Abiotic Stresses of Extra-short-duration Pigeonpea

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Introduction

Extra-short-duration (ESD) pigeonpea genotypes that can mature in 90-110 days have been recently developed (Laxman Singh et al. 1990). They are suitable for intensive cultivation as sole crops and have been tested for adaptation to rainfed semi-arid environments (Chauhan et al. 1993). In some situations, they are capable of producing higher yields than medium-duration (MD) genotypes, because their duration better matches the length of the growing season, and they escape terminal drought stress (Chauhan 1990). However, although the ESD genotypes have good yield potential (up to 3 t ha^{-1}), its realization varies with the soil moisture status, to which these genotypes are very sensitive. This paper summarizes our present knowledge of the major abiotic constraints to the production of ESD pigeonpea and discusses strategies for their alleviation.

Drought

Drought is a major factor limiting the realization of high yields in pigeonpea. Extra-short-duration genotypes escape terminal drought and have therefore shown good adaptation to environments with a short growing season (3-4 months). They have, however, shown sensitivity to intermittent drought (Nam 1994). Intermittent drought coinciding with the flowering and early pod-filling stages causes the most yield reduction; drought at preflowering and pod-filling stages, the second most (Nam 1994). Among the few genotypes tested so far, ICPL 88039 has been found to be the best adapted to intermittent drought coinciding with the flowering stage. ICPL 88032, which yielded more (2.5 t ha^{-1}) than ICPL 88039 (1.93 t ha^{-1}) under irrigation, yielded 23% less than ICPL 88039 when intermittent drought stress occurred at flowering stage. This suggests that environments need to be characterized for possible periods of stress in order to maximize yields of different genotypes. A few genotypes,

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such as ICPL 84023, performed well irrespective of the stage at which stress occurred (Nam 1994).

Waterlogging

Waterlogging has been recognized as one of the major constraints affecting stability of production in most regions in India where pigeonpea is grown (Reddy and Virmani 1981). Pigeonpea is highly sensitive to waterlogging, which could result in considerable loss in crop vigor and stand (Chauhan 1987). Further, susceptibility to waterlogging predisposes pigeonpea to phytophthora blight. The susceptibility of ESD pigeonpea to waterlogging is a major concern, as the crop has little time to recover from it and in subtropical environments, its growth is likely to extend into cooler, unfavorable periods. The yields of ESD pigeonpea on Vertisols prone to waterlogging are generally half of those that can be obtained on well-drained Alfisols (Chauhan et al. 1993). Nitrogen fixation of a short-duration pigeonpea, ICPL 87, is considerably reduced by anaerobic conditions in Vertisols, which is one reason why yield responses to nitrogen fertilizer are obtained on these soils (Kumar Rao 1990; Matsunaga et al. 1994).

Using the pot screening method developed at ICRISAT (ICRISAT 1992), we screened many pigeonpea genotypes of different maturity groups and found genotypic differences in their tolerance of waterlogging (Table 1). Some of the ESD genotypes, e.g., ICPL 84023 and ICPL 93072, which are tolerant of waterlogging, could grow and produce seed in pots. Further studies are needed to confirm the performance of waterlogging-tolerant lines under field conditions. Nam (1994) reported yield losses of up to 40% due to waterlogging in ESD pigeonpea and also considerable genotypic differences in response to timing of waterlogging, although only a few genotypes were tested.

Until we have more information in this area, agronomic management of waterlogging in pigeonpea is best done by growing the crop in well-drained fields, either on ridges or in broadbeds with furrows. Yields were higher when pigeonpea was grown on ridges than in flat beds, because of improved soil aeration (ICRISAT 1989).

Another management option to alleviate waterlogging effects on ESD pigeonpea is to topdress with nitrogen. Matsunaga et al. (1994) reported that topdressing of N at 50 kg ha^{-1}, soon after waterlogging stress, alleviated damage in a short-duration pigeonpea, as shown by final yields. Similar studies are needed to work out appropriate rates of N fertilizer for ESD pigeonpea.

Solar Radiation

The level of solar radiation may limit performance of ESD pigeonpea genotypes, which usually flower during the rainy season, when light levels are low. More studies are needed to determine whether the low light levels affect flowering and yields of ESD pigeonpea; if so, to what extent.

Table 1. Effect of waterlogging for 8 days on plant survival and total plant dry matter of extra-short-duration pigeonpea genotypes, ICRISAT Asia Center[1].

