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DRY MATTER PRODUCTION AND RADIATION USE EFFICIENCY OF PULSES GROWN UNDER DIFFERENT LIGHT CONDITIONS

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Abstract

A field experiment was conducted to determine the effects of varying light conditions on growth, morphology and seed yield of pulses. Treatments consisted of 50, 75 and 100% of the full sunlight tested in pigeonpea, cowpea, lablab and blackgram species. Under field condition, artificial shade was created by erecting white nylon nets at 30 days and maintained until final harvest. Results showed that shading at both 50 and 75% of the full sunlight had significant ($p < 0.05$) negative effect on leaf area index (16 - 35%), total dry matter production (11 - 18%), grain yield (19 - 32%) of pulses over full sunlight. However, radiation use efficiency (RUE) of pulses based on either grain or biomass production was higher in shade plants. Pigeonpea and lablab were relatively shade tolerant compared to cowpea and blackgram with potential crops for growth under reduced light environment conditions.

Introduction

It is well documented that the photosynthetic response of a plant is affected by the light intensity at which it is grown (Valladares *et al.* 2003). Strong correlations also exist between the yield of a crop and its light environment. Considerable changes in morpho-physiological nature of sun and shaded plants were reported by many workers across the globe. Legumes are sensitive to reduced light levels either due to crop combinations or overcrowding (Valizadeh and Shakiba 2006). Either biomass or yield reduction by reduced light depends upon crop species as well as degree of shading. Generally shading occurs due to dense plant population, intercropping, altered planting geometry and excessive vegetative growth which affect the performance through reducing photosynthetic capacity of plants. Adoptive response to low irradiance is leaf area, chlorophyll content, leaf to stem mass and stem length. Grain yield of pulse species has been reported to reduce, when intercropped with cereals and other crops (Liu *et al.* 2016). The low yield in intercropped pulse species was mainly due to shading that resulted in weak plant growth. The reduction in light reaching the legume canopy when intercropped with other crops was about 30 - 50% of the total incoming radiation and began around 30 - 35 days after seeding of the crops (Armstrong *et al*. 2008). To obtain the maximum yield of the pulses under low light, selection of suitable pulse species plays an important role in crop mixtures. The species may respond differently to shading stress in terms of morpho-physiology as well as yield (Kakiuchi and Kobata 2006).

In particular, photosynthetic active radiation (PAR) is the major factor regulating photosynthesis and other physiological processes in plants. Hence, the dry matter production and yield depends on it to a greater extent (Lemaire *et al.* 2007). Selection of pulses that perform a stable photosynthesis under different light intensities will be a greater advantage to get high and stable productivity under the natural environment. Therefore, the present field investigation was carried out to identify the low light tolerant pulse species by comparing their relative performance

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under different levels of reduced light and identify morpho-physiological parameters contributing to low light tolerance.

Materials and Methods

A field experiment was conducted during rainy season of 2014 and 2016 at Agricultural College Farm (16°12' N 77°19'3 E, 407m elevation) Raichur, Karnataka, India. The experimental site was clay in texture (50.67%) having a pH 8.26 and EC 0.18 dS/m. The available nitrogen, phosphorous and potassium before start of experiment was 245.5, 34.4 and 278.6 kg/ha, respectively. The experiment was laid out in split plot design with three replications. The treatments consisted of light levels of 50, 75% shade of normal sunlight compared to normal sunlight as main plot treatments and pulses Lablab (*Dolichos lablab* L.), Pigeonpea (*Cajanus cajan* L.), Cowpea (*Vigna unguiculata* L.) and Blackgram (*Vigna mungo* L.) as sub plot treatments. Shading conditions for the respective level of light intensity were created from 30 days after seeding until maturity. The normal annual rainfall of experimental site was 835.9 mm of which highest in June (194.1 mm) and September (292.5 mm). The crops were sown on 21 July, 2016 raised as per the package of practices. Leaf area index (LAI) and light interception were measured by using a SunScan canopy analyzer (Delta-T Device, Cambridge. UK) probe. According to the method of Tsubo *et al*. (2001) the fraction of PAR (fPAR) transmitted was measured during 11:00 to 14:00 on a sunny day. Data during the crop growing season were recorded in 15 days interval. Then the daily incident PAR values were multiplied by corresponding daily fIPAR values to compute daily intercepted PAR (IPAR).

$$\text{fPAR} = 1 - \frac{I_o}{I_t}$$

Where, F = Fraction of incident solar radiation intercepted by a canopy layer. I_o= Measured incident PAR below a canopy layer. I_t = Radiant flux density on the top of the canopy. Radiation use efficiency (RUE) was calculated as per the procedure provided by Tsubo *et al*. (2001).

$$\text{RUE} = \frac{Y_{\text{biomass}}}{I_o \times F}$$

where, $Y_{biomass}$ was aboveground biomass (g/m^2), I_o was the flux density of the incident PAR above the crop canopy (MJ m^{-2}) and F is fraction of PAR intercepted. I_o = Incident light was calculated as per the procedure by Allen *et al.* (2006).

