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Shading effect of Shisham (*Dalbergia sissoo* L.) increase growth and yield of turmeric (*Curcuma longa* L.) in the Tarai Region of Uttar Pradesh

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Abstract
A field experiment was conducted at the Agricultural Farm of Krishi Vigyan Kendra, Sargatia, Kushinagar, Uttar Pradesh, during 2017-18 and 2018-19 (ratoon crop) to evaluate the effect of different shade levels on the growth of turmeric (*Curcuma longa L.*) under Tarai conditions. The experiment was laid out in a Randomized Block Design with four shade treatments, namely control (0% shade), 50, 70 and 80% shade, replicated three times. Turmeric variety ‘Megha^{-1}’ was planted using healthy rhizomes weighing 30-40 g with 1-2 viable buds at a spacing of 30 × 25 cm. The results revealed that shade levels significantly influenced both growth and yield of turmeric. Among the treatments, 50% shade recorded the highest plant height, maximum number of leaves plant^{-1} and superior dry matter accumulation at all growth stages. This treatment also produced the maximum corm yield (51.95 q ha^{-1}), which was markedly higher than the control (36.14 q ha^{-1}) and higher shade intensities of 70% (46.10 q ha^{-1}) and 80% (44.74 q ha^{-1}). Excessive shading (70-80%) resulted in comparatively lower yield due to reduced light availability, while full sunlight conditions showed reduced performance due to possible light and temperature stress. The study concludes that moderate shading (50%) provides an optimal microclimatic environment for enhancing growth and yield of turmeric in the Tarai region of Uttar Pradesh. Cultivation of turmeric under partial shade, such as in Shisham (*Dalbergia sissoo*)-based agroforestry systems, can be recommended for achieving better growth and sustainable productivity in the region.

Keywords: Turmeric, shade levels, agroforestry, Shisham, growth attributes, Tarai region

Introduction

Agroforestry systems, which integrate trees with agricultural crops, are increasingly recognized for their role in improving productivity, sustainability, and resilience of farming systems in tropical and subtropical regions. The presence of trees modifies the microclimate by regulating light intensity, temperature, humidity, and soil moisture, thereby influencing the growth and yield of understory crops (Nair, 2011) [8]. In such systems, shade-tolerant crops are particularly suitable as intercrops, as they can utilize reduced light conditions more efficiently while benefiting from improved soil and environmental conditions.

Turmeric (*Curcuma longa* L.) is an important spice and medicinal crop widely cultivated in India for its rhizomes rich in curcumin. Being a C_3 plant, turmeric exhibits moderate shade tolerance and performs well under partial shade conditions. Several studies have reported that turmeric grown under reduced light intensity shows enhanced chlorophyll content, better photosynthetic efficiency, and improved vegetative growth compared to crops grown under full sunlight (Alam *et al*., 2020) [1]. Moderate shading has also been found to reduce photo-oxidative stress and evapotranspiration losses, resulting in better biomass accumulation and higher rhizome yield (Kumar *et al*., 2018) [6].

Shisham (*Dalbergia sissoo* Roxb.) is a fast-growing, nitrogen-fixing, multipurpose tree species widely distributed in the Indo-Gangetic plains, including the Tarai region of Uttar Pradesh. It is commonly used in agroforestry systems due to its light, filtered canopy, deep root system, and ability to improve soil physical and chemical properties through litter addition and biological nitrogen fixation (Dhyani *et al*., 2013) [4]. The canopy structure of Shisham allows partial penetration of sunlight, creating favorable shaded conditions for understory crops such as turmeric.

In the Tarai region of Uttar Pradesh, characterized by fertile alluvial soils, high rainfall, and humid subtropical climate, excessive solar radiation and high temperatures during the growing season may adversely affect turmeric growth under open field conditions. Partial shading provided by Shisham trees can moderate these extremes by lowering soil temperature, conserving soil moisture, and improving nutrient availability, thereby enhancing growth and yield attributes of turmeric (Parihar *et al*., 2020) [9]. Studies conducted under Shisham-based agri-Silvi systems have reported improved plant height, leaf area index, rhizome weight and economic returns of turmeric compared to sole cropping systems (Anshuman *et al*., 2024) [2].

Therefore, evaluating the shading effect of *Dalbergia sissoo* on the growth and yield of turmeric under Tarai conditions is essential for optimizing agroforestry-based production systems. Such studies help in identifying suitable tree-crop combinations that enhance productivity, ensure sustainable land use and improve farmers' income in the region.

Materials and Methods

Experimental Site

The field experiment was conducted at the Agricultural Farm of Krishi Vigyan Kendra (KVK), Sargatia, Kushinagar, Uttar Pradesh, during the *kharif* season of 2017-18 and 2018-19 (ratoon crop). The experimental site falls under the Tarai agro-climatic region of eastern Uttar Pradesh, characterized by a humid subtropical climate with fertile alluvial soils. The area generally experiences high rainfall during the monsoon season, which is conducive for turmeric cultivation.

Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) with four shade treatments and three replications. The treatments consisted of different shade levels, namely:

- Control (0% shade)
- 50% shade
- 70% shade
- 80% shade

Shade treatments were imposed using shade nets of respective densities to simulate different light interception levels under tree canopy conditions.

Planting Material and Crop Establishment

Turmeric variety 'Megha-1' was used as the test crop. Healthy, disease-free seed rhizomes weighing 30-40 g and having 1-2 viable buds were selected for planting. The rhizomes were planted in lines at a spacing of 30 × 25 cm, maintaining uniform plant population across all treatments. Standard agronomic practices recommended for turmeric cultivation in the region were followed uniformly in all plots throughout the cropping period.

Crop Management Practices

All plots received identical cultural operations such as irrigation, weeding, and plant protection measures as and when required to ensure that observed differences among treatments were solely due to shade effects. Fertilizer application and other management practices were kept uniform across treatments as per regional recommendations.

Observations Recorded

Growth parameters were recorded at 60, 120 and 180 days after planting (DAP) from randomly selected plants in each plot. The observations included:

- **Plant height (cm):** Measured from the base of the plant to the tip of the longest leaf.
- **Number of leaves plant^{-1}:** Counted manually for each selected plant.
- **Dry matter production (g plant^{-1}):** Plants were harvested, oven-dried at 65 ± 2 °C until constant weight, and expressed on a per-plant basis.
- **Corm yield:** Corm (rhizome) yield was recorded at harvest by uprooting plants from each net plot, cleaning the rhizomes and weighing the total fresh corm yield. The yield obtained per plot was converted and expressed as q ha^{-1}.

Statistical Analysis

The recorded data were statistically analyzed following the procedure appropriate for Randomized Block Design. The significance of treatment effects was tested using analysis of variance (ANOVA). The standard error of mean (SEm±) and critical difference (CD) at 5% probability level were calculated to compare treatment means as described by standard statistical methods.

Results and Discussion

Effect of Shade Levels on Plant Height

Shade levels significantly influenced plant height of turmeric at all stages of crop growth (60, 120 and 180 DAP). The tallest plants were consistently recorded under 50% shade, registering plant heights of 39.28, 107.09 and 109.21 cm at 60, 120 and 180 DAP, respectively. These values were significantly higher than those observed under control (0% shade) and higher shade intensities (70 and 80%). The control treatment recorded the minimum plant height at all growth stages. The enhanced plant height under 50% shade may be attributed to improved microclimatic conditions, such as moderated temperature and reduced light stress, which favor cell elongation and better photosynthetic efficiency in turmeric, a shade-tolerant crop (Alam *et al.*, 2020) [1]. However, further increase in shade beyond 50% resulted in reduced plant height, possibly due to insufficient light availability limiting photosynthate production (Kumar *et al.*, 2018) [6]. Turmeric is a shade-tolerant C_3 crop, and partial shade reduces excessive light intensity and temperature stress, thereby improving photosynthetic efficiency and assimilate production (Alam *et al*., 2020; Liu *et al*., 2016) [1, 7]. Improved vegetative growth under moderate shade may also be attributed to enhanced chlorophyll content, better leaf expansion, and reduced photo-inhibition, as reported earlier under similar agroforestry environments (Behera and Reddy, 2019) [3].

Effect of Shade Levels on Number of Leaves Plant^{-1}

The number of leaves plant^{-1} was significantly affected by shade treatments throughout the growth period. At 180 DAP, the maximum number of leaves (8.59 leaves plant^{-1}) was recorded under 50% shade, which was significantly superior to the control (5.98 leaves plant^{-1}) and higher shade levels. The 70% and 80% shade treatments produced intermediate values but were inferior to 50% shade. The increased leaf production under moderate shade conditions can be linked to improved canopy architecture and enhanced chlorophyll synthesis, resulting in better leaf initiation and expansion. Similar observations were reported by Parihar *et al*. (2020) [9], who observed enhanced leaf area development of turmeric under Shisham-based agroforestry systems with partial shading.

Effect of Shade Levels on Dry Matter Production

Dry matter production per plant showed significant variation among shade treatments at all observation stages. The highest dry matter accumulation was recorded under 50% shade, with values of 18.32, 42.34 and 78.59 g plant^{-1} at 60, 120 and 180 DAP, respectively. The control treatment recorded the lowest dry matter production, while 70% and 80% shade treatments showed moderate but significantly lower values than 50% shade.

The superior dry matter accumulation under 50% shade suggests efficient utilization of available light and enhanced photosynthetic performance due to reduced photo-inhibition and better moisture conservation. Excessive shading (70-80%) likely restricted photosynthetically active radiation, thereby limiting carbohydrate synthesis and biomass accumulation (Nair, 2011) [8].

Effect of Shade Levels on Corm Yield

Corm yield of turmeric was markedly influenced by different shade levels. The highest corm yield (51.95 q ha^{-1}) was recorded under 50% shade, which showed a substantial increase over the control (36.14 q ha^{-1}). The yield improvement under 50% shade was 43.7% higher than the control, indicating a strong positive response of turmeric to moderate shading. Among the higher shade intensities, 70% shade produced a corm yield of 46.10 q ha^{-1}, followed by 80% shade with 44.74 q ha^{-1}. Although these treatments yielded more than the control, they were inferior to 50% shade, suggesting that excessive shading adversely affects yield potential due to restricted photosynthetically active radiation.

