fit in these cropping systems are developed. Similarly, in the rainfed rice growing areas of South Asia that are mono-cropped under medium and long duration varieties of rice and termed as rice-fallows, the top soil layer generally dries completely at the time of the rice harvest and thus planting of a post-rainy season crop is not feasible. Under such conditions, extra early lentil varieties could convert these mono-cropped areas into double cropped areas, and thus increase legume production and sustain productivity of the rice-based systems. The focus at ICARDA is placed on extra early varieties with multiple disease (wilt, stemphylium blight and rust) resistance, early vigor, adaptation to terminal drought, large seeds and fast grain filling process for these systems. Short duration varieties of lentil shows a typical drought avoidance strategy at the reproductive stage when high temperatures and water deficits induce rapid senescence and early maturity (Erskine *et al*., 1994; Shrestha *et al*., 2006). Under the short season rainfed environments, the superior performance of lentil genotypes from South Asia and derivatives from crosses between South and West Asian lentils has been correlated with rapid canopy cover, early phenology and high harvest index (Shrestha *et al*., 2005). Therefore, genotypes with rapid ground cover, early phenology, and prolonged flowering and podding period, leading to increased dry matter production, more pods, high harvest index, efficient water use and large seeds, are targeted to adapt to drought and heat stresses. Most of the progress in breeding for terminal heat escape has been made in development of short duration varieties such as BARI M4, BARI M5, BARI M6 and BARI M7 without compromising yield level. Evaluation of lentil germplasm under delayed planting in field and wooden boxes in plastic house with and without irrigation at regular interval has resulted in identification of tolerant genotypes for heat (ILL 3597, Sel # 33108, 33109, 33110 and 33113) and drought (ILL1878, ILL 6002, ILL 759 and ILL 6465).

Widening the genetic base of lentil cultivars in South Asia : Pilosae group, the cultivated germplasm of South Asia, has very narrow genetic base as gene flow from other group such as CWANA is almost nil due to crossing barrier and duration difference. Introgression of useful genes from Macrosperma germplasm and wild species has been taken up at ICARDA to widen the genetic base of lentil cultivars in South Asia by introducing exotic early flowering material into the Indian subcontinent. For example, flowering of Precoz, an early maturing Argentinean lentil, is well synchronized with the local South Asian germplasm. Precoz has been used extensively to incorporate such traits as large seed size, rust resistance and early vigor in locally adapted background since 1985. The crosses between Precoz and local lentils have resulted in the development of extra bold and extra early maturing cultivars in South Asia. Some of them *viz.* VL Masoor 507, Narendra M1, Priya and Angoori with large seeds are popular with farmers in India.

Winter hardiness lentils for CWANA region : In the highlands of CWANA region, lentil suffers from low temperature at seedling stage. To overcome this problem, long duration varieties with winter hardiness, cold/frost tolerance and Ascochyta blight resistance are developed. Ali *et al*. (1991 and 1999) screened lentil cultivars under different temperature regimes and identified cold hardy genotypes. Evaluation of 3,592 accessions under field conditions in Central Anatolia showed large genetic variability for cold tolerance with as many as 238 accessions as tolerant (Erskine *et al*., 1981). Some of the winter hardy genotypes identified are ILL52, ILL465, ILL468, ILL590, ILL662, ILL669, ILL780, ILL857, ILL975, ILL1878, ILL1918, ILL7115, ILL7155, WA8649041 and WA8649090 (Erskine *et al*., 1981; Hamdi *et al*., 1996). ICARDA breeding program has been successful in incorporating winter hardiness in elite breeding lines such as ILL9832, ILL9918 and ILL9919, and improved varieties such as Kafkas, Uzbek and Cifci in Turkey; Gachsaran in Iran; Shiraz-96 in Pakistan; and Bichette and Zaria in Morocco. In winter sown lentil, weeds (parasitic and non-parasitic) are major production constraints. Non-parasitic weeds compete for light and nutrients, often leading to up to 40% yield losses in legume crops (Tepe *et al*., 2005; Ali and Gupta, 2012). Manual weeding has become uneconomical and impractical for many smallholder farmers due to competing on- and off-farm activities and high labor wages. Herbicide-tolerant varieties have recently been developed in Canada and Australia (Slinkard *et al*., 2007) which hold great promise in expansion of lentil area under conservation agriculture. Besides common weeds, parasitic weeds like *Orobanche* have also emerged as a threat to lentil production in some Mediterranean countries (Rubiales *et al*., 2006). Screening of 1,774 germplasm accessions in the infested field did not show genetic resistance to *Orobanche* (Erskine *et al*., 1994). Only recently, potential resistant sources with significant reduction in infection density have been reported in Spanish germplasm (Fernandez-Aparicio *et al*., 2008) that could be used in lentil breeding. Evaluation of wild germplasm against *O. crenata* showed higher resistance in *Lens ervoides*, *L. odemensis* and *L. Orientalis*. Two accessions, ILWL 361 and LENS166/92 showed true resistance to *Orobanche* (Fernandez-Aparicio *et al*., 2009).

