Field Studies on Genetic Variation for Frost Injury in Pigeonpea

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Pigeonpea (*Cajanus cajan*) cultivation in China is being revived primarily for soil conservation and fodder production. Experiments show that in certain areas freezing temperatures (<0°C) cause considerable damage to the foliage of the crop. Considering the potential of pigeonpea in China, this study was conducted to understand the nature and magnitude of damage caused by freezing temperatures and to assess the feasibility of identifying freezing tolerant genotypes.

Three genotypes (ICPL 151, ICP 8863, ICP 11298) bred by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, India and one local landrace were evaluated. Four test sites were selected in different agroecological zones in Yunnan province in China. At each location, about 500 plants of each genotype were grown in June 1999 in an unreplicated block. The crop was grown with recommended cultural practices. In September/October, 30 competitive plants of each genotype were tagged randomly during the vegetative stage and in January 2000, these plants were scored for frost injury on five-point scale as: 0 = resistant, no visible symptom of damage; 1 = tolerant, up to 10% leaves killed; 2 = moderately tolerant, only terminal branches and tender leaves killed; 3 = moderately susceptible, upper-half of plant canopy killed; and 4 = susceptible, entire plant killed. In March 2000, when the temperatures for pigeonpea growth were conducive, 40 moderately susceptible (score 3) plants were tagged randomly in each block for visual assessment for their regeneration capability. Mean frost injury grade (ã) and average frost injury index (δ) were estimated for each genotype using the formulae given by Wang (1987):

$$\tilde{a} = \frac{\Sigma\,(a \times n)}{N} \qquad \delta = \frac{\Sigma\,(a \times n)}{a_{max} \times N}$$

where a = frost injury score; n = index in certain grade; and N = total number of plants.

The minimum, maximum, and average temperatures were recorded daily at each location to correlate frost injury with the prevailing temperatures of the coolest period (December 21 to 31). The minimum temperatures in Jingdong (range –0.3 to –3.0°C) and Yongren (range –1.3 to –4.1°C) remained below zero for nine consecutive days (Fig. 1) and killed the entire population of all the four lines. In Binchuan, on the other hand, the sub-zero temperatures persisted only for seven days and distinct varietal differences in response to freezing tolerance were observed. Both ICP 11298 (δ = 0.333) and the landrace (δ = 0.225) suffered least mortality. In these lines about 50% plants recorded no damage. In ICP 8863, over 90% plants died while in ICPL 151, there were no survivors (Table 1). It appears that both the temperature as well as its tenure (duration) are responsible for causing frost injury in pigeonpea. The results suggested that some genotypes such as ICP 11298 and local landrace could tolerate temperatures up to –4°C for a maximum period of seven days. In Yunxian, where the temperature persisted at –1°C for about a week, no plant mortality was recorded in any genotype suggesting that in such areas pigeonpeas of all durations could be grown successfully.

The study on regeneration of the plants partially killed due to freezing temperature (score 3) in Binchuan revealed significant variation among the genotypes. The local landrace recorded highest revival (82.5%) followed by ICP 11298 (65.0%). The regeneration rates in ICPL 151 (12.5%) and ICP 8863 (20.0%) were low. In comparison to the long-duration types, the early-maturing pigeonpea lines are known to have weak canopy and less food reserves and thus produce relatively less regenerated growth even under conducive environments. Of the test genotypes, ICPL 151, the most susceptible line to freezing temperature, is the earliest to mature (120 days); it has relatively less biomass and food reserves. On the contrary, the plants of the local landrace were of long-duration (>250 days) with high biomass and food reserves. The stress of freezing causes ice formation inside the plant and the most common symptoms are wilting and death of the whole plant. According to Wery et al. (1993) the intra-cellular ice, created around small particles inside the cell, is responsible for cell dehydration and, later, for cell membrane destruction due to freeze-thaw cycle which forces water back into the cell too rapidly. The extra-cellular ice produces a matrix around the plant cell causing mechanical damage to it and this results in the development of necrotic zones on the plants. Cold tolerance or winter hardiness has also been reported to be positively correlated with sugar content of cell and osmotic potential in chickpea (*Cicer arietinum*) (Malhotra and Saxena 1993). The osmotic adjustment promotes accumulation of solutes within cells and thereby helps in lowering the osmotic potential to maintain turgor, which consequently imparts tolerance to dehydration (Ludlow and Muchow 1988).

