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SHORT COMMUNICATION

CHANGES IN THE CROP PHENOLOGY OF GREEN GRAM (*VIGNA RADIATA* L.) AND SOYBEAN (*GLYCINE MAX* L. MERRIL.) UNDER VARYING REGIMES OF SHADE IN A SEMI-ARID AGROCLIMATIC LOCATION

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The experiments were conducted during 2007 and 2008 under simulated shade net house conditions by growing crops namely green gram (*Vigna radiata* L.) and soybean (*Glycine max* L. Merril.) with three different regimes of shade (33, 50 and 75%) or without shade as control (open sunlight) to test the influence of shade on the phenology of crops beginning with the germination. Although seed germination was successful (93% to 100%) in all the three regimes of shade and open field, germination was faster in shade than open field in both the crops. However, there was differential response with the requirement of days to achieve maximum germination between the crops where green gram showed faster rate of germination than soybean. Time taken for leaf maturity or full expansion varied with the crops and the intensity of shade. Expansion rates of leaf length (LER) and lamina width were higher in shade than in open field. These were faster in green gram than soybean. However, degree of difference in LER between shade and open grown plants was less in soybean than in green gram. In green gram, flowering initiation was observed within 31-38 DAS (days after sowing) either in open field or 33% shade and within 34-40 DAS in 50% or 75% shade. In soybean, flowering initiation was observed within 33-41 DAS in all the three regimes of shade and it took relatively more time to flower initiation in open condition i.e. 37-44 DAS. A trend similar to flowering initiation was also observed in pod formation in green gram and soybean. The observed consistent trend for all the parameters of crop phenology indicate a relatively better shade adaptability in terms of its resilience to shade induced changes in crop phenology in soybean than green gram in a semi-arid region.

Key words: **Flowering, germination, leaf expansion rate (LER), microclimate, pod formation, shade**

Extreme shade imposes a limitation to crop productivity. The extent of the limitation varies with shade tolerance of the crops. The capacity of crop plant to adapt to shade is a major physiological determinant to crop productivity under light limiting conditions as it is the case of crop plants growing under trees in agroforestry practices. Low light due to overcast of clouds during monsoon season pose a great limitation to the crops like rice (Venkateswarlu *et al.* 1977). This also holds true for crops like green gram and soybean preferably grown in Central India which is known as a dry semi-arid region of our country. Shade induced low light levels affect the important physiological processes (Alam *et al.* 2002, Cowan and Faraquhar 1977, Givnish 1986). A variety of acclimation takes place at physiological and biochemical levels in plants growing in low light or high light (Syvertsen *et al.* 1984). These are manifested through the crop growth pattern including crop phenology (Constable and Ross 1988, Dybing 1994).

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Systematic studies on crop phenology have significance to decipher if there is any shift in crop growth pattern with reference to their prevailing climatic situations. This may help immediately or in the long run to understand the differential responses of the crops to the changing climate (Craufurd and Wheeler 2009). Soybean and green gram are among some of the major crops in Central India which are also vulnerable to the implications of climate change scenarios. Hence, it is important to comprehensively study the crop phenology aspects of the two crops i.e. soybean and green gram at different intensity of shade in comparison to open field grown plants. With this background, we have conducted comprehensive experiments in the consecutive two years 2007 and 2008 to examine the crop phenology of soybean and green gram by growing them in field in three different regimes of shades under shade net, and comparing them with open field grown plants. For this we tested the hypothesis that shade can considerably change the crop phenology in the important crops like soybean and green gram in a semi-arid agroclimatic conditions of Central India.

The experiment was conducted at National Research Centre for Agro forestry, Jhansi (25° 27′ N latitude and 78° 35′ E longitude, 271 m above MSL) in the semi-arid tract of central plateau of India. The experiment was conducted in simulated shade net houses of varying level of shade and in open field (full sunlight) during kharif seasons in the years 2007 and 2008 with soybean (*Glycine max* L. Merill variety JS-335) and green gram (*Vigna radiata* L. variety PDM-54). There were three shade net houses (25×8×3 m) and providing 75%, 50% and 33% shade based on the incident sunlight. Different intensity of shade was obtained in each of three separate shade net houses as different category (porosity) of agro-shade net (made up of high density polyethylene) was used to cover the respective shade net house. For example agro shade net of 75% category allowed about 25% of incident sunlight, whereas 50% agro shade net allowed 50% incident sunlight and like wise 67% sunlight intensity was allowed in 33% shade net house.