Machine harvestability : Manual harvest of lentil is becoming increasingly uneconomical because of the rising labor cost and shortage of labor at the peak harvest time. Delaying crop harvests leads to significant grain losses and their quality. While harvesting of lentil crop is mechanized in the developed world, developing countries largely follow hand-harvest due to lack of improved varieties amenable to machine harvesting. In order to use combine-harvesters, lentil varieties need to be modified. This requires development of varieties with erect and tall plants, strong stems, top pod bearing habits, synchronous maturity, and tolerance to lodging and pod shattering. Genetic variability for these traits exists in the germplasm. Mutants with upright growth habit have been identified and used for development of improved breeding lines (Erskine and Goodrich, 1991). Lines amenable to mechanical harvest are ILL590, ILL1005, ILL6037, ILL6212, ILL6994, ILL7155 and ILL7947. These are tall (>30 cm) with more ground clearance (>15 cm) without reduction in the pod bearing length and number of pods. These lines have strong stem and tolerance to lodging, pod shattering and pod drop. ICARDA developed economic machine harvest systems involving a flattened seedbed, cultivars with improved standing ability and the use of cutter bars. On-farm trials and demonstrations confirmed the value of the mechanization package. Idleb 2 variety has been found to be suitable for machine harvest (El-Ashkar *et al*., 2003).

Large seeded varieties : There are two broad kinds of lentils: large seeded with yellow cotyledon, no pigmentation, grown mostly in Mediterranean region and the New World; and small seeded with red or yellow cotyledon, grown mostly in the Indian subcontinent and parts of Africa. Both types are grown in West Asia. Green lentils are generally traded as whole seeds with the seed coat intact. But the green seed coat turns brownish in storage – so retention of seed coat color is an important selection criterion. Another criterion is large seeds: above 6 mm in diameter and 100-seed weight above 4.5 g. Red lentils are sold after the seed coat is removed and the seed is split. Selection criteria are therefore different: smaller, round seeds with 100-seed weight below 4.0 g. With careful seed selection during the breeding program, ICARDA's breeders are helping to develop varieties that will fetch premium prices in each distinct market. Recently, efforts have been made to capture the enormous variability existing for iron (Fe) and zinc (Zn) content in lentil. Fe content varied from 41.0 to 132.0 mg kg^{-1} and Zn content ranged from 22.0 to 103.7 mg kg^{-1}.

Soil minerals imbalance : Lentil is generally grown in soil with imbalance in key minerals such as Fe and boron (B) constraining its yield in countries like India and Ethiopia. However, these stresses remain of local importance. For example, Fe-deficiency is a common soil disorder especially in high pH soils, causing 18-25% yield losses in susceptible genotypes in India and up to 47% in Syria (Ali *et al*., 2000; Erskine *et al*., 1993). Screening of 3,512 accessions from 18 countries indicated that tolerance to Fe-deficiency was common among genotypes from Syria and Turkey (Erskine *et al*., 1993). Similarly, B-deficiency has been observed in the eastern Terai plains of Nepal, eastern India and northern Bangladesh. Landraces from Nepal and Bangladesh such as ILL2580, ILL5888, ILL8009 and ILL8010 were tolerant to B-deficiency (Srivastava *et al*., 2000). B-toxicity has also been reported from South Australia, India, Iraq, Pakistan, USA and the Mediterranean environment of West Asia and North Africa (WANA) region where lentil is usually grown under rainfed conditions (Yau and Erskine, 2000). Screening of 231 accessions of different origins showed ILL1765, ILL5883, ILL2439, ILL7127, ILL5845 and ILL6797 as tolerant to B-toxicity. In general, frequency of occurrence of tolerance was more among accessions from Afghanistan followed by those from India, Iraq, Syria, Europe, Ethiopia and Nepal. Hobson *et al*. (2006) identified ILL2024, ILL1818, ILL1763, ILL1796 and ILL5845 as tolerant genotypes to B-toxicity.