Pigeonpea is a unique plant with its ability to survive through various stresses. It is intrinsically perennial and this quality helps in retaining a sufficient supply of assimilates and other nutrients essential to maintain the primary functioning of roots, to tide over unfavorable conditions, and in providing reserves for new growth. Also, during stress periods the deep root system of pigeonpea helps in maintaining optimum water status within the plant. Therefore, the ability of pigeonpea plants to withstand extra-cellular ice formation, as observed in this study, could be attributed to the avoidance of cell dehydration. Although this study was conducted with limited number of genotypes, it provides some understanding about the

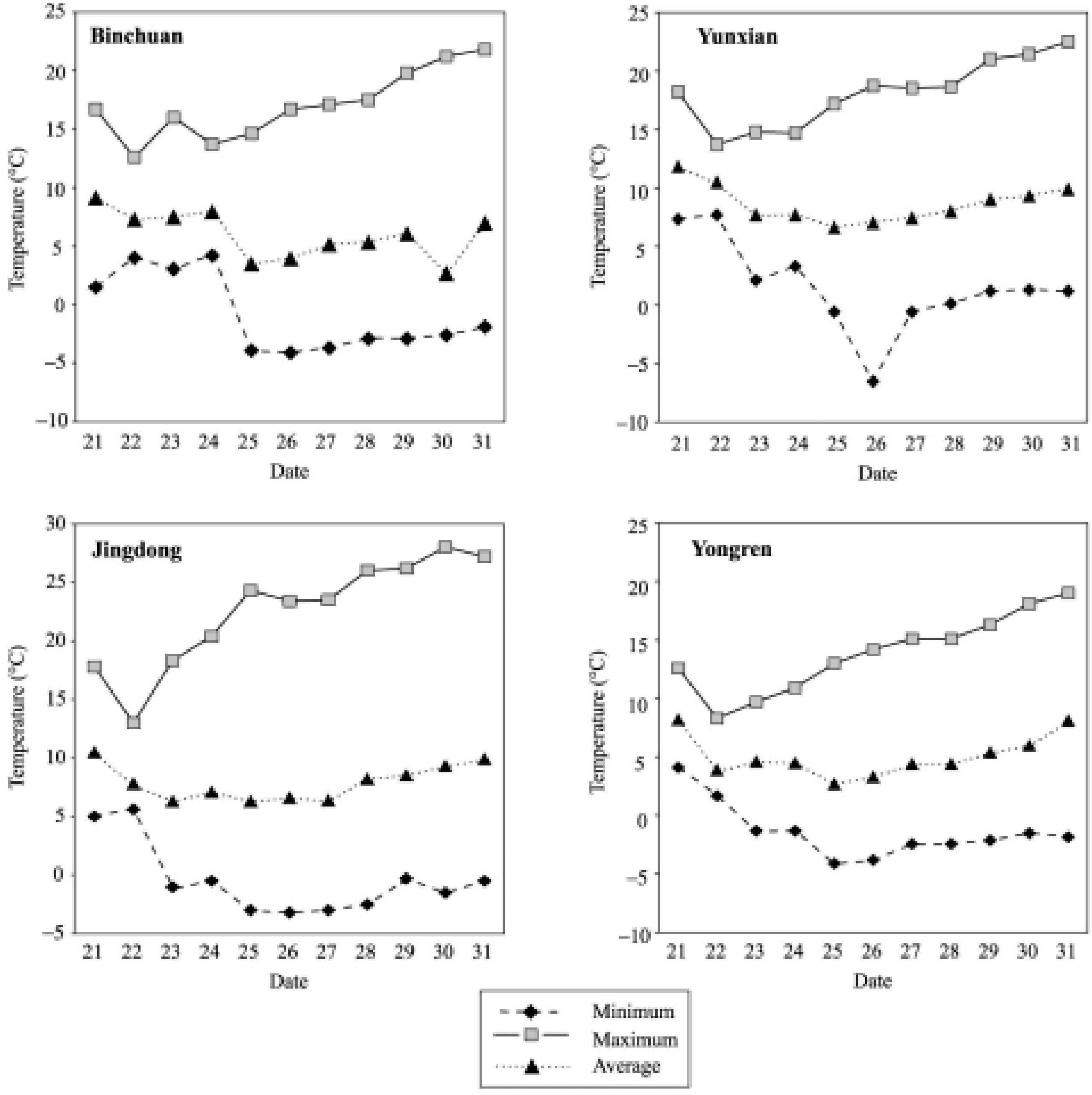

Figure 1. Temperatures at four locations in Yunnan province of China during 21–31 December 1999.

Table 1. Frequency distribution of pigeonpea genotypes to frost injury at four locations in Yunnan province of China during 1999.

