Annals of Plant and Soil Research 17 (2): 150-155 (2015)

GROWTH DYNAMICS AND LEAF CHARACTERISTICS OF PULSE UNDER WATER DEFICIT AND IRRIGATION REGIMES

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Received: November, 2014: Revised accepted: April, 2015

ABSTRACT

The research was carried out to investigate the effect of different irrigation levels during reproductive phase on growth, leaf traits, photosynthetic pigment and yield on vigna species at Punjab Agricultural University, Ludhiana. The experiment was laid out in split plot design with 4 replications. Irrigation levels were kept in main plot and genotypes in subplots. Moisture stress hampered the growth significantly resulting in reduced chlorophyll, LAI, SLW, SLA,LWR,LAR and yield attributes in mungbean and mash bean cultivars. All morpho-physiological attributes showed best performance when two sequential irrigations were applied at initiation of flowering and podding (I_3) and the lowest performance under no irrigation/water stress. Seed yield increased by 21%, 29.7% and 33.5% when irrigation was applied at the initiation of flowering (I_1), initiation of podding (I_2) and two sequential irrigations during reproductive phase (I_3) respectively. Based on the yield indices, photosynthetic pigments, LAI, SLW, pod number, seed weight ML1265 out yielded other two mungbean cultivars while Mash114 was higher yielder than Mash338.

Key words: Water stress, irrigation, specific leaf weight, leaf area index, drought susceptibility index, drought tolerance index

INTRODUCTION

Leaf area of a crop is an important variable in models for predicting crop growth and dry matter production, quantifying crop-weed competition or modeling heat energy and water exchanges in the plant soil-atmosphere continuum. Leaf area influences the interception and utilization of solar radiation of crop and consequently the DM production. Penning de Vries *et al.* (1989) predicted LA from leaf biomass using the parameter specific leaf area, assuming that LA is limited by assimilate or carbon supply. The growing season is limited by variable rainfall and temperature causing moisture deficit. Drought stress affects all plants vital mechanisms while stomata and non-stomatal factors together play a role in photosynthesis reduction and one of theses factors may have more influence over leaf's assimilation capacity depending on the severity and duration of the stress and plants growth stages. Drought stress directly makes drastic changes in LAI and therefore, severely decreases total photosynthesis due to its multiple effects on growth including limitation of leaf development. Ranawake *et al.* (2011) and hihabuddin *et al.*(2013) found that water stress affected crop phenology, leaf area development and number of leaves in mungbean. Leaf area is important because photosynthesis is a function of it. However, rapid development of LA may have a negative effect on water availability of plants. Thus drought stress reduces biomass, production per unit area and this significantly decreases chlorophyll concentration and ultimately seed yield. Most of the important pulses have marked moisture sensitive stage of growth in relation to seed yield. The stage that is less sensitive to moisture deficiencies is the period from emergence up to flowering .The greatest sensitivity to indicate water supply is very important during pod and seed development .The main component of yield affected is the number of pods which is increased by irrigation at flowering and seed weight which is increased by irrigation during pod growth (Assaduzaman *et al.*2008). Studies were needed to evaluate the genotypic responses to irrigation modules and further visualize the effect of irrigation applied at specific intervals during the reproductive phases on the leaf traits and the associated characteristics influencing the seed yield potentials.

MATERIALS AND METHODS

Experiments were carried out during two Kharif seasons on the field areas of pulses section, Department of Plant Breeding and Genetics at Punjab Agricultural University, Ludhiana, Punjab, India. The experimental site is located at 30 $^{o}54^{1}$N 75^{o}48E 247m altitude. The experiment was conducted in split plot design with the four replications. Main factor included irrigation levels (4) and sub plot included genotypes (5). Three mungbean (SML668, ML818, and ML1265) and two Mash bean (Mash114, Mash 338). The treatments consisted of water stress and irrigation modules designated as: $I_{0:}$ Control /moisture stress/no irrigation, I_1 Irrigation at initiation

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of flowering, I_2: Irrigation at initiation of podding, I_3 :Irrigations at initiation of flowering and podding. All recommended package and practices were followed to raise a healthy crop. Various stages of crop growth (30, 40. 50 and 60DAS) were selected for chlorophyll estimation and leaf characteristics. Total chlorophyll content of the leaves was measured by the method of Arnon (1949) and was determined by the following equation:

Total Chl. (mg/g F.W.) = [20.2 (A645) +8.02 (A663)] x V/1000xw

Where 'V' is the final volume (ml) of the supernatant, w weight (g) of the sample

Sampling of the three plants (above ground) in each plot was made at 10 days interval starting after 30 days of sowing. The plants were separated into leaves and shoots. Total leaf area of all the lamina of leaves per plant was recorded using leaf area meter (Li-COR model 3100A).Rest of the leaf parameters were calculated by the following formulae

LAI=LA/G where LA is the leaf area (cm^2) and G is the ground area (cm^2)

Specific leaf weight (SLW, g m^{-2}) = Dry wt of leaves (g)/LA (m^2)

Specific leaf area (SLA, m^2 g^{-1}) = LA (m^2)/dry matter of leaves (g).

