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# CURRENT PROBLEMS AND FUTURE PROSPECTS OF LEGUME PRODUCTION IN SEMIARID TROPICS OF SOUTHERN TAMIL NADU

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## ABSTRACT

**Drought as a major abiotic constraint to productivity of legumes in the semiarid tropics. Drought is a broad term and can be defined as a meteorological event which implies the absence of rainfall for a period of time long enough to cause moisture depletion in soil and water deficit with a decrease of water potential in plant tissues. It prevents the crop from reaching the determined and expected yield and drastically lowers the production. Thereby, affecting grain yield of leguminous crop attributable to plant water deficit which reflects whole economy of the country. Further the grain legumes dependent on current rainfall are prone to intermittent drought stress during the vegetative or reproductive growth period and the crop recovery from drought is determined by subsequent rainfall. Terminal drought stress, which occurs during the pod filling phase of crops, is common and a major yield reducer for crops growing with current rainfall. This is even more critical for crops grown during a post-rainy season and reliant on stored soil moisture. Groundnut, chickpea, and pigeon pea that are major crops in semiarid tropics are very sensitive to high temperatures and water deficits during the flowering stage and seed or pod development stage resulting in heavy loss to productivity.**

**Keywords:** Terminal drought stress, Kharif, Rabi pulses, Semi-arid tropics, Tamil Nadu

Water scarcity is increasing and this is exacerbated by population growth and ongoing climate change and variability (Conway *et al*., 2009). Most of the regions categorized as ‘water scarce’ lie in the semi- and arid tropics. It is also in these regions that approximately 70% of the population depends on agriculture for their food and livelihood (AGRA, 2013 and Graeub *et al*., 2016). The prevalence of food and nutritional insecurity in semi- and arid tropics also remains high. In India, the irrigated area under pulses was only 12 per cent, while under wheat and paddy; it was more than 60 per cent of the total area (Reddy and Reddy, 2010).The cultural practices such as improper sowing time, low seed rate, defective sowing method, insufficient irrigation, inadequate intercultural operations are major agronomic constraints in pulse crop (Reddy, 2009). Consequent upon delayed planting, early encounter with severe cold, growth and development of lentil crop gets hampered for a considerable period. Typically, late sown rabi pulses especially lentil and chick pea undergoes three distinct phases and considerable degrees of phenological modifications are bound to happen. Eventually, lentil crop during its early seedling phase grows slowly due to its energy invested in the initial establishment (Singh *et al.*, 2012). However, in mid-phase, very insignificant growth and development is observed. This poses serious threat to realization of yield potential due to cold injuries. This phase is very important for creating source of channelizing the energy at later stage. In the last and most important phase lentil faces heat injury, resulting in early onset of reproductive phase, causing imbalance in resources and inputs, biotic stress and forced maturity (Singh and Bhatt, 2013). An earlier study revealed that area under pulses in mostly predetermined, but as the irrigated area increases, pulses are relocated to rainfed areas and their area is replaced by cereals or some cash crop (Singh *et al.*, 1995). Groundnut, chickpea, and pigeon pea that are major crops in semiarid tropics are very sensitive to high temperatures and water deficits during the flowering stage and seed or pod development stage resulting in heavy loss to productivity.

### Groundnut

Groundnut (*Arachis* hyp*o*gea L.) is a major oilseed legume native to South America and forms an important legume in Asia and Africa. It is mainly grown under rainfed, irrigated, and residual moisture conditions. The crop is cultivated on 24.8 million

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hectares with an average productivity of 1.323 t $ha^{-1}$. About 93.8 per cent of the world's production of groundnut is grown by resource poor, small farmers in 96.9 per cent of world's groundnut area in developing countries where scanty and unseasonal and unpredictable rainfall is observed (Nageshwara Rao and Nigam, 2001).

Asia accounts for 66.5 per cent groundnut production on 56.8 per cent area while Africa produces 24.7 per cent on 38 per cent area subjected to groundnut production.