There were three replications per crop in each treatment (shade or open sunlight) in RBD (randomized block design) having plot size of 5.8×3.4 m. Soil in the experiment field was black having a mean pH 7.02. The study was conducted taking all the standard agronomic practices including irrigation and plant protection measures. Diurnal microclimatic data of the experimental sites were also taken through a Steady State Porometer (LI-1600, LICOR, USA) during the entire crop season in 2007 and 2008 (Table 1).

Observation on seed germination was taken daily in all the plots across all the four treatments *viz*. 33% shade, 50% shade, 75% shade and in open field during 2007 and 2008. Seed germination observation was recorded by counting the number of plants emerged after sowing till germination of plants were completed. Seed germination percentage was calculated by daily counting the emerging plants plot wise from all the three replications from each treatment. As germination was progressing day wise, percentage of germination data on the basis of each DAS (days after sowing) was progressively calculated. For estimation of leaf expansion rate, 3 plants were tagged in each treatment i.e. all three category of shade (33%, 50% and 75% shade) and in open field of both the crops during both the years. These tagged plants were closely monitored from leaf formation to maturity to measure the leaf length and lamina width daily. When the leaf was fully expanded, the leaf length and width were measured and used to calculate the expansion rate by dividing it with the number of days taken from the initiation. Mean data of two years i.e. 2007 and 2008 are presented.

Experiment field were regularly monitored for observation on flowering initiation and pod formation during both the years. This observation was taken daily till flowering initiation and pod formation of all plants was completed in all the replications. Data from two years i.e. 2007 and 2008 are presented separately for exhibiting the consistency of the observed trends (Table 3).

ANOVA was done using statistical software (SYSTAT-11) for morpho-metric data namely leaf length, leaf width, leaf expansion rate (LER) and lamina characteristics followed by the calculation of CD at 5% level of significance.

Depending on the degree of shade, seed germination was faster in shade than in open field in both the crops and the requirement of days to achieve maximum

Table 1. Diurnal microclimatic data of the experimental sites during the crop growing season in two consecutive years.

Months and intensity of shade	2007						2008					
	9:30 AM			2:00 PM			9:30 AM			2:00 PM		
	PPFD	R.H. (%)	Ta	PPFD	R.H. (%)	Ta	PPFD	R.H. (%)	Ta	PPFD	R.H. (%)	Ta
July												
Open	1406.4±176.4	65.03±2.4	33.5±0.3	1214.5±90.6	63.07±3.1	34.2±0.8	1127.9±139.3	68.81±1.1	34.1±0.7	1165.6±133.3	55.31±1.9	35.6±1.6
33% Shade	867.6±76.6	69.06±3.2	32.5±0.4	707.2±61.1	64.96±2.9	33.9±1.1	669.0±88.4	69.34±0.8	33.8±1.0	705.9±88.4	61.56±2.9	34.8±1.1
50% shade	640.4±74.2	72.22±3.4	31.8±0.6	524.4±52.7	65.57±3.9	32.8±0.6	503.6±75.0	70.31±2.4	33.3±1.2	523.0±72.2	62.13±2.7	34.2±0.7
75% shade	366.8±28.1	73.90±0.9	31.7±0.6	306.9±30.6	66.27±2.0	32.3±0.8	229.6±53.7	70.72±1.2	32.3±1.5	238.6±53.0	64.43±3.4	33.3±1.5
Aug.												
Open	1478.6±99.1	67.13±3.9	32.9±0.9	1107.2±143.1	62.07±3.0	33.8±0.5	1139.9±125.8	67.6±2.1	36.3±2.3	1196.2±126.2	54.85±6.9	37.1±1.7
33% Shade	889.2±53.6	69.50±3.5	32.2±0.7	651.7±96.1	62.30±4.3	33.7±1.2	673.8±80.9	68.12±1.9	35.1±2.1	748.3±95.7	56.23±7.1	36.4±2.3
50% shade	640.3±74.3	72.33±3.4	31.8±0.6	513.9±59.6	62.84±2.1	33.6±1.3	504.5±77.8	69.67±2.0	34.3±1.9	520.8±72.9	58.57±6.3	34.4±1.6
75% shade	316.7±81.8	73.63±1.4	31.3±0.2	249.9±57.6	63.11±4.0	33.4±0.9	229.6±53.7	70.43±2.0	33.4±1.6	238.6±53.0	59.42±6.3	33.9±1.6
Sept.												
Open	1402.5±55.9	58.05±3.7	33.9±0.5	1068.3±119.2	52.20±6.7	35.3±0.3	1062.6±73.0	55.8±4.2	37.5±0.3	959.9±75.6	48.78±4.0	38.1±1.2
33% Shade	832.6±33.1	64.57±3.8	32.9±0.5	686.8±91.2	53.80±5.2	35.2±0.3	637.1±43.9	57.25±4.4	36.2±0.3	575.3±45.4	50.81±3.9	36.5±1.3
50% shade	642.4±27.7	66.87±4.2	32.8±0.8	473.1±69.8	58.00±5.2	35.1±0.2	487.9±33.7	63.54±3.0	34.2±0.6	441.5±35.0	53.11±3.8	35.2±1.4
75% shade	321.2±29.6	67.32±1.0	32.7±1.1	267.9±37.7	58.47±4.4	35.0±0.3	263.8±18.2	65.37±3.1	33.1±0.7	231.3±21.9	54.8±3.7	34.2±1.4
Oct.												
Open	1105.8±51.3	34.23±4.4	31.9±0.5	1044.2±123.7	25.01±2.2	35.2±0.7	1000.8±93.0	37.88±2.8	36.9±0.6	928.6±81.7	27.13±1.9	37.2±1.6
33% Shade	661.4±28.0	35.35±4.5	31.7±0.7	629.1±76.5	25.12±2.9	34.7±0.5	600.0±55.7	39.22±2.9	35.9±0.7	555.9±48.1	28.41±2.1	36.4±1.5
50% shade	507.7±22.9	36.21±1.8	31.4±0.7	480.9±56.8	27.60±2.7	34.0±0.7	460.7±42.2	41.95±2.8	34.1±1.3	426.3±38.1	29.55±2.3	35.8±0.7
75% shade	247.2±13.3	37.68±1.6	31.3±0.7	259.1±31.8	28.54±1.6	33.5±0.9	250.9±23.9	42.98±2.7	33.1±0.5	231.6±20.7	30.66±2.3	34.3±1.0