Leaf area ratio (LAR, cm^2 g^{-1}) =LA (cm^2)/total dry matter (g, shoot +leaves)

Leaf weight ratio (LWR) = Leaf weight (g)/total plant weight (g)

Leaf shoot ratio (LSR) = Leaf weight (g)/shoot weight (g)

At harvest five plants were randomly selected from each plot to record plant height, number of branches and number of pods and their averages were calculated .Number of seeds of 10 randomly selected pods in each plot was counted and averaged for seeds/pod. The sample of 100 grains was taken from seed lot of each plot and expressed in grams. Total biomass of central four rows in each plot was recorded after harvest and sun dried separately. After threshing the grain yield was obtained .Biological and grain yield obtained on per plot basis were converted to kg/ha. From these parameters the following yield indices were calculated:

Mean productivity (MP) = (yield $_{irrigated}$ +yield $_{drought}$)/2

Rate productivity (RP) = yield $_{drought}$/yield $_{irrigated}$

Drought susceptibility index (DSI) = (1-yield $_{drought}$/Yield $_{irrigated}$)/D

D= (1-mean yield $_{drought}$/mean yield $_{irrigated}$)

Drought tolerance index (DTI) = (Y_p x Y_s)/X_{p2}

Where Yp is yield of genotype under non-stressed /irrigated and Ys yield of genotype under stress/drought and Xp mean yield of all genotypes under non-stressed /irrigated conditions

Data was subjected to analysis of variance (Anova) and irrigation means were compared using the least significant differences (LSD) at $p<0.05$ using CPCS software (2008).

RESULTS AND DISCUSSIONS

Chlorophyll content

Photosynthetic pigment revealed a significant decline under moisture deficit at all the growth stages. Irrigation applied at initiation of flowering recorded significantly higher chlorophyll content at 40DAS.Increase in chlorophyll was seen with each increment of time being highest at 60DAS. Chlorophyll content was statistically higher with all the irrigation regimes at 60DAS (Table1). At 70DAS chlorophyll content declined significantly. Non-significant differences were accorded to genotypes at 40DAS whereas genotypes differed significantly in rest of the growth stages for chlorophyll content. Amongst the mungbean cultivars ML1265 (1.12 mg/g F.W.) registered higher chlorophyll content and Mash338 (1.28mg/gF.W.) as compared to Mash114 (1.15mg/g F.W).Higher chlorophyll pigments indicates more photosynthetic rates and availability of photo assimilates for growth and development.

Table 1: Chlorophyll content at different stages of crop growth in response to water stress and irrigation modules

Treatment	Total chlorophyll (mg/g. F.W.)				
	DAS				
	30	40	50	60	70
Irrigation					
Control (I_0)		0.520	0.722	0.893	0.538
Initiation of flowering (I_1)		0.710	0.749	1.13	0.680
Initiation of podding (I_2)		0.609	0.696	1.22	0.648
Initiation of flowering + podding (I_3)		0.605	0.823	1.25	0.627
LSD 0.05		0.120	0.102	0.197	0.446
Varieties					
SML668	0.390	0.653	0.678	0.797	
ML818	0.430	0.620	0.717	0.767	
ML1265	0.558	0.766	0.793	1.12	
Mash338	0.543	0.744	1.20	1.28	1.12
Mash114	0.585	0.776	0.950	1.15	0.617
LSD 0.05	0.334	NS	0.089	0.113	0.271

Leaf characteristics

Leaf weight ratio (LWR) varied significantly at 40 DAS within the cultivars and also with irrigation modules .Irrigation applied at initiation of flowering and podding (I_3) improved LWR significantly. Within the cultivars highest LWR was registered in SML668

(0.48) and also in both the cultivars of black gram (0.52) at the same stage (40DAS) as in the irrigation regime. Non-significant differences were recorded for LWR at 60DAS but this trait slightly increased within the cultivars (Table 2).

