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Impact of Different Shade Environments on Growth and Development of Purple Nutsdge (*Cyperus rotundus* L.)

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ABSTRACT: Purple nutsedge (*Cyperus rotundus* L.) is one of the most invasive perennial sedges and is considered the world's worst weed. The sedges propagate mainly by producing a complex underground system of rhizomes, basal bulbs and tubers. The tubers will remain viable for more than three years and can withstand any adverse environmental conditions. In addition, the lack of an effective long-term strategy to control, this weed becomes aggressive and troublesome throughout the world. Because of their extreme competitiveness, weeds continue to dominate crops. Understanding the dynamics of crop-weed competition is thus critical for expanding weed management approaches and improving them over time. Because both crops and weeds compete for light by shading each other, a thorough understanding of the different competitive potentials of crops and weeds in the shade is essential for developing effective weed control strategies. The present experiment was founded on all of the preceding deductions and reasoning. This experiment was conducted in the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore to examine the effect of different shading on the growth and development of purple nutsedge. Maximum plant height (33.15 cm) and leaf area 6.165 cm^2) were recorded in 70 % shaded environment and the minimum plant height (10.45cm) and leaf area (0.788 cm^2) were recorded in an open condition. Leaf breadth and number of leaves were decreased under low light intensity. Overall biomass was higher in plants grown under direct sunlight. When compared to plants grown in dark or partial shading, the plants grown in full sunlight devotes a major portion of their photosynthates to tuber production. Plants were grown under full sunlight and 50% shade, produced tubers of 1.5 and 0.7 numbers, respectively. In plants grown under 70% shade and full shade, there was no tuber formation and effectively prolonging the period of vegetative growth.

Keywords: Purple nutsedge, weed, shade, tuber, biomass, leaf area

INTRODUCTION

Weed infestation is one of the main issues to limit crop productivity in diverse cropping systems. In order to achieve the maximum yield of the crop is mainly depends on the proper weed management practices (Mishra *et al.,* 2020). Weeds not only reduce the yield but also complicate the harvest operations of several crops. Weeds cause 33 per cent of yield losses in India, which is more than any other category of agricultural pests such as insects (26 per cent), nematodes (6-8 per cent), diseases (20 per cent), rodents (6 per cent), and so on. As a result, better weed control is essential for maintaining food grain production and ensuring food security (Singh *et al.,* 2014).

Among the diverse weed population, purple nutsedge (*Cyperus rotundus L.*) is a perennial and pestiferous weed that seriously impacts agriculture across the world. Purple nutsedge has become a major weed of sugarcane, corn, cotton, rice, vegetables and numerous other crops around the world, became very difficult to manage, caused considerable yield reduction (William, 1976; Bangarwa *et al*., 2008; Wang *et al.*, 2008), and thus called as the world's worst weed (Holm *et al*., 1991). It also has an allelopathic effect that cannot be reversed, even under ideal conditions of nutrient, light and moisture. Purple nutsedge had more serious allelopathic effects on orange, cotton and mustard in this regard (Valliappan, 1989). Purple nutsedge can reduce sugarcane yields by 75% and sugar yields by 65% and cause losses of 6% in maize, 12% in sorghum, 16% in cowpea, 22% in greengram, 32% in groundnut and soybean yields by 58 per cent under extreme circumstances. Apart from direct yield consequences, *C. rotundus* rhizomes and tubers might obstruct peanut harvesting and other intercultural operations.

Light is an important factor in plant competitiveness since it is a dynamic component of photosynthesis (Holt, 1995). Plants exposed to low irradiance commonly exhibit a range of shade-avoidance and/or tolerance mechanisms, such as elongation of shoots, increased leaf area with low leaf mass per unit area, low chloroplast numbers and changes in chlorophyll A to chlorophyll B ratios (Salter *et al.,* 2003). When solar radiation is lowered, it changes the photo-equilibrium of the photoreceptor phytochrome, which affects phenology and reproductive biology through altered chloroplast formation, delayed blooming, and lower aboveground dry matter (Gundel *et al.,* 2014; Mishra *et al.,* 2020).