Plant samples for dry matter studies were collected at 20 days interval after 30 days of sowing up to harvest in all the four crops. At each sampling, five plants were uprooted at randomly in each treatment and partitioned into leaf, stem and reproductive parts. These samples were oven dried at 70ºC in hot air oven for 72 hrs till a constant weight obtained. The dry weight of different plant parts were recorded, the dry matter production per plant was obtained with the summation of dry weight of all plant parts and was expressed per plant basis (g/plant). Grain yield of all pulses were determined by harvesting all the plants in a sampling area of 3.6 m × 3.4 m. The reported grain yields were determined by accounting for a water content of 12% in the sun-dried grains.

Results and Discussion

The LAI of pulses under shade was much lower than unshaded at various growth stages. It increased dramatically during the initial growth stage peaked at grand growth stage between 50 and 60 DAS, later declined with leaf senescence in all the species. However, the rate of LAI decline was not similar across the species (Fig. 1). At 90 DAS, unshaded lablab recorded higher LAI (5.51) followed by pigeonpea (3.55) cowpea (3.01) and least in blackgram (1.27). Extent of LAI reduction by shading was higher in pigeonpea (10.7 - 34.6%) followed by lablab (22.0 to 27.5%). Whereas, shading had no significant effect in blackgram and cowpea was due to species attained maturity at 90 DAS. It was more pronounced in 75% over 50% shading. Significantly ($p < 0.05$) higher LAI under normal sunlight might be due to more number of leaves per plant, broader leaves and higher dry matter accumulation per plant. While, higher LAI of lablab was mainly due to larger size and more number of leaves per pant. It implied that shading had remarkable impact on LAI in all the species. The results of Ade-ademilua and Eyemi (2013) also indicated variation in LAI due to reduced light.

