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S. P. Vyas*

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*e-mail: satyapvyas@gmail.com

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Review Article

Impact and Strategies for Yield Improvement of Arid Legumes under Drought

S.P. Vyas*

Mahila P. G. Mahavidyalaya, Kamla Nehru Nagar
Jodhpur 342 009, India

ABSTRACT

Arid legumes like Cluster bean, Cowpea, Horse gram, Moth bean and Mung bean are important sources of proteinacious diet in Indian desert. There are several environmental impediments which restrict growth and productivity of these crops out of which drought is most prominent. There are three types of drought and myriads of morpho-physiological responses to this kind of abiotic stress. The present paper reviews the available knowledge on genotypic variability in drought tolerance and suggests breeding and agronomic strategies to optimize crop production under water limiting conditions.

KEY WORDS : Abiotic stress, Arid legumes, Drought, Drought tolerance.

Introduction

The designated arid legumes viz. cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.], cowpea [*Vigna unguiculata* (L.) Walp.], horse gram [*Macrotyloma uniflorum* (Lam) Verdc.], moth bean [*Vigna aconitifolia* (Jacq.) Morechal] along with mung bean [*Vigna radiata* (L.) Wilczek] play a pivitol and unparallel role in the agricultural productivity of desert region of the country. These crops besides being the major source of protein in the vegetarian diet also have industrial, medicinal and many other uses (Table 1)[16]. However, the meager and erratic rainfall, extremes of temperatures, high wind velocity accompanied with frequent droughts have adverse effects on the productivity and production with large variation from year to year. Drought, among other

Table 1. Botanical, vernacular names and uses of arid legumes

Botanical name	Vernacular name/s	Uses
Cyamopsis tetragonoloba (L.) Taub.	Hindi – Guar English – Cluster bean	Food, fodder, vegetable, manure, industrial, medicinal.
Vigna aconitifolia (Jacq.) Morechal	Hindi – Moth English –Dew bean, Aconite bean	Green-small vegetable, source of vegetable protein, green manure, confectionery items.
Vigna ungiculata (L.) Walp.	Hindi – Chawala English – Lobia, Cowpea	Confectionery items, vegetable, medicinal (dissolving stone, gynecological problems, whooping cough, purgative).
Macrotyloma uniflorum (Lam.) Verdc.	Hindi – Kulthi English – Horse gram	Food item, medicinal.
Vigna radiata (L.) Wilczek	Hindi – Mung English – Green gram	Main staple source of protein for vegetarians.

Corresponding Author
***S. P. Vyas**
e-mail: satyapvyas@gmail.com

factors is the most important environmental factor which determines the productivity level[26]. Since, there is urgent need to increase the productivity of these crops to meet their growing demand it is essential to increase production of these crops. The production can be enhanced either by increasing the area of cultivation or by developing technologies which help to increase the yield of these crops in the present areas of their cultivation. As it seems next to impossible to bring additional land under cultivation of these crops therefore, there is urgent need to understand the deleterious effects of water deficit situation on growth, yield and metabolism[10] and to evolve/identify techniques to ensure high yields of these crops under stressful environmental conditions. This article provides an insight into injurious effect of drought on various physiological, biological processes and identifies suitable techniques to negate the adverse drought effects to achieve maximum crop yields.

Types of Droughts

Drought, from agricultural point of view is a situation of inadequacy of soil water availability in quantity and spread, which inhibit full expression of the potential of a plant genotype. Droughts, which are common in arid areas have been variously described[25, 17, 29, 30]. Vyas [31, 32, 33] taking crop growth stage as main criterion for classification has described droughts as follows:

a) **Phasic:** When water deficit situation arise at a particular developmental stage of crop growth.

b) **Intermittent:** In this type of drought moisture deficit situation arise many a time during total cropping period. Such type of drought affects the growth stages in formation.

c) **Persistent:** Water availability remains low throughout the period of crop growth.

Responses to Drought

Since arid legumes are cultivated in the regions characterized with water deficient situation at one, other or one-more stages of crop growth drought directly affect cellular processes, plant growth and development and finally yield. Jones[13] describe plant water potential and leaf relative water content as the most important physiologically important indicator of drought status of plant. Nayyer and Gupta[19] noticed significant decrease in relative water content in a number of legumes, however, this effect varies with growth stage, stress intensity, and the plant genotypes[32, 9]. At cellular level drought affects membrane structures and structure of macromolecules viz. protein, nucleic acids and enzymes[1, 4, 8, 33, 12]. Table 2 describes some of the important plant processes which are influenced by water stress and their relevance to yield of various arid legumes. The yield, metabolic alteration of individual arid legumes such as cluster bean[27, 7], moth bean[32, 7], cowpea[27, 28] and mung bean[20,21,22,24] has been studied under stressful environment.