PPFD = photosynthetic photon flux density (µmol $m^{-2}s^{-1}$), Ta = air temperature (°C), R.H = relative humidity (%)., ± S.E.

Table 2. Effect of different regimes of shade on leaf expansion rate and lamina characteristics of green gram and soybean.

Crops	Treatments	Leaf expansion rate		Lamina characteristics	
		Leaf length (cm/day)	Leaf width (cm/day)	Leaf length (cm/day)	Leaf width (cm/day)
Green gram	open	0.88	0.67	13.62	10.38
	33% shade	1.13	0.88	14.17	10.99
	50% shade	1.27	1.04	14.86	11.38
	75% shade	1.51	1.15	15.10	11.49
CD at 5%		0.23	0.30	0.03	0.04
Soybean	open	0.81	0.58	10.12	7.27
	33% shade	0.92	0.67	10.63	7.67
	50% shade	1.04	0.76	10.92	7.96
	75% shade	1.07	0.78	11.28	8.17
CD at 5%		0.46	0.20	0.03	0.02

Table 3. Effect of shade on phenological events as flowering initiation and pod formation of green gram and soybean.

Phenological Events	Crops	Kharif 2007				Kharif 2008			
		Treatments							
		Open DAS	33% shade DAS	50% shade DAS	75% shade DAS	open DAS	33% shade DAS	50% shade DAS	75% shade DAS
Flowering	Green gram	31-38	31-38	34-40	34-40	26-31	28-33	30-34	30-34
Initiation	Soybean	37-44	33-41	33-41	33-41	33-37	28-34	28-34	28-34
Pod	Green gram	36-41	36-41	38-43	38-43	28-34	28-34	30-35	30-35
Formation	Soybean	46-51	42-49	42-49	42-49	45-49	40-46	40-46	40-46

DAS-Days after sowing

germination varied between the crops where green gram showed faster rate of germination than soybean during both the years. During 2007 and 2008 seed germination ranged up to (99% to 100%) in green gram within 5 DAS in all three categories of shade and in open field (Fig. 1). In soybean, seed germination ranged up to (92% to 98%) within 6 DAS in 50% or in 75% shade and within 7 DAS in 33% or in open field (Fig. 2). Shade induced difference in germination was reported in many wild plant species and also in weed (Frankland and Taylorson 1983, Penneys 2004). Faster germination could be attributed to the favorable microclimate in shade as we found in our study (Table 1). Hence microclimatic benefit of shade is also reflected from our study which has considerable importance during climate change scenarios.