Leaf shoot ratio (LSR): Non-significant differences with irrigation modules were recorded at all the stages of crop growth except at 60DAS.Irrigation both at flowering and podding registered higher LSR (1.61) as compared to control/ water stress and also with other two irrigation modules. Within the cultivars maximum LSR was recorded at 60DAS. Maximum LSR was recorded in green gram cultivar ML 1265(1.63) and Mash 338(1.48) for black gram cultivar.

Leaf thickness (SLW and SLA): Leaf thickness is expressed as specific leaf area (area per mass) or specific leaf weight (mass per area).Thick leaves are associated with high yielding capacities of crop cultivars. All the crop growth stages recorded significant differences within the cultivars and with irrigation regimes for SLW and SLA. In control (I_0) and with the irrigation at initiation of flowering (I_1) maximum SLW was at 50DAS whereas irrigation at podding (I_2) and also both at flowering and podding (I_3) showed maximum SLW at 60 DAS (Table 2).Within the cultivars maximum SLW was achieved at 60 DAS. SML 668 registered 64.1 g/m^2 of SLW while Mash 114 had 65.36 g/m^2.Specific leaf area recorded significant variation with irrigation regimes however; this trait was highest at 40DAS followed by a decline. SLA was statistically lower(0.28 m^2/g) with two irrigations applied at initiation of flowering and initiation of podding (I_3) but higher when irrigation was given at flowering stage(0.42 m^2/g).Cultivars registered maximum SLA at 30 DAS followed by non-significant differences at 40 and 50DAS and decline at 60DAS. ML1265 had SLA of 0.68 m^2/g and Mash 114 of 0.44 m^2/g which was the highest recorded SLA.

Table2: Pattern of leaf characteristics as influenced by irrigation modules during the crop growth

Treatment	Leaf weight ratio (LWR)				Leaf shoot ratio (LSR)				Specific leaf weigh SLW (g/m^2)			
	Days after sowing											
	30	40	50	60	30	40	50	60	30	40	50	60
Irrigation												
I_0	0.41	0.43	0.40	0.44	0.44	0.40	0.35	1.49		29.45	48.23	47.57
I_1	0.46	0.49	0.42	0.44	0.41	0.41	0.33	1.47		23.84	42.82	42.27
I_2	0.45	0.51	0.44	0.44	0.39	0.42	0.32	1.48		31.49	39.14	46.76
I_3	0.46	0.53	0.45	0.46	0.42	0.38	0.32	1.61		35.31	37.88	40.83
CD (P 0.05)	NS	0.012	NS	NS	0.011	NS	NS	0.013		2.34	0.91	1.22
Varieties												
SML668	0.46	0.48	0.43	0.45	0.43	0.44	0.33	1.47	17.29	30.11	48.15	64.10
ML818	0.44	0.47	0.45	0.44	0.43	0.42	0.32	1.52	15.27	26.91	43.38	45.22
ML1265	0.42	0.45	0.43	0.45	0.42	0.39	0.32	1.63	14.60	25.44	35.38	51.58
Mash338	0.47	0.52	0.39	0.43	0.40	0.38	0.34	1.48	31.09	48.56	39.90	62.91
Mash114	0.44	0.52	0.42	0.46	0.40	0.38	0.37	1.47	22.51	37.44	40.70	65.36
CD (P 0.05)	NS	0.041	0.02	NS	NS	0.021	NS	0.121	2.81	4.12	3.51	5.34

Treatment	Specific leaf area SLA (m^2/g)				Leaf area ratio LAR(cm^2/g)				Leaf area index (LAI)				
Irrigation													
I_0		0.34	0.21	0.21		177.3	110.3	125.6		2.60	2.90	3.50	2.23
I_1		0.42	0.23	0.24		227.1	130.7	140.7		3.40	4.20	4.16	2.74
I_2		0.32	0.26	0.21		174.4	147.3	127.7		3.25	3.88	3.91	2.24
I_3		0.28	0.26	0.24		164.8	153.3	151.1		3.15	4.21	4.51	2.80
CD (P 0.05)		0.28	0.113	0.013		2.7	3.1	8.2		0.128	0.177	0.941	NS
Varieties													
SML668	0.58	0.21	0.21	0.16	300.0	174.2	117.1	92.9	2.95	3.07	3.15	2.73	
ML818	0.65	0.23	0.23	0.22	332.9	197.9	134.9	133.4	3.34	3.53	3.65	3.80	
ML1265	0.68	0.28	0.28	0.19	344.7	209.6	160.9	120.1	3.47	3.80	4.30	3.49	
Mash338	0.32	0.25	0.25	0.16	172.5	118.9	133.8	94.8	1.74	2.20	3.18	2.81	2.33
Mash114	0.44	0.25	0.25	0.15	231.6	154.8	131.1	91.0	2.18	2.95	3.51	2.80	2.67
CD (P 0.05)	0.031	0.0 14	0.029	0.031	1.3	2.1	1.3	3.1	0.481	0.017	0.81	0.271	NS