Disease resistant varieties : Among root diseases, Fusarium wilt caused by *Fusarium oxysporum* f.sp. *lentis* is a widespread disease of lentil particularly in rainfed areas worldwide. Losses due to vascular wilt vary (5-12%), and may reach up to 72% in Syria (Bayaa *et al*., 1986) and a complete crop failure in India (Khare, 1981). Pathogenic variability has not yet been established though geographical differences in pathogenicity have been noticed (Erskine and Bayya, 1996). Over the years, screening of about 20,000 lines in a well-established wilt sick plot at Tel Hadya has resulted in identification of 325 accessions with complete resistance (Kumar *et al*., 2010). High level of resistance was also observed in wild species, *Lens culinaris* ssp. *orientalis* (ILWL 113) and *L. culinaris* ssp. *ervoides* (ILWL 138), according to Bayya *et al*. (1995). Utilization of resistance sources such as ILL5883, ILL5588, ILL4400 and ILL590 has resulted in the development of a wide spectrum of improved varieties for cultivation in different countries. Some of the prominent wilt resistant varieties are Idleb 2, Idleb 3, Idleb 4 and Ebla 1 in Syria; Talya 2, Rachayya and Hala in Lebanon; Firat 87 and Syran 96 in Turkey; Ada'a, Alemaya, Assano, Alemtina and Teshale in Ethiopia; IPA 98 in Iraq; and Pant L406, Pant L4, Priya, Seri, JL3, Noori and VL507 in India. In spite of good progress in breeding wilt resistant varieties in lentil, its impact could not be translated into a success story due to their susceptibility to pathogens causing other root rot diseases such as collar rot (*Sclerotium rolfsii* Sacc.) and dry and wet root rot (*Rhizoctonia*). Due to lack of efficient screening techniques, stable resistance for these pathogens has not been identified, and thus remain the major breeding goals of lentil in South Asia, Sub-Saharan Africa and WANA region.

Among foliar diseases, rust caused by *Uromyces vicia-fabae* is a serious yield constraint in Bangladesh, Ethiopia, India, Morocco, Nepal, Pakistan and South America. The extent of damage depends upon the crop stage, host genotype, inoculums load and severity of the infection. Yield losses to the extent of 60-69% have been reported in India (Singh *et al*., 1986) and up to 100% in Ethiopia (Negussie *et al*., 2005). Studies have indicated pathogenic variability in the fungus (Singh *et al*., 1995). Screening of germplasm at hot spots in Ethiopia, India and Pakistan has resulted in identification of effective rust resistance donors such as ILL358, ILL4605, ILL5604, ILL6002 and ILL6209 (Bejiga *et al*., 1995; Singh and Sandhu, 1988). The most frequently used donor for rust resistance in South Asia was Precoz. Some of the successful rust resistant varieties developed are BARI M2, BARI M4, BARI M5 BARI M6 and BARI M7 in Bangladesh; Masoor93 and Masoor2002 in Pakistan; R186, Ada'a, Alemaya, Gudo, Assano, Alem tina and Teshale in Ethiopia; Bakaria, Hamira, Bichette, Zaria and Chouia Abda in Morocco; and Pant L4, Lens 4076, L4147, Sapna, Priya, Seri, Noori, KLS218, HUL57, VL126, IPL406 and WBL77 in India.

Ascochyta blight caused by *Ascochyta fabae* f.sp. *lentis* is a devastating fungal disease posing a serious obstacle in realizing the potential yield of winter lentils in the cool and humid climates around the world, especially Canada, Australia, Latin America, Ethiopia, Pakistan, Northwest plains of India, the USA and highlands of WANA region (Erskine *et al*., 1994). In epidemic form, it causes up to 70% yield losses in Canada (Gossen and Morrall, 1983) and 30-40% in Pakistan. Although pathogenic races have not been reported, differential reaction of some lines in different countries suggests pathogenic variability in the fungus. Cultivated and wild species were screened using efficient and reliable field and laboratory screening techniques. These efforts have culminated in identification of useful resistance sources (Ahmad and Morrall, 1996; Cromey *et al*., 1987; Iqbal *et al*., 1990; Singh *et al*., 1982). Resistance to Ascochyta blight has been common in wild species such as *Lens orientalis*, *L. odemensis*, *L. nigricans* and *L. ervoides* (Bayya and Erskine, 1994). Resistance sources such as Indianhead, ILL358, ILL857, ILL5562, ILL5588, ILL5684, ILL5883 and ILL6024 have been used as donors, and prominent varieties such as Pant L406 in India; Masoor 93 in Pakistan; Laird, CDC Redwing, CDC Milestone and CDC Matador in Canada; and Nugget, Nipper and Cassab in Australia have been developed.

Stemphylium blight caused by *Stemphylium botryosum* has emerged as an important disease in Bangladesh and may cause up to 62% yield reduction (Bakr, 1993). Occurrence of this disease has also been reported from northeast India (Sinha and Singh, 1991). Disease intensity as high as 83% was observed on an unsprayed local cultivar in Bihar of India, causing >90% yield loss (Sinha and Singh, 1993). Recently, the disease has also been reported from Nepal and Canada. Limited efforts have been made to screen lentil germplasm against the pathogen. Genotype ILL 4605 has been reported to have resistance to Stemphylium blight. Collaborative efforts between ICARDA and Bangladesh national programs have resulted in development of Stemphylium blight tolerant varieties like BARI M4, BARI M5, BARI M6 and BARI M7.