Similarly, a proportional increase in resource allocation to above-ground parts of the plant may occur, resulting in a decreased overall biomass (Maule *et al*., 1995; Weihe, 1997). Under high-irradiance environments, C_4-plants are photosynthetically efficient. However, with limited irradiance and ambient levels of CO_2, C_4 plants are not as photo-synthetically efficient as plants that use the C_3-photosynthetic pathway (Hand *et al*., 1993). Several studies have shown that shade can be an effective management tool for controlling C_4 plants. McWhorter and Jordan (1976) reported that growth of johnsongrass (*Sorghum halepense* L.) decreased between 3 and 20 folds at 56 and 11% of full sunlight, respectively. Santos *et al*. (1997) discovered that shoot and tuber biomass of yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) had a negative linear response to shade level in the greenhouse. Under varying light intensities, Bayat *et al.* (2018) found that a shaded environment could change chlorophyll content and photosynthesis activity in plants and weeds.

Purple nutsedge is one of the most extensively researched non-cultivated plant species on the planet, yet the complexities of its life cycle and its multiple adaptations to environmental extremes and weed control tactics are yet incompletely understood. Little is known about the effect of shade on purple nutsedge growth and development. Because the emerging of purple nutsedge is earlier in the crop growing season leads to suppress the crop growth. In certain situations, under cover crop field, its growth and effect are less but not completely controlled. It has been assumed that this species has some shade tolerance. If purple nutsedge is not shade tolerant, management measures like provision of early canopy closure (shading) could be the beneficial management tool for its control. Keeping this in view, the objective of this study is aimed to look at the effect of different levels of shade on purple nutsedge growth and development.

METHODOLOGY

A pot culture experiment was carried out in the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, India which is located in the western agro-climatic zone of Tamil Nadu with the coordinates of 11^o N, 77^o E and 426.8 m above mean sea level. The trial was laid out in a completely randomized design with five replications containing 3 plants per pot. Purple nutsedge tubers were collected from the Eastern block farm, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, India. The tubers were sown in plastic pots containing sandy clay loam soil. The pots were randomly assigned by four cultivation environments with shading levels *viz.,* 0% shade (full sunlight/open condition), 50 % shade, 70 % shade and 100 % shade (complete shade). The shaded structures consisted of wire cages covered with green Lumite saran shade cloth which approximately provides 70 % shade (greenhouse), structures consisting of wire cages covered with a plastic sheet that provides approximately 50 % shade (drying yard) and a complete shade (cupboard which covered with black cloth). Light interception in different levels of shading was measured in each treatment with the help of a lux meter at 10 am. (R-Tek, Environmental meter, model – RT/ET - 965). The pots were irrigated based on moisture availability. Observations on plant height, number of leaves, leaf length, leaf width and leaf area were measured after 4 weeks. Plant height was taken from the soil surface to the uppermost portion of the plant. Then plants were removed from the soil and washed with tap water to remove the debris. Root length, tuber production, rhizome length and dry weight of plants were recorded. The data collected from the pot culture experiment were analysed statistically using the "Analysis of variance test" as single factor analysis. The critical difference at the 5 % level of significance of different treatments was compared as reported by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

A. Effect of Shade on vegetative growth of purple nutsedge

Plant height. The results revealed that the plant height was significantly influenced by the shaded environment compared to full sunlight (Table 1). Significantly, higher plant height (33.15 cm) was observed under partial shading of 70 % shade. The lower plant height was observed under a fully shaded environment (10.45 cm) followed by an open condition (15.18 cm). Increase in plant height is one of the foremost physiological responses under shading and the same was observed in the present study. Further, it was observed that the plant height nearly doubled under shaded conditions. Plant seeks to extend its stem to reach above the canopy as a key response to shading. The change in R: FR (Red: Far Red) ratio under the canopy has more impact on this process. By mediating phytochrome based signalling, R: FR ratio drops under shade and causes the elongation response. Patterson (1979); Bello *et al*. (1995); Gouache *et al.* (2012) observed moderate to high height stimulation in itch grass (*Rottboellia exaltata*), cogon grass (*Imperata cylindrica*), *Abutilon theophrasti* and texas weed (*Caperonia palustris*) identical trials. Another study in Philippines found that rice interference could affect the height of distinct weedy rice biotypes by shading them (Chauhan, 2013).