This also accounts for low average yields of 0.86 t $ha^{-1}$ in Africa and 1.55 t $ha^{-1}$ in developed countries despite the potential to produce 10 t $ha^{-1}$. Poor yields in these countries is mainly due to the biotic and abiotic constraints like erratic rainfall, low residual moisture, lack of high yielding adapted cultivars, damage by pests and diseases, poor agronomic practices and limited use of inputs. The loss due to biotic factors that include various diseases caused by fungal pathogens, viruses, bacteria and nematodes is estimated to be US $2 billion (Sharma *et al.,* 2001).

Yield losses due to drought are highly variable in nature depending on timing; intensity and duration coupled with other location specific environmental stress factors such as high irradiation and temperature. Annual estimated losses in groundnut production equivalent to over US $520 million are caused by drought. According to Johansen and Nigam (1994), almost half of it can be recovered through genetic enhancement for drought resistance with a benefit cost ratio of 5:2.

Drought affects the calcium uptake by pods and nitrogen fixation in groundnut where the photosynthesis is also reduced. When the crop reaches the harvesting stage, there is the possibility of high contamination of the seeds with aflatoxins that makes the seeds toxic and unfit for consumption by both humans and livestock. It has been suggested by Freeman *et al.* (1999) that in the medium term groundnut production and consumption is likely to shift increasingly to developing countries. Production will grow in all regions but most rapidly in Asia, slowly in sub Saharan Africa, and decline in Latin America; and there would be a shift in utilization of groundnut product from oil to confectionery products and suggesting on urgent need and shift in research for exploring the available genetic resources for their traits to tolerate drought.

**Chickpea**

Chickpea (*Cicer arietinum* L.) is the world's second most important pulse crop that is cultivated in more than 41 countries covering more than 11 million hectares of land and producing around 8 million tons of high protein food grain (FAO,1999).

The mean protein content of chickpea is about 24 per cent that serves as an important source of dietary nutrition to poor of the semi arid tropics (SAT).

Saxena (2001) reported that it is predominantly a rainfed crop grown after the end of the rains in South Asia and eastern Africa. This makes the crop to complete its lifecycle on stored and receding moisture where it is exposed to increasing drought. Despite having the yield potential of 5t $ha^{-1}$, the average yield is only about 0.8t $ha^{-1}$ due to poor management practices and diseases. The yield losses across the SAT and the west Asia and North Africa (WANA) regions from 40 – 60 per cent. Global yield losses due to drought in chickpea are estimated to be around 3.7 million tonnes and around 2.1 million tons of these can be recovered through crop improvement efforts. The yield losses in chickpea can be completely overcome with irrigation. Although some of the drought effects can be alleviated through agronomic and genetic options that do not involve external input of irrigation, these options can be only partial solution to this problem since the yield will always be lower than what can be achieved with irrigation.

It was shown that the yield gap between the most drought tolerance variety ICC 4958 and many other varieties with irrigation was large where the yield of ICC 4958 was only 30 per cent of the potential, irrigated yield of most of the varieties. Conventional plant breeding techniques to upgrade the quality of the variety to tolerate drought have not been successful in chickpea due to the unavailability of appropriate methods to screen and breed varieties tolerant to drought, and also the appropriate selection tools to select the tolerant varieties.

**Pigeon Pea**

Pigeon pea (*Cajanus cajan*) is an important grain legume crop of the SAT that has the ability to withstand drought conditions to produce grain of high protein concentration and biomass products such as fuel and fodder. It ranks sixth in area and production in comparison to other legumes of developing countries. It is widely grown in India mainly by resource poor farmers accounting for 90 per cent of the world's production. Other regions where pigeon pea is grown are South East Asia, Asia Africa and the Americas. Its seed has approximately 21 per cent of the protein content and is known as poor man's meat.

The crop is usually grown under rainfed conditions where intermittent and terminal drought stress is frequent. It can be exposed to intermittent drought stress during dry periods of the normal rainy season and to terminal drought stress in the post rainy season (Nam *et al*., 2000).