Location/Genotype[1]	Number of plants with freezing injury score 0	1	2	3	4	Frost injury grade (ã)	Frost injury index (δ)
Binchuan							
ICPL 151	0	0	0	0	30	4.0	1.000
ICP 8863	0	0	0	3	27	3.9	0.975
ICP 11298	15	3	3	5	4	1.3	0.333
Local landrace	15	6	6	3	0	0.9	0.225
Yunxian							
ICPL 151	30	0	0	0	0	0.0	0.000
ICP 8863	30	0	0	0	0	0.0	0.000
ICP 11298	30	0	0	0	0	0.0	0.000
Local landrace	30	0	0	0	0	0.0	0.000
Jingdong							
ICPL 151	0	0	0	0	30	4.0	1.000
ICP 8863	0	0	0	0	30	4.0	1.000
ICP 11298	0	0	0	0	30	4.0	1.000
Local landrace	0	0	0	0	30	4.0	1.000
Yongren							
ICPL 151	0	0	0	0	30	4.0	1.000
ICP 8863	0	0	0	0	30	4.0	1.000
ICP 11298	0	0	0	0	30	4.0	1.000
Local landrace	0	0	0	0	30	4.0	1.000

1. Total number of plants observed in each genotype is 30.

nature and extent of damage caused by freezing temperatures to pigeonpea. However, precise experiments under field and controlled environments are necessary to understand various aspects of frost injury. Also, its quantification in different agroecological zones is essential before a systematic screening of germplasm could be undertaken. Since the problems of soil erosion and shortage of fodder are widespread, the development of high-yielding frost tolerant varieties will help in promoting pigeonpea in China. According to Blum (1988) the genotypes with smaller cells having better osmotic adjustment and less intra-cellular water are likely to survive freezing temperatures. To breed such varieties, the genetic variation available within and among the landraces and other germplasm need to be exploited for identifying parental lines with high survival and revival rates. Alternatively, the tolerant selections from local landraces can be improved for yield and various organoleptic traits. The genetic variation observed in this study leads to an optimism for successful breeding of frost tolerant pigeonpeas in the near future.

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Pathology

Evaluation of Pigeonpea Genotypes for Resistance to Phytophthora Blight

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Phytophthora blight of pigeonpea (*Cajanus cajan*), caused by *Phytophthora drechsleri* f. sp *cajani*, appears from seedling to maturity stages of plant growth and causes damage to the crop during heavy and frequent rain, particularly in areas that are low lying and have poor field drainage. The management of disease through fungicidal spray is ineffective due to dilution or washing away of chemicals from the plant surface. The most effective, economical, and safe way to control phytophthora blight would be the development of resistant cultivars.

A large number of pigeonpea genotypes have been screened and resistant sources identified to phytophthora blight by several workers (Pal et al. 1970, Kannaiyan et al. 1981, Singh et al. 1985, Amin et al. 1993). However, these genotypes have become susceptible perhaps due to evolution of a new pathotype during the past few years. This study was carried out to evaluate some pigeonpea genotypes for resistance to phytophthora blight.

One hundred and twenty one genotypes of pigeonpea were evaluated against phytophthora blight during two consecutive years, 1998/99 and 1999/2000. Fifty seeds of each test line were sown in 5-m rows with spacing of 60 cm × 10 cm in phytophthora sick field at the research farm of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. The genotype ICP 7119 was grown as a susceptible check and sown after every two test rows of pigeonpea. The trials were conducted in a randomized block design with three replications.

When the crop was 2.5 months old, the plants that escaped natural infection were artificially inoculated by the knife-cut method (Nene et al. 1981). A mycelial disc (4 mm × 2 mm) of *P. drechsleri* f. sp *cajani* grown on potato dextrose agar medium for a week was inserted below the bark of the 'I'-shaped cut on the stem and banded with cellophane tape to retain moisture. Plant mortality after natural and artificial infection was recorded 15 days after artificial inoculation. Percent disease incidence was calculated and pigeonpea genotypes were categorized as resistant (0–10%), moderately resistant (10.1–20.0%), moderately susceptible (20.1–40.0%), and susceptible (40.1–100%).

The naturally infected plants of pigeonpea showing purple brown to brown lesions on stems toppled over and dried out. The symptoms on artificially inoculated plants appeared as brown to dark brown discoloration around the inoculation site and plants died within 10–12 days after inoculation. Of the 12 pigeonpea genotypes screened only AKT 9726 was resistant and six lines (C 11, MAL 13, KPBR 80-2-1, KA 32-2, 286-96 RSW-1, 337-97-20) were moderately resitant in both years. The remaining test lines were moderately susceptible (26 in 1998/99; 27 in 1999/2000) or susceptible (88 in 1998/99; 87 in 1999/2000).

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