Leaf parameters. The number of leaves decreased significantly as shading was increased (Table 1). Under the open condition, the plants had nearly six leaves. Plants under full shaded condition produced a very less number of leaves (1.1) per plant. A significant decrease in leaf area was also noted with increasing levels of shade (Fig. 2). Under 70 % shade condition, an increase in leaf area of 6.165 cm^2 was noted while at 50% shade, it ranged to 5.165 cm^2 and the lowest leaf area was recorded in full shaded condition. Leaf area is a derived parameter of leaf length and leaf breadth. Concerning the shade effect, leaf length was increased under increasing shade levels. The leaf breadth was decreased under increasing shade levels. Low light intensity causes an increase in leaf area, leaf length and decrease in leaf breadth and number of leaves, as reported by Pires *et al*. (2011), Pires *et al*. (2012). Under the intercropping system, well developed crops shade the weeds at a later stage to influence the leaf length and breadth of weeds (Kumar *et al*., 2021).

Total dry weight per plant showed a linear decrease with increasing shade intensity (Table 2). The fresh weight and dry weight were significantly higher under open condition and lower values were recorded in a completely shaded environment. The fully shaded treatment produced a lower proportion of total biomass than the unshaded or partially shaded treatments. Mishra *et al*. (2020) discovered that as the shading level increases, overall dry matter accumulation decreases, resulting in a significant reduction in dry matter. Plants grown in full sunlight produced significantly more tillers and leaves, as well as a greater whole-plant leaf area and biomass than plants grown in shaded environments. Similar results were found by Steckel *et al*. (2003).

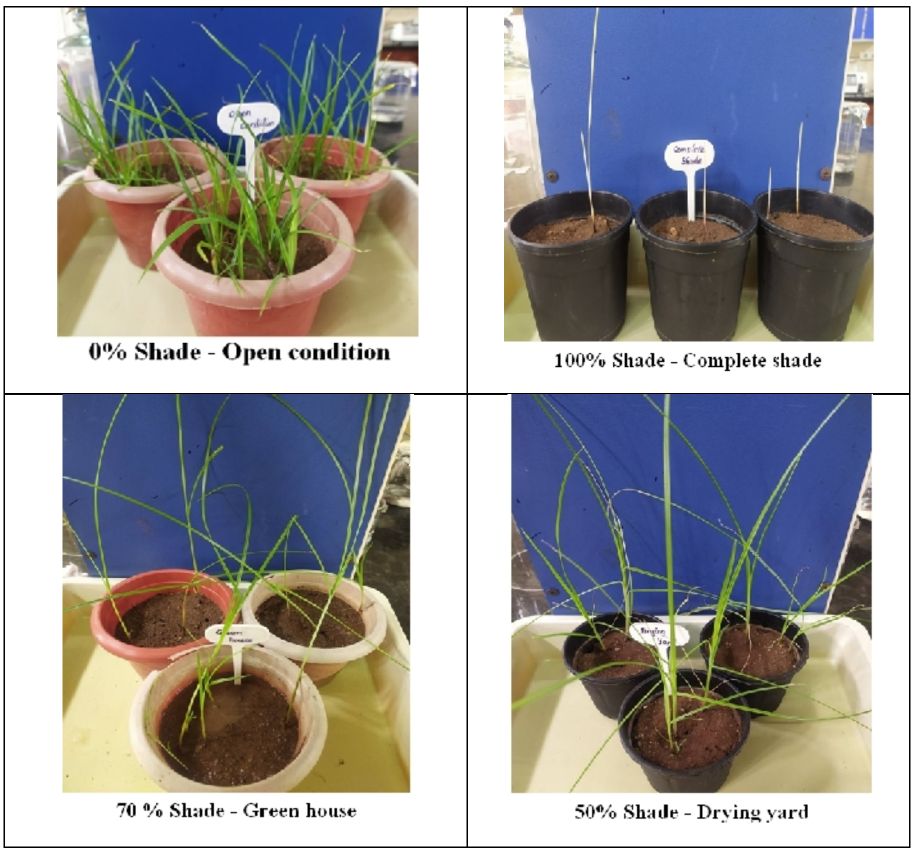

Fig. 1. Different shade environments on purple nutsedge growth.