Comparative Drought Tolerance

Although all the arid legumes are considered drought tolerant and the physiology of individual crop under the water stress situation is well illustrated[7,32,28,20,21,22,24,34] yet the crops differ in their potential to tolerate drought which permit the selection of area specific choice of crops. The information on comparative behavior of various morpho-physio-biochemical phenomenon and effect of drought on seed yield and dry matter (Table 3) production (DMP) of these crops under iso-stress situation indicates that at critical water sensitive stage moth bean is most tolerant. In this regard, it has been earlier[32] observed that moth bean posses an adoptive mechanism where in under stress situation the activity of GDH increases several times and takes up the normal GS-GOGAT system of ammonia assimilation and does not allow ammonia to accumulate to toxic level which help plant to adopt stress situation (Table 5).

Yield Improvement Strategies under Drought

Normally, arid legumes tolerate or avoid dehydration stress adopting escape avoidance mechanisms yet to breed for drought tolerance can be the most effective method for sustainable seed production under such situations. Although, researches

Table 2. Effect of water stress on various plant processes and their relevance to yield

Characters	Stress effects	Relevance to crop growth
(A) Morphological		
Seed germination	Decrease	Less plant population
Seedling establishment	Reduce	Decrease plant establishment
Root growth	Reduce	Lower water and nutrient uptake
Internodal length	Decrease	Change in plant architect
Leaf orientation and area	Decrease/after	Reduced WU and CO_2 assimilation
Shoot growth	Decrease	DMP decrease
(B) Physiological		
Membrane permeability	Increase	Cell turgidity decrease
Chlorophyll stability index	Decrease	Photosynthetic efficiency reduce
Assimilate transport	Decrease	Harvest index decrease
Water and nutrient uptake	Decrease	Decrease water and nutrient availability
Osmotic adjustment	Increase	Increase WUE from sub soil
Phenophases	Advance	Yield attributing character decrease
Stomatal conductance	Decrease	Reduced CO_2 absorption
Photosynthetic efficiency	Reduce	Decrease of light reaction calvin cycle and biomass
Respiration and photorespiration	Increase	Greater utilization of photosynthe
(C) Bio-chemical		
Protein synthesis	Decrease	Reduced plant size, poor seed quality
Stress related proteins	Increase	Protection of cellular structure
Starch availability	Reduced	Reduce absorption, grain quality
Assimilatory enzymes	Decrease	Anabolic activity decrease
Oxidative system	Decrease	Reduced protection against oxygen species
Reserve utilization	Increase	Reduce revival possibility

Table 3. Comparative account of change in various phenomena among arid legume crops under iso-stress condition

Character	Crop			
	Guar	Mung	Moth	Cowpea
Plant water potential	4	1	2	3
Relative turgiscence	1	2	4	3
Root growth/plant	2	3	1	4
Leaf area/plant	2	3	1	4
Seed yield/plant	2	3	1	4
Dry matter/plant	3	2	1	4
HI	2	1	3	4
N_2-fixation	1	2	3	-
Nodule/plant	2	1	2	-
NR-activity	4	3	2	1
Proline accumulation	4	2	3	1
GDD	2	3	1	4
HUE	2	3	1	4
CSI	2	3	1	4
Cell permeability	2	2	1	3
Soluble sugar	4	2	1	3
Starch	3	4	1	2
Free amino acids	3	2	1	4
Sol. protein	3	2	1	4
Average	2.4	2.4	1.5	3.1

*Increasing number indicate higher alteration

Table 4. Comparative seed and dry matter yield of arid legumes under drought

Crop	Seed yield			DMP		
	Control	Drought		Control	Drought	
Guar	7.60	6.03		23.38	21.23	
Moth	4.13	3.60		22.10	21.22	
Mung	7.64	5.13		23.68	18.54	
Cowpea	10.03	7.03		30.85	26.42	
	Drought	Crop	DxC	Drought	Crop	DxC
C.D. at 5%	0.58	0.67	1.16	1.18	1.36	2.36

Table 5. Effect of increasing drought and enzyme activity in moth bean

Days without water	Water Potential Plant	RT	NR	GS	GOGAT	GDH
0	-0.70	72.4	1750	360	90	50
2	-1.20	69.5	920	135	50	75
4	-1.50	66.2	380	129	48	90
6	-2.00	50.6	270	55	37	120
8	-2.22	43.3	240	45	28	135
10	-2.50	43.8	200	00	25	170

on breeding for drought tolerance has achieved many success yet it has large constrains which remain unresolved[18, 23]. Due to this breeding for drought remains a distant object.

