EFFECTS OF HEAT STRESS ON PHYSIOLOGY AND REPRODUCTIVE BIOLOGY OF CHICKPEA AND LENTIL

ABSTRACT:

Chickpea and lentil are two vital winter-season legumes; their production has been found to be seriously constrained by increase in temperature during reproductive stage. Considering this, we examined the effects of high temperature on both these legumes by growing them under late-sown environment to expose them to heat stress (>32/20°C) at reproductive stage as well as under varying degree of high temperatures in controlled environment. In chickpea, we used genotypes contrasting for heat sensitivity, while in lentil, few released cultivars were examined for their response. The significant reduction in pod set (%) was associated with reduced pollen viability, pollen load, pollen germination (*in vivo* and *in vitro*) and stigma receptivity in both the legumes to a varying extent. Heat stress inhibited pollen function more in the sensitive genotypes than in the tolerant ones in chickpea, and consequently showed significantly less pod set. Heat stress significantly inhibited the sucrose metabolism in leaves, anthers and seeds leading to decreased pollen function, seed filling and seed size.

INTRODUCTION

Background

Rising temperatures, especially during reproductive phase, would prove to be detrimental for winter-season food legumes (Gaur et al. 2013)

Modern cultivars of chickpea and lentil are not resilient to changing climate, hence there is need to develop heat-tolerance in these legumes.

Thus, It is imperative to understand the mechanisms associated with heat tolerance.

Challenges advanced by Research

Temperatures >35/23°C (day/night) are highly detrimental for pod set as well as seed development in both the legumes (Vara Prasad, et al. 2000; Kaushal et al. 2013).

Lentil is more sensitive to heat stress, compared to chickpea (Bhandari et al. 2016)

Pollen function is markedly inhibited by high temperatures (Kaushal et al. 2013, Bhandari et al. 2016)

Pod set is more sensitive than seed filling, and consequently results in substantial decrease in pod number.

Sucrose metabolism in leaves, anthers and seeds is a determining factor in affecting the pod number and seed size

MATERIALS AND METHODS

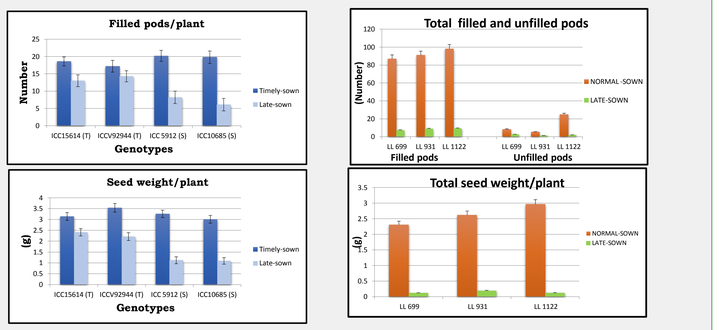
Chickpea seeds (heat-tolerant, heat-sensitive, drought tolerant, drought-sensitive) and lentil (heat tolerant, heat sensitive) were procured ICRISAT, IIPR Kanpur (India) and PAU (INDIA). Seeds were raised in outdoor conditions (normal sown vs. Late sown) as well as in controlled environment at varying temperatures. Late sowing (1 Feb) ensured higher temperatures (>32/23°C) during reproductive stage. In controlled environment, for chickpea, the plants were raised at 23 C till onset of flowering and than subjected to varying day/night temperatures of 30/20, 35/25, 40/30 and 45/35°C in the growth chambers (12 h light/12 h dark; light intensity, 250 µmol m^{-2} s^{-1}, 80% relative humidity) (Kumar et al. 2013; Kaushal et al.2013). For lentil, the plants were exposed to (33/15°C, 35/20°C; same duration, light intensity and RH) at the time of flowering till maturity. The leaves, anthers and seeds developing under heat stress were examined for photosynthetic function and sucrose metabolism The plants were examined for biomass, reproductive function, oxidative stress, pod set and seed yield under heat stress environment. The flowers produced during heat stress were tested for pollen and stigmatic function using standard methods (Kaushal et al. 2013; Bhandari et al.2016).