Leaf area ratio (LAR): Cultivars and irrigation modules had significant impact on the leaf area ratio (LAR) which was highest at 40 DAS (Table2). At this stage maximum LAR was achieved when irrigation was applied at initiation of flowering (I_1, 227.1cm^2/g) and was statistically higher than no irrigation. This ratio was also statistically higher at 50DAS with application of irrigation at initiation of podding (147.3cm^2/g) and with two irrigations given at initiation of flowering and initiation of podding (153.3cm^2/g). With no irrigation and irrigation applied at initiation of flowering LAR declined at 50DAS followed by an increase at 60DAS.However with other two irrigation modules a gradual decline in LAR was observed. Within the cultivars, LAR was highest at 30DAS. ML1265 (344.7cm^2/g) and Mash114 (231.6cm^2/g) registered highest LAR.

Table3: Effect of irrigation modules on yield attributes and yields in mungbean and mash bean

Treatments	Plant height (cm)	Branches /plant	Pods /plant	Seeds /pod	100seed wt. (g)	Biomass (kg/ha)	Grain yield (kg/ha)
Irrigation							
Control(I_0)	58.8	3.9	11.9	6.49	3.4	3571	961
Initiation of flowering (I_1)	63.1	4.4	16.1	7.32	3.61	4233	1217
Initiation of podding (I_2)	65.1	4.6	19.1	7.67	3.79	4619	1268
Initiation of flowering + podding (I_3)	66.1	5.0	19.2	7.77	3.85	5009	1446
LSD 0.05	2.98	0.40	1.5	0.31	0.21	251	36.2
Varieties							
SML668	61.1	3.8	15.8	7.91	5.19	3851	1386
ML818	72.1	4.2	14.4	7.76	3.45	5077	1255
ML1265	77.6	5.1	17.9	8.16	3.57	4476	1442
Mash338	53.2	4.3	15.4	6.32	3.16	4190	1017
Mash114	52.4	5.1	19.0	6.41	2.95	4196	1142
LSD 0.05	2.37	0.4	1.6	0.37	0.18	273	42.5

Leaf area index (LAI): Leaf area index is an important yield determining factor for field grown crops as it is a major determinant of light interception and transpiration (Fageria *et al.* 2006).Moisture stress significantly reduced while irrigation improved LAI. Irrigation applied at initiation of flowering enhanced LAI which was highest at 60 DAS (4.16, Table2)) and decreased at later stage.ML1265 registered highest LAI of 4.3 trailed by Mash 114 (3.51). Cultivars registered maximum LAI at 50 DAS. Fargeria *et al.* (2006) reported that LAI, one of the most important plant growth indices for determining dry matter production though by increasing LAI values dry matter production can be increased but net canopy photosynthesis cannot be increased indefinitely because of increased mutual shading of leaves. Irradiance is lower for leaves within a canopy, which leads to decreased photosynthetic rates per unit leaf area (Yoshida 1981). Reduced leaf area decreases the carbon assimilations as indicated by the positive relationship between the two and ultimately yield which in turn integrates many plant processes in a complex way (Garaca *et al.*2010).Under stress/no irrigation plants first show reduction in cell division resulting in reduced cell number, reduced cell elongation thus inhibiting leaf expansion .This modification in leaf anatomy is one of the basic causes which leads to reduction in average leaf size. However, with the irrigation cell turgidity is maintained thereby the metabolic processes proceeds in a normal manner (Baroowa and Gogoi, 2012). The impact of supplemental irrigations in chickpea (Moemeni *et al.*2013) revealed higher LAI during linear growth stage and also during flowering while grain filling recorded a decline in LA and consequently in LAI. These results may be due to superiority of both genotypes in leaf measurement i.e. branches /plant, LAI, LSR, LWR, LAR and SLA and also consistently higher chlorophyll content. Similar results on the varietal differences in growth analysis have been recorded by Hozayn *et al* (2007) and El-Karamany *et al* (2002).