Because of technical difficulties, such as identification of representative stress situations, performance variation of varieties, unpredictability and variability of drought situations, lack of precise screening techniques, negative association of stress tolerant traits with yield, simultaneous presence of multiple stress, absence of reliable selection criterion, multiple gene control phenomenon and involvement of multi disciplinary team it remains an unresolved phenomenon particularly for arid legumes[16,18,23]. Looking to the described technical difficulties the breeding for improved yield particularly, under the situation of drought yield improvement of these crops remains a difficult task. However, looking to increasing demand and sinking limited areas of cultivation alternate methods needs to be identified. In this regard the use of genotypic management, cultural practices, nutrient induced vigor and use of plant hormones, anti-transpirants etc. assume importance.

Genotypic performances are known to be governed by the rainfall situation and consequent soil moisture condition of the cropping area. In drought prone areas earliness is the most preferred character for all crops including legumes. Plants having short lifespan mature before the onset of terminal drought which affects seed development[16]. Earlier, Vyas *et al.*[31] observed that plants with low pre-flowering water use

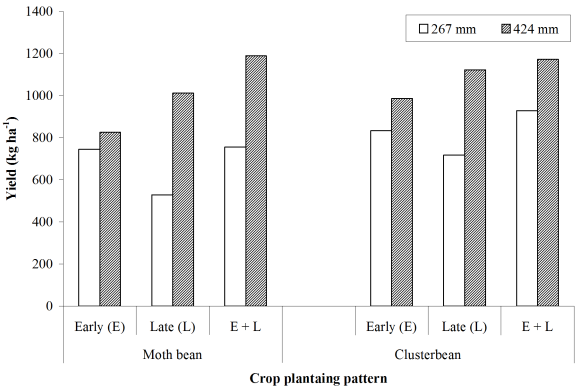

Fig. 1. Yield stability through varietal intercrops under diverse rainfall condition in moth bean and cluster bean

Table 6. Water use pattern and yield of early and late flowering genotypes of moth bean at different phenophases under stress situation.

Genotypes	Water use (mm)				Seed yield
	Pre-flowering	Flowering	Post-flowering	Total	
Early	40.8	70.8	61.7	173.3	557
Late	48.5	69.0	49.9	167.0	390

efficiency (WU) are better suited to the drought prone regions (Table 6). Similarly, varietal intercropping of early and late genotype in a proper plant population ratio (1:1) also provide stable yield irrespective of rain fall situation (Fig. 1)[15, 29,35]. The observed stability of yield under both the management practices were directly related to better nitrogen uptake, nitrogen use efficiency, nitrogen harvest index particularly under low rainfall conditions. In general early genotypes in low rainfall situation and late genotypes during high rainfall condition provide higher seed yield.

The cropping period in arid regions varies from 6-8 weeks. Although legumes fit well as main crop under such situation yet the optimum population per unit land plays significant role for successful crop production under stressful environment. In general plant population of 1.50 lac plants ha^{-1} was optimum under the crop geometry of 45 ´ 15 cm in mung bean, moth bean and clusterbean in a drought year[35].

The arid soils are not only thirsty but hungry also; however, fertilizer use is very low and rational. Lahiri[17] addressing fertility induced alleviation of drought effect indicated that drought reduced nutrient availability and absorption in dry land conditions and led to yield reduction. Rainfed arid lands are deficient in nitrogen, low in phosphorus. Phosphorus and Potassium application significantly improved plant water status, activities of NR and ammonia assimilating enzymes (Table 7), rate of photosynthesis and seed yield under drought[14, 29, 3, 9,11]. Drought ameliorative chemicals like kinetin, thiourea and anti-transpirants are known for their role in retention of metabolites, prohibition of chlorophyll and prevent protein break down procrastinating stress induced senescence also significantly improves the productivity of all these legumes under moisture deficit condition[5,6,2].

Table 7. Influence of drought and potassium on NR, GS and GDH in clusterbean

Treatment	NR			GS			GDH		
	K-level								
	Full	½	¼	**Full**	½	¼	**Full**	½	¼
Control	513	427	300	82	66	106	82	43	54
Drought	135	98	77	76	80	89	42	59	99
Mean	324	262	189	79	73	97	62	51	77
LSD (0.05)	D	K	D × K	D	K	D × K	D	K	D × K
	22	31	43	NS	9	13	NS	7	10

Thus performance improvement of arid legumes under situations of water shortage can be achieved by adopting better genotypic management as well as through suitable agronomic practices which enable plants to yield better despite high metabolic derangements caused under water deficit situation.

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CONTENTS

Review Articles

Research Articles

Short Communications

Opinion

News and Views

Correspondence