Constraints to Adoption of New Technologies :

Lentil is mostly grown by marginal and small holder farmers who have low purchasing power and limited accessibility to markets to buy production inputs. Productivity is below potential due to: low input usage, especially chemical fertilizers capable of increasing yields in field trials; limited availability of seed and limited familiarity with the new varieties; and limited usage of modern agronomic practices. Non-availability of quality seeds remains one of the greatest impediments in bridging the wide gap between potential and harvested yields. The present status of seed production in lentil indicates that indent for breeder seed is low because of poor seed replacement ratio (2-3%) as against the desired level of 10-15%. Furthermore, a new cultivar takes a much longer time than needed before it reaches to its ultimate user i.e. farmers. It is assessed that availability of quality seeds in time can uplift at least 20% production even with the available varieties and production technologies. Table 2 indicates different constraints to adoption of lentil technologies in different regions.

Table 2. Constraints to adoption of lentil technologies in different regions

Regions	Constraint / Technology	Barriers to adoption
South Asia	Low yields, Wilt and root rots, Weed menace, Harvesting problems, Market price	• Non-availability of quality inputs such as seeds of improved varieties, rhizobial inoculum, pesticides, etc.· • Lack of awareness of improved varieties and crop protection technologies • Non-availability of multiple stress resistant varieties • Vulnerability of the crop to drought and pest outbreaks • Non-availability of credit and policy support
CWANA	Low yield levels, Fusarium wilt and parasitic wees, *Sitona* weevils, Machine harvest	• Vulnerability to drought, insect pests, diseases and low temperatures • Non-availability of seeds of improved varieties • Non-access to improved crop protection technologies including post-emergence herbicides • Labor shortage and mechanical harvesting • Policy support and price stability
Sub-Saharan Africa	Low yields, Fusarium wilt, rust and Ascochyata bligh Market price and policy suppor	• Vulnerability to drought, insect pests, diseases • Non-availability of quality seeds • Crop protection and production technologies • Availability of credit and policy support

Lessons Learnt and Future outlook :

Considering first technical productivity issues, the major lesson learnt is to increase the competitiveness of lentil against more remunerative alternative crops. Considering research needs, lentil yields are low because of the crop's limited yield potential and vulnerability to an array of stresses. Lentil plants are typically short with slender stems due to lack of early seedling vigour, poor photosynthate assimilation and slow dry matter accumulation in the latter part of plant growth. This results in overall poor biomass and grain yield. Winter planting has been an effective strategy for improving lentil biomass in CWANA region but the advantage of winter planting is jeopardized due to lodging, weed menace and Ascochyta blight incidence. Therefore, selection of traits which reduce lodging is to be practiced. These traits are strong upright stem, increased harvest index and bushy dwarf plant type (Erskine and Goodrich, 1988). Both biomass and seed yield are closely dependent on nitrogen fixing ability of the genotype as nitrogen (N) requirement is especially large during reproductive growth in lentil (Sinclair and de Wit, 1975). However, at the later stages of pod filling, N_2 fixation rate decreases and consequently, seed yield is adversely affected due to competition for N and photosynthates between developing seeds and plant canopy causing in leaf senescence. During this period, substantial remobilization of N from vegetative organs into seeds occurs to an extent which can account for as much as 70% of the N in seeds by reproductive maturity (Kurdali *et al*., 1997; van Kessel, 1994; Whitehead *et al*., 1998). Therefore, there is always competition between source and sinks for optimum productivity in lentil which needs to be optimized through better nitrogen fixing ability, determinate plant type and synchronous maturity. A strong and positive correlation between seed yield and biomass has been reported in lentil (Erskine, 1983; Whitehead *et al*., 2000). To bridge the gap between supply and demand, it would be imperative to develop low-cost technologies besides anticipating and responding to emerging threats to lentil production. This calls for careful planning based on exhaustive database and implementation of effective research for less favorable environments and identification of opportunities for integrated managements. Focusing on improved plant type, widening the genetic base, pyramiding of resistance genes for key stresses, and identifying remunerative cropping systems and intercrops, besides efficient production and protection technologies, can help improve the production on sustainable basis. Looking ahead, escalating costs of producing inorganic nitrogen fertilizer, reducing availability of water for agriculture, climate change, food insecurity and an increasingly nutrition-conscious consumer society collectively give a bright future for lentil.

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