Table 4: Crop yield in terms of mean productivity (MP), rate of productivity (RP), drought susceptibility index (DSI) and drought tolerance index (DTI) of mungbean genotypes

	SML668				ML818				ML1265			
	MP	RP	DSI	DTI	MP	RP	DSI	DTI	MP	RP	DSI	DTI
Initiation of flowering (I_1)	1273	0.78	1.26	0.91	1071	0.84	0.72	0.65	1175	0.71	0.77	0.77
Initiation of podding (I_2)	1283	0.77	0.73	0.73	1166	0.72	0.89	0.59	1327	0.58	0.82	0.73
Initiation of flowering + podding (I_3)	1332	0.72	0.77	0.67	1249	0.64	0.99	0.58	1357	0.56	0.71	0.66
Mean	1296	0.76	0.92	0.77	1162	0.73	0.87	0.61	1286.3	0.62	0.77	0.72

Yield attributes, seed yield and yield indices

Significant differences in yield attributes, biomass and seed yield have been recorded at maturity (Table 3).Plant height improved by 7.3% (I_1), 10.7% (I_2) and 12.4% (I_3).ML1265 and Mash 338 were tallest among the mung and mash bean cultivars .Decline in plant growth in terms of plant height and branches is due to loss of cell turgor which greatly suppresses cell expansion and cell growth thereby inhibiting the linear growth of shoot. Hence it may be inferred that slow decrease in plant height might be due to lack of adequate moisture in the root zone. The reduction in height under stress is generally associated with a decline in the cell enlargement which greatly hampers water relations .Moisture available in the form of irrigation relives the stress thereby favoring the cell enlargement (Bhatt and Srivastava 2005).Number of branches /plant were maximum with I_3 . ML1265 and Mash114 had comparable number of branches per plant (5.1). These results are supported by the findings of Raza *et al.* 2012 .Stress limited the pod number while their number increased consistently with irrigation regimes.ML1265 recorded maximum pods (17.9) and Mash 114 (19.0) among the cultivars studied. Omid (2008) and later Raza *et al* .(2012) also studied the response of mungbean varieties to withholding irrigation at various phenological stages and concluded the varying timing of irrigation reported significant effect on yield and yield components whereas no irrigation at flowering stage reduced the number of pods/plant. Number of seeds per pod increased with irrigation regimes.

Table 5: Crop yield in terms of mean productivity, rate of productivity, drought susceptibility index and drought tolerance index of mash bean genotypes

Treatment	Mash 338				Mash 114			
	MP	**RP**	**DSI**	**DTI**	**MP**	**RP**	**DSI**	**DTI**
Initiation of flowering (I_1)	904	0.81	1.06	0.72	1023	0.83	0.94	0.93
Initiation of podding (I_2)	963	0.72	1.04	0.65	1083	0.75	0.95	0.83
Initiation of flowering+ podding (I_3)	975	0.71	1.02	0.63	1106	0.72	0.98	0.81
Mean	947	0.75	1.04	0.67	1070	0.77	0.96	0.85

Number of seeds/pod were 8.16(ML1265) and 6.41 (Mash114) .Irrigation had significant impact on 100 seed weight which improved by 6.1% with I_1 ,11.4 % with I_2 and 13.2% with I_3 .SML668 registered seed weight of 5.2 g .Sangakara (1994)and later Khan (2001) reported that seeds from irrigated plots had a greater weight owing to heavier cotyledons. Biomass was reduced significantly under water stress and enhancement in biomass was 18.5%, 29.3% and 40.2% with three irrigation regimes. ML1265 recorded 4476 (kg/ha) while Mash 114 (4196 kg/ha) of biological yield. Seed yield under moisture stress was 961 kg/ha. The yields of the pulses in non-stresses environment clearly out yielded in the stress environment. Irrigation applied at initiation of flowering (I_1) produced 21% higher seed yield ,29.7% increase with irrigation at initiation of podding (I_2) and 33.5% with two sequential irrigations at initiation of flowering and podding (I_3) over no irrigation. Our results are in accordance with the findings of Raza *et al.* (2012).Mean productivity in the genotypes increased while rate productivity declined with irrigation modules.SML668 possessed higher MP than ML1265 but lower DSI was associated with better performance as DTI was also appreciably high in the later cultivar (Table 4). Among the Mash bean cultivars Mash114 had higher MP, lower DSI<1 but higher DTI>0.85 (Table 5) .Irrigation given at podding recorded comparable DSI and DTI in SML668 while similar results were seen in Mash114 when irrigated at initiation of flowering . Based on the yield indices, higher chlorophyll pigment, LAI, SLW, more number of branches, number of pods, seed weight and biomass ML1265 out yielded other two mungbean cultivars while Mash114 was higher yielder than Mash338. Water stress/no irrigation reduced the leaf traits along with the seed yield. Irrigation applied during the reproductive phase significantly improved the morpho- physiological traits associated with the seed yield.

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