RESULTS

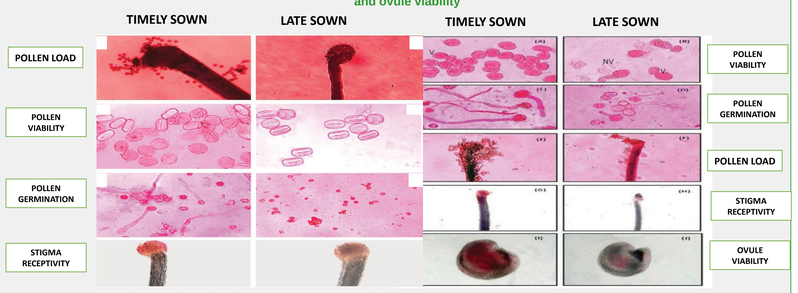
Effects of Heat stress on Chickpea and Lentil (selective results)

Profound reduction in Biomass and Seed yield

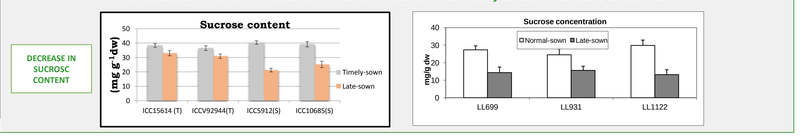
Marked decrease in pod and seed size



Damage to pollen function as Loss of viability, decrease in pollen load, decrease in stigma receptivity and ovule viability



Substantial reduction in sucrose content in leaves to adversely affect the anthers and seeds



DISCUSSION

Heat stress decreased the biomass, substantially (up to 80% in lentil) due to reduction in leaf water content, owing to poor stomatal conductance and decrease in photosynthetic efficiency.

The reduction in leaf water content occurred due to decrease in stomatal resulted in water stress, which also accentuated the effects of heat stress.

Heat stress reduced the flowering and podding duration markedly, due to accelerated phenology

The reduction in seed yield occurred due to poor pod set, which was attributed to decrease in pollen and stigmatic function resulting in impaired fertilization.

High temperature resulted in damage to membranes as a result of increase in oxidative damage, measured as lipid peroxides and hydrogen peroxide concentrations.

Though, the heat-stressed plants increased their anti-oxidative mechanism, but rise in oxidative molecules had an overriding influence on leaf tissue to damage membranes and photosynthetic efficiency.

Sucrose production was inhibited markedly in leaves, anthers and seeds to affect pollen development, seed development to decrease the pod set and seed size.

The decrease in sucrose concentration was related to marked inhibitions in the activities of sucrose synthesising enzymes sucrose phosphate synthase, sucrose synthase) and sucrose-hydrolysing enzymes (acid invertase).

Controlled environment studies indicated that the detrimental temperature for chickpea and lentil were found to be > 35/25°C and> 33/15°C, where substantial reduction in pod set was noticed

Seed size was found to show strong and positive correlation with sucrose synthesising enzymes and anti-oxidative enzymes (Ascrobate peroxidase, glutathione reductase)

The tolerant genotypes of chickpea and lentil show higher pod set and seed size owing to superior sucrose metabolism in leaves, anthers and seeds.

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Harsh Nayyar,[A] Neeru Kaushal[A], Kalpna Bhandari[A], Rashmi Awasthi[A], P.Gaur[B], Vincent Vadez[B], Shiv Kumar[C], Neil Turner[D], Kadambot Siddique[D],

[A]Department of Botany, Panjab University, Chandigarh 160 014, India
[B]International Crops Research Institute for Semiarid Tropics, Hyderabad
[C]ICARDA, Morocco
[D]The UWA Institute of Agriculture, The University of Western Australia, Crawley, WA 6009, Australia.

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