Leaf expansion rates (LER) and lamina characteristics of leaf were higher in shades than in open field in both the crops during 2007 and 2008. Expansion of leaf length and lamina width was higher in green gram than soybean in all treatments (Table 2). However, degree of difference in LER between shade and open grown plants was less in soybean than in green gram. Higher LER in shade can be considered as an adaptation to compensate the limited availability of incident light.

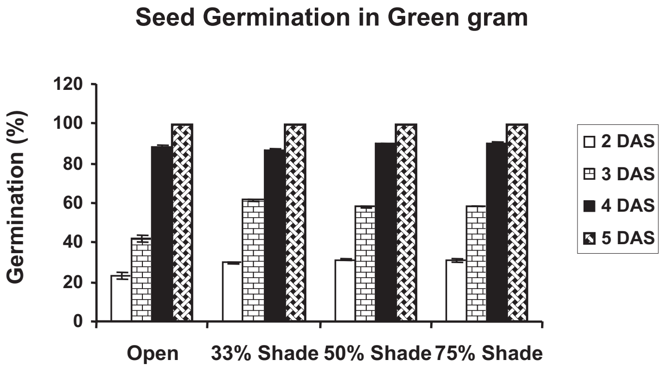

Fig. 1. Effect of different levels of shade on seed germination of green gram.
Vertical bars represent ± SE. DAS = days after sowing

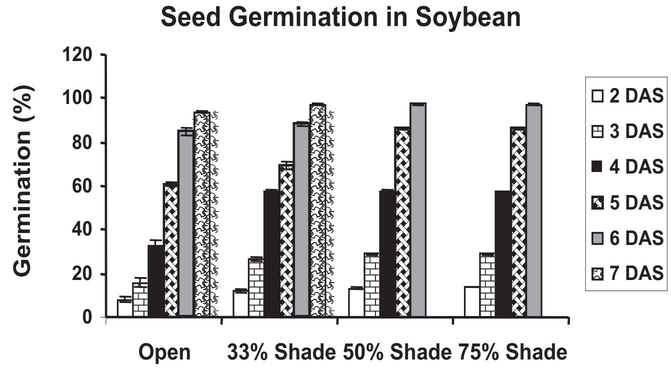

Fig. 2. Effect of different levels of shade on seed germination of soybean.
Vertical bars represent ± SE. DAS = days after sowing

Our data corroborate with the adaptive capability of plants in low light as reported (Mullet 1988, Oguchi *et al.* 2003, Sims and Pearcy 1994, Yano and Terashima 2004). Changes in leaf phenology in response to climate change have been observed by Morin *et al*. (2010).

During 2007, in green gram flowering initiation was observed within 31-38 DAS either in open field or in 33% shade, within 34-40 DAS in 50% or in 75% shade. In soybean, flowering initiation was observed earlier in shade (33%, 50% and 75%) within 33-41 DAS and it took relatively more time to flowering initiation in open field i.e. 37-44 DAS (Table 3). Similar pattern of flowering initiation was also observed during kharif of 2008 (Table 3). Shade induced changes in flower production and pod formation in soybean was found in temperate climate which indicates that phenology of soybean is an important aspect to study in the context of changing climate (Jiang and Egli 1993, Yoshida *et al.* 1983, Dybing 1994).

Similar trend as in flowering initiation was observed with pod formation in green gram and soybean during *kharif* of 2007 and 2008 (Table 3). It is obvious that flowering initiation is reflected in pod formation and thus pod formation is dependent on flowering phenology. Due to early flowering as in the case of soybean, pod filling was also found earlier in shade. Accordingly, flowering phenology determined the duration of pod set and seed filling in soybean. Early flowering traits of soybean in shade as we found is noteworthy. Seed filling in soybean was largely dependent on the light enrichment (Illipronti *et al*. 2000, Board and Tan 1995, Egli 1997).

We conclude that rate of seed germination was higher in shade than in open field due to conducive microclimate namely higher relative humidity (RH) and moderate temperature favouring in soil moisture retention in shade. Expansion rate of leaf length and width was more in shade than in open field. Soybean showed a faster rate of flower and pod initiation than green gram in shade. The consistent trend in all the parameters of crop phenology indicate that soybean has relatively better shade adaptability than green gram in a semi-arid regions.

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