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Effect of different environmental conditions on growth and production of mustard (*brassica juncea*) in semi-arid zone of Rajasthan

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Abstract
Light intensity, temperature, relative humidity, soil moisture content and various other local environmental factors directly influence crop growth and subsequently the production of crops. Light intensity directly manipulates the water content of plants, temperature and soil moisture content as well. Local environmental temperature controls germination rate at one side and play crucial role in pod formation and yield of crop on other side. An experiment was carried out to investigate the alterations in local environmental factors and its impact on growth and productivity of Mustard crop (*Brassica juncea*) grown under low light intensities at research farm of Bhagwant University, Ajmer (Rajasthan) during rabi (winter) seasons of 2017-18 and 2018-19. The observations reveal that the low light intensity directly reduced the temperature inside the shade net house. The relative humidity increased under low light environment. Soil moisture content was higher inside the low light intensity as compared with open area. The germination was faster in low light environment. Plant height, Leaf area and other growth traits was improved under low light intensity as compared to 100% light intensity of open area. Chlorophyll a and chlorophyll b were also altered under low light environment, which clearly exposed the effect of various local environmental factors at leaf level. Marginal impacts on seed yield and pod size were observed under low light conditions. This study may help to understand and select suitable environmental conditions under semi-arid zone of India.

Keywords: Environmental factors, microclimate, temperature, relative humidity, growth traits.

Introduction
The impact of climate change is now visible and the predictions are focusing on alarming situations in future. Current climate change scenario may cause more extreme and variable climates in the future, threatening agricultural productivity in many areas of the world. Because many small and marginal farmers particularly from rural areas depend on subsistence, rain-fed agriculture, researcher's main concern is to focus on management practices that can protect these farmers from future vulnerabilities.

Environmental factors of a system may directly influence the growth and productivity of the crops. Soil temperature directly manipulates the germination rate of seeds and root development of plants. Very high temperature is harmful for root and shoot growth as well as elongation, it may cause lesion of the whole system as well. Extreme low temperature impede intake of nutrients. Soil moisture intake of plants may also stops under very low temperature.

Climate is referred to as a statistical weather condition over a place in a long duration of 30-50 years (Royal Meteorological society, 1989) [8]. But in reality, climate can be regarded as the characteristics condition of the atmosphere near the earth surface at a given place or over a given region since it is always changing in time and space. On the other hand, weather is a state or condition of atmosphere at a given place and at a given time. It is a variations or conditions of lower layer of the atmosphere. Weather pattern of smaller areas like villages and districts are expressed by numerical values of meteorological parameters such as solar radiation, air temperature, atmospheric pressure, wind speed, relative humidity, precipitation and clouds. Solar energy is the main factors influencing temperature and thus varies from one

Place to another. The principal heating of air during the day is produced by its contact with a land surface that has been heated by the Sun's radiation. Heat from the ground is transferred to the air by conduction and convection. Greenhouse System is primarily built for temperature control purposes, which also influence other meteorological elements.
Each plant species reveal their adaptive features depending upon their growth habitat whether under sun or low light intensity. Light is one of the main factors influencing the establishment and development of crops. A certain degree of reduction of solar radiation by provision of low light plays a crucial role in affecting the plant growth and productivity. Due to the variation of incident solar radiation, plants have been frequently thought to have a strong potential to adjust to different growth irradiances (Valladares 2003) [13]. Adaptation of plants to low light environments allowed coordinated resources distribution not only to achieve and maintain growth and development, but also to function efficiently under limiting light conditions (Singh and Alam 2010a) [10]. This limitation of light poses great problem to get potential crop productivity and the plants need to adjust its whole mechanism including major physiological process according to the available growth light (Singh and Alam 2010b) [10]. Thus, low light as occurs during many physical phenomena in the atmosphere mainly cloud overcast, aerosol deposition, fog and smog etc. or due to following agroforestry or mixed cropping practices poses major constraint to crop productivity in the context of changing climate.
Plants which appears to be adapted to low light intensity make use of available light energy and these plants invest a greater portion of this towards the synthesis and maintenance of light harvesting machinery than do sun grown plants (Alam et al. 2011) [1]. Adaptability of crops takes place through major physiological traits which maintains their strength with external environment growing in low light. These changes maximize light interception and tend to increase carbon gain at low solar irradiances through more efficient investment in photosynthetic machinery (Alam et al. 2011) [1]. Differential physiological responses especially chloroplast functioning and associated processes in the chloroplast would certainly determine the efficiency of low light adaptability of crops grown under different light intensities which needs more research in greater details (Valladares and Niinemets 2008) [12].