Pigeon pea crop has an excellent deep and lateral rooted system that makes it salinity and alkalinity tolerant crop. Despite having such stress tolerant traits in it, the yield and productivity of pigeonpea, however is very poor mainly due to the poor crop resource management. While the traditional long duration pigeon pea can survive periods of drought stress during its growth cycle, the challenge is to improve the ability of the land to produce under drought conditions. A thorough characterization of the drought environments where pigeonpea is grown has not been adequately done so as to enable proper targeting of drought resistance traits (Johansen, 2001).

**Cowpea (*Vigna unguiculata*)**

Under rainfed tropical conditions, cowpea usually grown in soils subjected to frequent water deficits. Nitrogen fixation, one of the most important physiological processes in these plants is affected by soil water deficits, and water stress limits N accumulation, dry matter and yields. Sprent and her Co workers have investigated water stress effects on nodulation and nitrogen fixation in excised nodules, intact plants grown under controlled conditions and field grown crops (Engin and Sprent, 1973; Sprent, 1976). The process of nitrogen fixation is highly sensitive to water stress in a number of temperate and tropical legumes (Sprent, 1976; Sheoron, 1986; Venkateswarlu and Rao, 1987).

Sprent (1976; 1981) and Rao and Venkateswarlu (1987) reported that the decrease in the rate of nitrogen fixation was more drastic in cowpea than groundnut for a comparable stress level. The leaf water potential range in cowpea in which the photosynthesis and nitrogen fixation processes became negligible was quite narrow (-0.4 to -1.0 MPa) compared to groundnut where the stress development was slow and the ARA was maintained even upto a leaf water potential of – 2.1 MPa while nodule dehydration with decreasing leaf water potential caused the decline in activity in both the crops such as cowpea and groundnut, the rapid fall in cowpea was essentially due to shedding of nodules. This was also evident from the fact although the decrease in nodule moisture content showed similar trend in both the crops with increasing water stress, the decrease in total fresh weight was much higher in cowpea.

Cowpea and other species of *Vigna* generally show minimum change in leaf area under water stress. In the present study with only a 15 per cent decrease in photosynthesis, ARA declined by about 90 per cent in cowpea. The decline in ARA has been attributed to both photosynthate limitations from shoot and direct effects on the nodules due to dehydration (Huang *et al*., 1975; Sprent, 1976).

**Black Gram (*Vigna mungo*)**

Black gram (*Vigna mungo* Hepper (L.) is cultivated as a pure crop as well as a mixed crop in kharif season. It is also grown in Rabi season. It is grown in plains and also in cool hills up to an altitude of 2000 m, where the cooking quality is superior. In Tamilnadu, area under black gram cultivation is 4.08 lakh ha with a production of 1.72 lakh tones and productivity of 423 kg ha $^{-1}$. India is the largest producer and consumer of pulses in the world accounting for more 33 per cent of the world area and 22 per cent of world production. The productivity of pulse in India is low around 550 – 650 kg $ha^{-1}$ against 1600 kg in USA, 1400 kg in China and a world average of 900 kg $ha^{-1}$ (Venkataramani, 2002).

The world health organization recommends a per capita consumption of pulses at 80 g per day and the Indian council of medical research has recommended a minimum consumption of 47 g in 1968, the average consumption in India was 56 g per person per day, but at present the actual consumption is much less at 30.3 g.

**Soybean**

Soybean (*Glycine max* (L.) Merr.), the wonder legume with its multifarious uses, a potential source of both plant protein and vegetable oil is gaining importance world over including India since two decades. Despite its commercial potential its production remains one of the most underestimated options in India mainly because it has not found its way as a component of the average man's diet. Soybean has played a significant contribution to yellow revolution in India (Chauhan and Joshi, 2005) and as a food plant it forms a part of routine diet of the people. A wide variation in the tolerance to acid soil conditions had been reported among *Brady rhizobium* strains of many agriculturally important legumes from various countries (Raza *et al.*, 2001; Appunu *et al*., 2005).