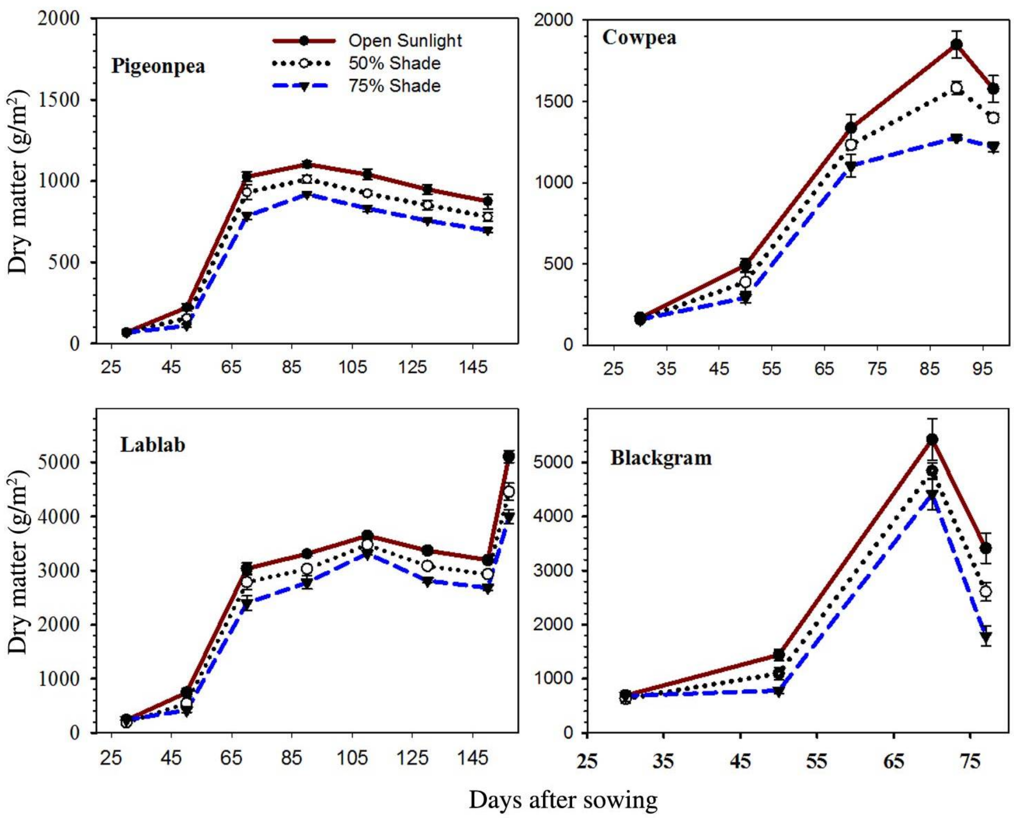

Fig. 1. Light interception (fPAR) and leaf area index (LAI) of pigeonpea, lablab, blackgram and cowpea species grown in shade and unshade under field conditions. Observations are mean of three replications and two spots in each treatment.

Seasonal interception of PAR (fPAR) was significantly influenced by both shade and pulse species (Fig. 2). It increased with plant age and that reached the highest between 50 and 60 DAS in all the species. Open sunlight plants were intercepted more PAR over 50 and 75% shade. Quick growth, higher light availability, canopy coverage, and biomass accumulation in unshaded plants were responsible for higher values of fPAR. The fPAR reached maximum in lablab (0.98) followed by cowpea (0.95), pigeonpea (0.76) and least in blackgram (0.67) in open sunlight plants. Differences in PAR interception between shade and unshaded pigeonpea and cowpea were 11.7%

and lablab 7.5%, respectively. Pigeonpea had lower fPAR during early part of crop growth mainly due to slow growth rate and biomass accumulation. During vegetative growth cowpea absorbed 90% of PAR as reported by Alimadadi *et al.* (2006).

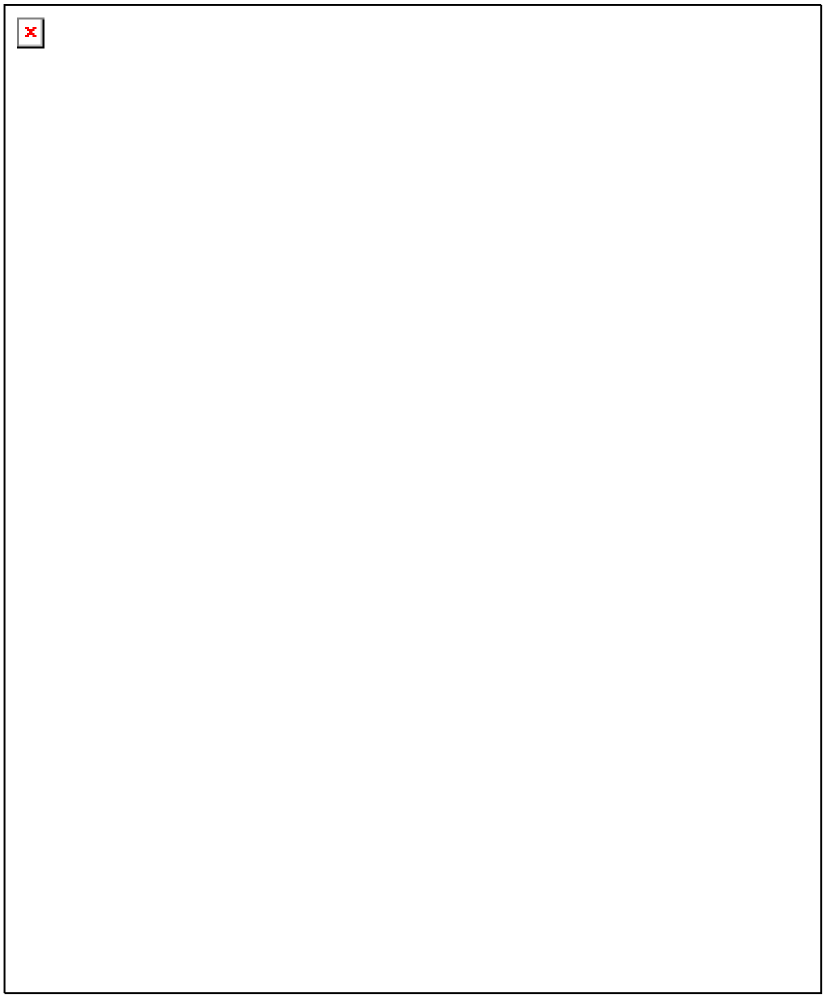

Fig. 2. Variation in dry matter production of pulse species per sq. meter at final harvest grown in shade and unshade under field condition. Observations are average of three replications and two spots in each location.