Materials and Methods

Plant material and growth conditions The experiment was conducted at Agriculture farm of Bhagwant University, Ajmer (Rajasthan) located at 26.4499° N, 74.6399° E of northern India. The experiment was conducted under low light environment and in full sun light (open field) during rabi seasons (sowing in November and harvesting in April) in the years 2017-18 and 2018-19 with mustard (*Brassica juncea* Coss.). There were two net houses (25×8×3 m) and each providing 67% and 50% of incident sunlight and crop grown in adjacent open filed taken as control. Different intensity of sun light was obtained in each net houses as different category (porosity) was used to cover the respective net house. There were three replications per crop in each light environment prepared in RBD (randomized block design) having plot size of 5.8×3.4 m. Soil in the experiment field was sandy loam with FYM (1:1). The study was conducted taking all the standard agronomic practices including irrigation and plant protection measures. Microclimatic data of the experimental sites were taken in the morning at 09:30 A.M (local time) during the experimental period in both the years (Table 1). Nine uniform plants (visual appearance on the basis of uniform height of the plants) were tagged and selected from each category of light environment at 45-50 DAS (days after sowing). Fully matured (top most) healthy leaves of tagged and selected plants from each category of light environment were taken for all the measurements.
Estimation of Leaf Pigments, epicuticular wax level and Soluble Protein of leaf
Chlorophyll (Chl) was extracted from the leaves with acetone and DMSO (Dimethyl sulphoxide) solvents and estimated according to Arnon (1949) [2]. Anthocyanin in leaf was extracted in methanol and HCl solvents and estimated as per the technique of Kho et al. (1977) [5]. Epicuticular wax level of leaf was estimated as per the gravimetric technique of Silva Fernandes et al. (1964) using chloroform solvent extraction. The amount of wax was calculated against fresh weight. Soluble protein in leaf was estimated as per the technique of Bradford (1976) [3].
Estimation of crop yield
For yield estimation, five plants from each replication meaning fifteen plants from each category of light environment were tagged and harvested to determine the grain yield. Comparative reduction under varying light intensities in grain yield with respect to open grown crops has been calculated. Statistical analysis
The numeric data obtained from the consecutive two years (2017-18 and 2018-19) of experiments were analyzed through calculation of mean and CD (critical difference) at $p = 0.05$ to compare the significance of means of all the light environments i.e. two regimes of low light and full sun light grown crop as control.

Results and Discussions

Different environmental conditions were observed under different light environments. In open environment (100% light intensity) the rate of photosynthetic photon flux density was different in comparison to other low light environments. The photosynthetic photon flux density gradually decreased as the light intensity decreases. The relative humidity was also gradually increased as the light intensity decreases. In open, 67% light intensity and in 50% light intensity the relative humidity were 32.11%, 42.58% and 48.23% respectively. The minimum and maximum temperatures were lower in low light intensity and gradually increased with increase in light intensity. These data clearly indicated that light intensity affected other environmental factors of local environment. All the microclimatic data was presented in Table 1.

Table 1: Different environmental factors such as relative humidity (RH), Temperature (maximum), Temperature (minimum) (°C), and Soil temperature (° C) under various light treatments.

Light environments	RH (%)	Tmax	Tmin	ST
Full sun light	32.11±5.2	28.9±1.5	11±2.1	26.2±1.2
67% sun light	42.58±6.1	25.4±1.9	9.8±2.4	23.6±1.3
50% sun light	48.23±6.8	23.3±1.4	7.1±1.8	21.7±1.1

Under low light environment the leaf chlorophyll content increased. Chlorophyll a and Chlorophyll b gradually increased with decrease in light intensity. With increase in chlorophyll a and b the total chlorophyll content also increases. Anthocyanin, a leaf pigment decreased with decrease in light intensity. Wax level and leaf soluble protein decreased with decrease in light intensity as well as presentedin Table-2.

Table 2: Different biochemical traits as chlorophyll a (mg/gm fresh weight), chlorophyll b (mg/gm fresh weight), Total chlorophyll, anthocyanin, wax level and total leaf soluble protein content under different light environment.

Crop	Light environments	Chl *a*	Chl *b*	Chl *(a+b)*	Anthocyanin	Wax level	Soluble protein
Mustard	Full sun light	1.52	0.46	1.98	1.38	1.52	96.21
	67% sun light	1.77	0.61	2.38	1.19	1.07	87.54
	50% sun light	1.98	0.66	2.64	0.97	0.94	73.06

The adverse effects of change in microclimatic conditions were clearly seen in per plant yield. The percentage reduction in yield as compared with open grown crop was also estimated. In 67% light condition the percentage reduction was marginal.

The crops grown in full sun light had higher anthocyanin but it gradually decreased with decreasing light intensity. The formation of anthocyanin mainly depends on quantity of light which plays an essential role in light dissipation and as an important antioxidant in plants. The reduction of anthocyanin with decreased in sunlight indicates its less requirement in low light conditions (Zhou and Singh 2004) [14]. Our results indicate that in high light the deposition of wax was higher than in low light. As under full sun light, deposition of wax was more, this could be related to thicker leaves in full sun light than low light grown leaves for more reflectance of excess light (Osborn and Taylor 1990) [7]. Our findings are consistent with the fact that low light induced reduction in leaf protein (Burkey et al. 1997) [4]. The low level of soluble proteins in low light grown leaves might be due to decrease of Rubisco synthesis, a major soluble protein in leaves (Misra 1995) [7].

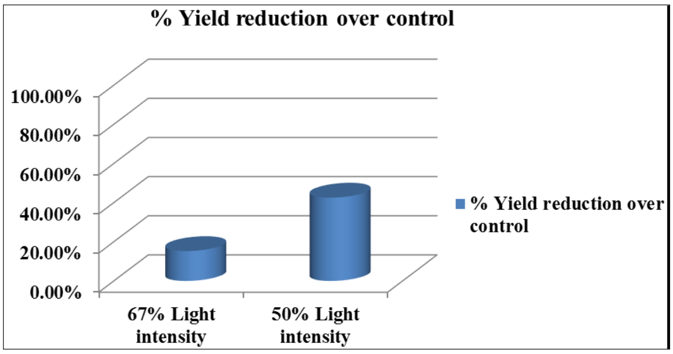

Fig 1: Yield reduction (%) of low light intensity grown crop in comparison to open grown crop.

Figure 1 clearly indicated that under slightly changes in environmental factors, marginal effect on crop yield were noted. But under deep change in environmental factors the yield and production decreased largely. These results elucidate the effects of environmental factors on growth, leaf biochemical traits and finally productivity of the crops. Such study may help to understand the impact of changing climate on crop production and to make more dominant strategy to improve crop production.

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