Soybean stands apart from the majority of vascular plants in passing the capacity for symbiotic nitrogen fixation of elemental nitrogen and in producing seeds exceptionally rich in protein. These features and the ability of soybean to utilize combined forms of nitrogen as an alternative to nitrogen, provide a fascinating area for further understanding the phenomena of nitrogen metabolism and its relationship with yield.

Rhizobial inoculation has been widely reported to increase soybean yield (Imshande, 1986; Papastylianou, 1987). Soybean nodules are large and not as convoluted as in most legumes and having also proved to be a good source of respiratory pigment, leghaemoglobin content (Philips, 1980). The absence of fixed nitrogen in the root zone is known to restrict yield while fertilizer nitrogen addition depress the contribution made by the nodular mechanism (Norman, 1978).

Benjamin and Nielsen (2006) reported that water deficit did not affect the relative soybean root distribution and approximately 97 per cent of the total soybean roots were in the surface 0.23 m at both sampling times and under both water regimes. In contrast, water deficit stress resulted in a greater proportion of chickpea and field pea roots to grow deeper in the soil. From a rooting perspective, chickpea might be the best suited species for dryland crop production in Semi Arid Tropics due to an adaptive root distribution based on water availability and large root surface area per unit root weight.

Sinclair *et al*. (2007) reported that drought was by far the most important environmental factor contributing to crop yield loss and symbiotic nitrogen fixation of atmospheric nitrogen was sensitive to even modest soil water deficits. Decline of nitrogen fixation with soil drying causes yield reductions due to inadequate N for protein production. Nitrogen fixation activity was found to persist at lower soil water contents.

**Green Gram**

Mungbean (*Vigna radiata* L.) or greengram is a short season summer growing legume grown predominantly under dryland conditions throughout the tropics and subtropics. Due to the erratic nature of summer rains and variation in stored soil water and sowing, the crop was exposed to varying timing and severity of water deficit, which results in variability in grain yield, nitrogen accumulation and grain quality. In the field study, mungbean crops were exposed to varying timing and severity of water deficit in order to examine the contribution of the second flush of pods to final grain yield with variable timing of relief from water deficit, the sensitivity to water deficit of the accumulation of biomass and nitrogen and its partitioning to grain and how the timing of water deficit affects the pattern of harvest index increase through pod filling. There was a larger effect of water deficit on N accumulation, and hence nitrogen fixation, than on biomass accumulation (Thomas *et al*., 2004).

.**Future Prospects**

- Drought tolerant leguminous cropping system has to be improvised by overcoming the existing system.
- Location specific weather data have to be interpretation with the past ten years data, with this proper sowing should be undertaken.
- Pressurized micro irrigation system should be evolved under water scarcity condition using advanced soil moisture measurements.
- Slow release encapsulation of pesticide (Soil applied herbicide for leguminous crop) should be introduced with new mode of action.
- Drought tolerant *Rhizobium* strains could be used for pre treatment at field level.
- Ongoing resource conservation technologies (Zero tillage, Minimum tillage, Permanent soil organic cover etc.,) should be practiced under rainfed ecosystem in general but, particularly in drought condition.

## CONCLUSIONS

In semi- arid tropics, there is a high prevalence of food and nutrition insecurity. Increasing food production should create a balance between increasing productivity, water scarcity and nutrition. The fact that grain legumes are rich sources of proteins and micronutrients suggests that they have a role to play in contributing to food and nutrition security in poor rural communities. There is need to increase the legume basket by adding minor grain legumes. This will also act as a buffer when major grain legumes are not successful due to prolonged climatic change. Ramasamy,K., Vice Chancellor of Tamil Nadu Agricultural University suggested at one of the Year of pulses-ICRISAT 2016 that the pulse researchers need to focus on reaching farmers and increasing their incomes rather than only on increasing productivity. Biofortification is another area that should be explored to deal with nutritional deficiencies among children in India, as well as developing need-based varieties.

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