Above ground dry matter (ADM) production was significantly influenced by shade and pulse species (Fig. 2). Under non limiting light condition, ADM production was similar for all species and faster during the initial exponential growth phase. Compared to the unshaded plants, ADM production was severely affected by 50 and 75% shade. At final harvest, the magnitude of ADM production increase in unshaded plants was 18 and 11%, respectively over 50% shade and 36 and 23%, respectively over 75% shade. The higher ADM production under unshaded conditions was mainly due to higher number of leaves, leaf area, branches per plant, LAI and then those under low light intensity. Significantly higher dry matter accumulation in leaves and stem was recorded in lablab. The magnitude of increase was 54, 22 and 61% in leaves and 1, 37 and 74% with respect to stem portion of pigeonpea, cowpea and blackgram, respectively. This might be due to higher number of leaves, leaf area, leaf thickness and higher photosynthetic rate in lablab over other pulses. Similar results of higher biomass production and distribution under full sunlight were obtained by Santelices *et al.* (2015), Araki *et al.* (2014) and Tossi and Baki (2013) and Divya *et al.* (2013).

Grain and stover yields of pulses were significantly influenced by shading (Table 1). Open sunlight plants gave significantly higher seed yield over 50 and 75% shaded plants. Relative yield reduction due to the light deficit was noticed in all pulses. Irrespective of shade levels pigeonpea and blackgram recorded significantly higher and lower seed yield, respectively. More sensitive to reduced light was observed in blackgram and cowpea. The magnitude of decrease in grain yield

Table 1. Yields and radiation use efficiency of different pulses as influenced by different light levels.

	Grain yield (kg/ha)	Stover yield (kg/ha)	Seed yield (g/plant)	Grain based RUE (g/MJ)	Biomass based RUE (g/MJ)
Shade level (S)					
Open sunlight	1350	3944	18.5	0.48	1.32
50% shade	1089	3497	15.7	0.82	2.52
75 % shade	916	3217	13.6	1.49	5.08
LSD (p = 0.05)	138	242	1.8	0.36	0.96
Pulses (P)					
Pigeonpea	1687	4743	45.6	1.31	3.78
Cowpea	1028	2777	4.6	0.96	2.83
Lablab	1354	5566	12.2	0.77	3.21
Blackgram	404	1124	1.2	0.68	2.09
LSD (p = 0.05)	107	251	1.5	0.23	0.76
Interaction LSD (0.05)					
Factor (P) at same level of S	204	463	2.8	0.47	NS
Factor (S) at same level of P	210	444	2.8	0.50	NS

NS = Non significant, DAS = Days after sowing.

was 19 to 32 per cent across shade levels over unshaded plants in blackgram and cowpea, respectively. Unshade plants put forth higher leaf area and dry matter accumulation in leaves which might have supplied required photosynthates to the reproductive parts more precisely to the seed (Ewansiha *et al.* 2014). Whereas, Fagwalawa and Yakasai (2013) reported that 27% reduction in light decreased 91% cowpea grain yield compared to unshaded plants. Similar results of higher yield under open sunlight compared to shade were reported by Gomez *et al.* (2012). Across species, light had significant impact on stover/stalk yield. It was higher in plants grown under open sunlight over 50 and 75% of the sunlight shaded plants (Table 1). Biomass was accumulated significantly higher in lablab followed by pigeonpea and least in blackgram. This might be due to higher total dry matter production in the plant parts at harvest under open sunlight and in lablab and pigeonpea. Araki *et al.* (2014) reported that reduction in stover yield due to reduction in light levels was obvious in greengram.

Radiation use efficiency based on grain yield and biomass of pulse species was significantly influenced by shading. Similar to the differences in grain yield, RUE based on grain (RUE_g) and biomass (RUE_b) were significantly ($p < 0.05$) influenced by light regimes (Table 1). Shaded plants had both RUE_g and RUE_b higher than unshaded pulses. Higher RUE_g (2.22 g/MJ) and RUE_b (6.7 g/MJ) were obtained when pigeonpea was grown under 75% shade. Extent of RUE_g reduction under open sunlight was 60% in cowpea and blackgram and 73% in lablab and pigeonpea. Whereas, RUE_b decreased 70 to 76% in open sunlight over 75% shaded plants. This might be due to RUE associated with changes in above ground dry matter and fPAR throughout the crop period. While significantly lower RUE_g and RUE_b was recorded when lablab (0.35 and 1.41 g/MJ) and blackgram (0.40 and 0.95 g/MJ) grown under normal sunlight, respectively. Species that intercept a large fraction of PAR are responsible for variation in RUE, major component of grain yield in pulses. Sandana *et al.* (2012) reported reduced light in intercropped beans had 79% higher RUE than that of sole crop. Both RUE_g and RUE_b values of the present study are within the range of previous reports suggesting that low RUE in grain legumes could be inherent characteristics of these species.