The superior yield under 50% shade can be attributed to enhanced vegetative growth, greater leaf production, and higher dry matter accumulation observed under this treatment. Moderate shade likely improved the microclimate by lowering canopy temperature, conserving soil moisture and reducing photo-inhibition, thereby facilitating better translocation of assimilates towards rhizome development. These findings are in agreement with earlier reports indicating that turmeric performs optimally under partial shade conditions in agroforestry systems (Alam *et al*., 2020; Kumar *et al*., 2018) [1, 6].

In contrast, the lower yield recorded under full sunlight conditions may be due to excessive radiation and higher soil temperatures, which can limit photosynthetic efficiency and increase respiration losses. On the other hand, higher shade levels (70-80%) possibly reduced carbohydrate synthesis due to insufficient light, leading to sub-optimal rhizome formation. Similar trends of yield reduction under excessive shading have been reported in turmeric grown under dense tree canopies (Parihar *et al*., 2020; Singh *et al*., 2021) [9, 10].

The results clearly indicate that moderate shade (50%) created a favorable growth environment for turmeric compared to full sunlight and excessive shading. The beneficial effect of moderate shade can be attributed to improved physiological efficiency, reduced thermal stress, and enhanced resource use efficiency. Improved microclimatic conditions such as lower soil temperature, higher relative humidity, and better soil moisture retention under partial shade might have enhanced nutrient uptake and assimilate partitioning (Jose, 2009) [5]. These findings corroborate earlier reports that turmeric performs best under partial shade in agroforestry systems involving tree species such as *Dalbergia sissoo* (Dhyani *et al*., 2013; Anshuman *et al*., 2024) [4, 2].

Table 1: Growth attributes of turmeric affected by different shade levels

Treatments	Plant height (cm)			Number of leaves plant^{-1}			Dry matter production (g plant^{-1})		
	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP	60 DAP	120 DAP	180 DAP
Control (0% shade)	27.31	74.51	75.98	3.08	6.66	5.98	12.76	29.44	54.68
50% shade level	39.28	107.09	109.21	4.42	9.57	8.59	18.32	42.34	78.59
70% shade level	34.75	94.96	96.89	3.93	8.5	7.62	16.25	37.57	69.74
80% shade level	33.01	92.11	93.95	3.81	8.24	7.4	15.77	36.45	67.68
SEm±	0.33	0.93	0.94	0.04	0.09	0.08	0.176	0.391	0.745
CD (P=0.05)	0.95	2.64	2.66	0.114	0.256	0.23	0.5	1.11	2.11

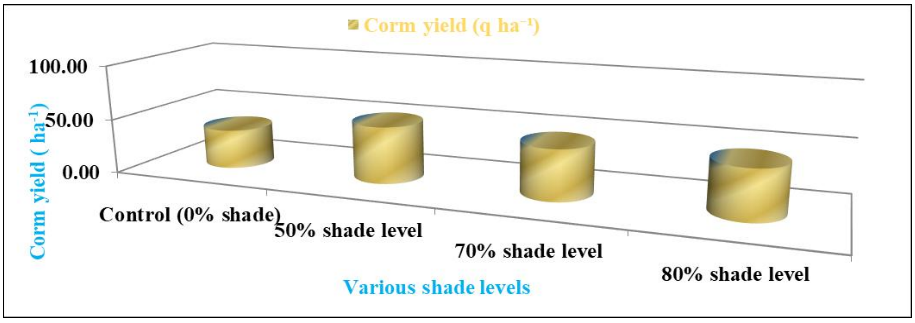

Fig 1: Corm yield of turmeric affected by different shade levels

Conclusion

The results of the present investigation clearly demonstrate that different shade levels significantly influenced the growth performance of turmeric (*Curcuma longa L.*) in the Tarai region of Uttar Pradesh. Among the evaluated treatments, 50% shade level proved to be the most favorable for turmeric growth, resulting in significantly higher plant height, number of leaves per plant, and dry matter production at all growth stages (60, 120, and 180 DAP) compared to the control (0% shade) and higher shade intensities (70 and 80%). Moderate shading created a congenial microclimate by reducing excessive solar radiation and temperature stress, thereby enhancing photosynthetic efficiency and biomass accumulation. In contrast, excessive shading (70-80%) restricted light availability, which adversely affected growth attributes, while full sunlight conditions led to comparatively lower growth due to possible photo-inhibition and moisture stress.

Based on the findings, it can be concluded that turmeric is well suited to partial shade conditions, and its cultivation under Shisham (*Dalbergia sissoo*)-based agroforestry systems or under approximately 50% shade can be a viable and sustainable production strategy in the Tarai region of Uttar Pradesh. Adoption of such systems can improve turmeric growth, optimize land use, and enhance farm productivity, making them economically and environmentally beneficial for farmers of the region.

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