Genotype	Plant survival (%)[2]		Total plant dry mass (g $plant^{-1}$)		
	Control	Waterlogged	Control	Water-logged	Loss (%) due to waterlogging
ICPL 84023	100 (90)[3]	83 (70)	3.01	2.15	28.0
ICPL 85010	100 (90)	100 (90)	2.93	1.82	37.4
ICPL 85012	100 (90)	92 (80)	2.69	1.51	43.9
ICPL 86023	100 (90)	67 (60)	2.30	1.61	29.8
ICPL 87095	100 (90)	100 (90)	2.67	1.40	46.7
ICPL 88009	100 (90)	17 (20)	4.68	2.75	39.8
ICPL 88039	100 (90)	100 (90)	3.06	1.76	42.3
ICPL 91002	100 (90)	100 (90)	2.48	1.37	44.9
ICPL 91031	100 (90)	100 (90)	2.19	1.75	19.2
ICPL 93072	100 (90)	100 (90)	2.00	1.57	20.4
ICPL 93074	100 (90)	100 (90)	2.57	1.56	38.8
Prabhat	100 (90)	83 (70)	2.44	1.63	32.5
ICP 14199 (Tolerant control)	100 (90)	100 (90)	1.72	1.40	18.4
ICP 7035 (Susceptible control)	100 (90)	0 (0)	2.41	1.84	23.6
ICPL 86012 (Susceptible control)	100 (90)	0 (0)	4.36	2.59	40.3

1. Forty-two-day-old plants grown in the greenhouse in pots containing a Vertisol.
2. Mean of 3 replications, each with 4 plants pot^{-1}.
3. Values in parentheses are after angular transformation.

Photoperiod and Temperature

Pigeonpea is a quantitative short-day plant. The ESD genotypes, however, have a long critical daylength (14 h). The rates of progress from sowing to flowering (1/f) are therefore mostly unaffected by, but sometimes slightly responsive to, photoperiod (Omanga et al. 1995). However, ESD genotypes respond very strongly to mean temperatures below and above an optimum value close to 24°C for flowering (Omanga et al. 1995). In the suboptimal range, the effects are positive and in the supraoptimal range, they are negative. At higher latitudes, as in northern India, the longer days prevailing during summer months (Apr-Jul) can combine with supraoptimal temperatures to delay flowering and maturity of ESD genotypes. This could be why ESD genotypes take longer to flower in northern India than at lower latitudes in peninsular India (Gupta et al. 1989).

Nutrition

In India, the most important nutrient deficiency affecting pigeonpea is that of P, followed by Zn and N (Johansen 1990). Low P levels (<5 mg kg^{-1}) have been found to delay flowering and maturity in SD pigeonpea (Chauhan et al. 1992). To what extent the yield of ESD genotypes is affected by deficiency of these nutrients is not yet established. These deficiencies are best overcome by addition of appropriate fertilizers and soil amendments. The role of biofertilizers (*Rhizobia*, vesicular-arbuscular mycorrhizae, phosphate solubilizers, and other beneficial microorganisms), either alone or in combination with inorganic fertilizers, in meeting the nutrient requirements of ESD pigeonpea also needs to be studied.

Johansen (1990) reported that pigeonpea, like other legumes, is adversely affected by soil conditions such as salinity and acidity. Johansen et al. (1990) reported that half-maximal growth of 40- to 45-day-old seedlings of a range of pigeonpea genotypes growing in sand or solution culture occurred at 5-7 dS m^{-1}. In a saline Vertisol, this critical range corresponded to 1.5-3 dS m^{-1} in a 1:2 soil-water extract. Cultivated pigeonpea genotypes show little variation in salinity tolerance. Subba Rao et al. (1991) have demonstrated sources of substantial salinity tolerance among wild relatives of pigeonpea, *Cajanus (Atylosia) platycarpus* and C. *albicans*. These species can grow, flower, and set pods at 10 dS m^{-1} and thus offer the extent of salinity tolerance needed for significant genetic enhancement in cultivated pigeonpea. Only C. *albicans* readily crosses with cultivated pigeonpea, and the F_1 hybrids of such a cross exhibit the level of salinity tolerance of the tolerant wild parent, indicating that this trait is genetically dominant (Subba Rao et al. 1990).

Although pigeonpea can grow and fix N_2 in acid soils of pH range 4.5-5.5 (Edwards 1981; Abruna et al. 1984), it cannot below pH 4 (Chong et al. 1987). Liming can alleviate acid soil effects, but high rates of lime (e.g., 5 t ha^{-1}) may induce Zn deficiency (Dalal and Quilt 1977; Edwards 1981). The adverse effect of acidity on pigeonpea can be attributed to Ca deficiency and also Al toxicity. Narayanan and Syamala (1990) reported that in solution culture, 20 mg kg^{-1} Al was determined as a critical level for pigeonpea, with root growth becoming distorted at higher concentrations. They also reported genotypic differences in pigeonpea response to Al. Before we embark on research to determine sources of tolerance of salinity and acidity, we need to know whether these ESD genotypes are limited by salinity and acidity in northern India.

Conclusion

Extra-short-duration pigeonpea genotypes that can mature in 90-110 days are a relatively new plant type. They can yield well in environments with short (3-4 months) growing seasons, where they can escape terminal drought. However, they are sensitive to intermittent drought and waterlogging. Strategies involving both genetic and management options have been suggested for the alleviation of these abiotic stresses. The effects of various other abiotic factors–solar radiation, photoperiod, temperature, nutrients, salinity, and acidity–on ESD pigeonpea need to be studied in detail to assess their importance before research is planned to alleviate them.

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