The present study showed shading effect on pulses growth, dry matter partitioning, yield, interception and use efficiency of radiation. All the pulses exhibited sensitive to shade but quantum of reduction varied with species. Further, the degree of shading was also responsible for morpho-physiological changes. Leaf area index and light interception was significantly affected throughout growing period in shaded plants. Pigeonpea and lablab were less affected and adapted to shade as compared to cowpea and blackgram. The shaded plants had greater RUE than the unshaded and shading reduced the availability of radiant energy at the canopy surface. Thus the study indicated that shade tolerant pulse species are potential crops for light limited growing environment such as intercropping.

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References

Ade-Ademilua OE and Eyemi M 2013. Effect of open field and open shade conditions on the growth and phytochemical constituents of Amaranthus. J. Bio. Agri. Health. **3**: 12.

Allen RG, Pereira LS, Raes D and Smith M 2006. FAO No. 56 Irrigation and Drainage Paper. pp. 41-64.

Alimadadi A, Rostamza M, Jahansooz MR, Ahmadi A and Afshari TR 2006, Cowpea, common bean and mungbean radiation use efficiency, light extinction coefficient and radiation interception in double cropping. Pajouhesh and Sazandegi **19**(2): 67-75.

Araki T, Thay T and Kubota F 2014. Effects of shading on growth and photosynthetic potential of greengram (*Vigna radiata* L.) cultivars. Env. Control Bio. **52**(4): 227-231.

Armstrong KL, KA Albrecht JG Lauer and H Riday 2008. Intercropping corn with lablab bean, velvet bean, and scarlet runner bean for forage. Crop Sci. **48**: 371.

Divya R, Venkatessn K, Jeyakumar P and Pugalendhi L 2013. Season influence on physiological parametres and yield of dolichos bean (*Dolichos lablab* (L.) var. typicus) genotypes. Madras Agric. J. **100**(3): 57-61.

Ewansiha SU, Kamara SU and Onyibe JE 2014. Performance of cowpea cultivars when grown as an intercrop with maize of contrasting maturities. Arch. Agron. Soil Sci. **60**(5): 597-608.

Fagwalawa LD and Yakasai MT 2013. The effect of different light intensities (%) on the grain yield components of some varieties of cowpea (*Vigna unguiculata* L.) Bayero J. Pure App. Sci. **6**(1): 35-39.

Gomez S, Guenni O and Guenni LB 2012. Growth, leaf photosynthesis and canopy light use efficiency under differing irradiance and soil N supplies in the forage grass *Brachiaria decumbens* Stapf. Grass and Forage Sci. **68**: 395-407.

Kakiuchi J and Kobata T 2006. The relationship between dry matter increase of seed and shoot during the seed-filling period in three kinds of soybean with different growth habits subjected to shading and thinning. Pl. Prod. Sci. **9**: 20-27.

Lemaire G, Oosterom VE, Sheehy J, Jeuffroy MH, Massignam A and Rossato L 2007. Is crop nitrogen demand more closely related to dry matter accumulation or leaf area expansion during vegetative growth. Field Crops Res. **100**: 91-106.

Sandana P, Ramirez M and Pinochet D 2012. Radiation interception and radiation use efficiency of wheat and pea under different P availabilities. Field Crops Res. **127**: 44-50.

Santelices R, Espinoza S and Cabrera AM 2015. Effects of four levels of shade on survival, morphology and chlorophyll fluorescence of *Nothofagus alessandrii* container-grown seedlings. Forest **8**: 638-641.

Tossi AF and Baki BB 2013. Allometry, growth pattern and seed germination of *Brassica juncea* (L.) Czern. Var. Ensabi influenced by different light and temperature. Int. J. Agri. Crop Sci. **5**(22): 2716-2723.

Tsubo M, Walker S and Mukhala E 2001. Comparisons of radiation use efficiency of mono-/inter-cropping systems with different row orientations. Field Crops Res.**71**: 17-29.

Valizadeh M and Shakiba MR 2006. Response of common bean (*Phaseolus vulgaris* L.) to different levels of shade. J. Agron. **5**: 595-599.

Valladares F, Hernandez LG, Dobarro I, Garcia-Perez C, Sanz R and Pugnaire FI 2003. The ratio of leaf to total photosynthetic area influences shade survival and plastic response to light of green-stemmed leguminous shrub seedlings. Ann. Bot. **91**: 577-584.

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