Table 1: Effect of shade on growth attributes of purple nutsedge.

Treatments	**Height (cm)**	**No. of leaves**	**Leaf length (cm)**	**Leaf breadth (cm)**	**Leaf Area (cm^2)**	**Root length (cm)**
T1 – 0% shade	15.18	6.463	10.82	0.290	3.680	12.68
T2 – 50% shade	27.73	4.867	16.30	0.240	5.156	6.790
T3 – 70 % shade	33.15	3.133	18.14	0.210	6.165	4.273
T4 – 100% shade	10.45	1.100	5.775	0.107	0.788	3.123
SEd	0.378	0.088	0.303	0.007	0.069	0.139
CD(P=0.05)	0.795	0.190	0.640	0.014	0.145	0.400

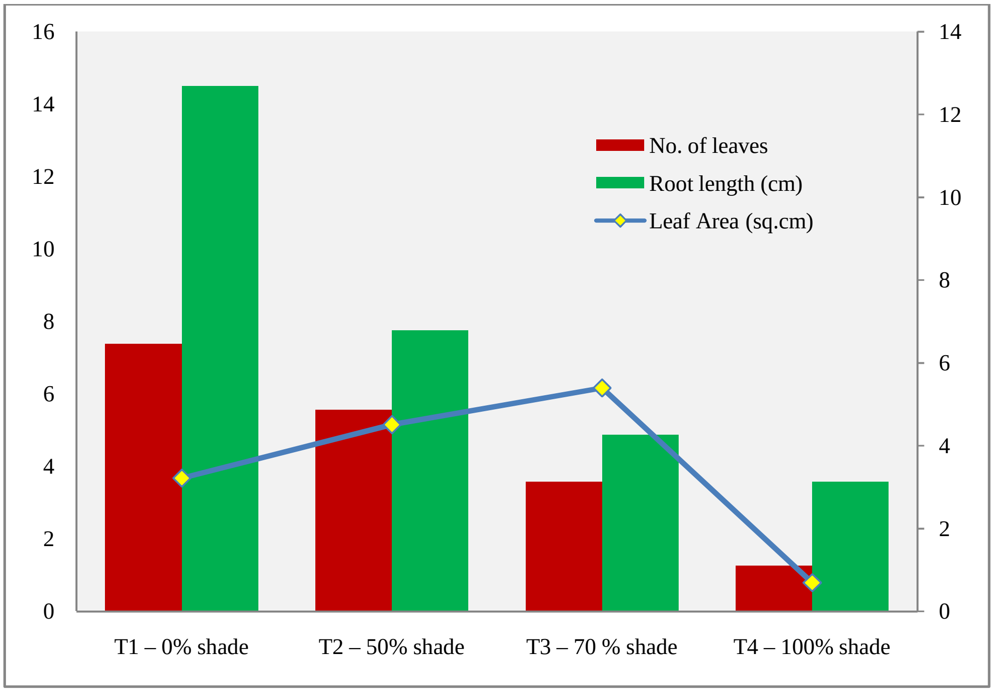

Fig. 2. Effect of shading on number of leaves, leaf area (cm^2) and root length (cm) of purple nutsedge.

Table 2: Effect of shade on fresh weight, dry weight of purple nutsedge.

Treatments	**Fresh weight (g)**	**Dry weight (g)**
T1 – 0% shade	4.197	1.607
T2 – 50% shade	1.640	0.707
T3 – 70 % shade	0.995	0.557
T4 – 100% shade	0.604	0.297
SEd	0.044	0.015
CD(p=0.05)	0.093	0.032

B. Effect of shade on biochemical properties of purple nutsedge

Many weed species are tolerable to partial shading. The effect of shade on chlorophyll content of purple nutsedge is given in Table 3. Higher chlorophyll a, chlorophyll b and total chlorophyll content (2.3, 0.726 and 3.027 mg g^{-1} respectively) were recorded in a 70% shaded environment. The lower chlorophyll content was observed under completely shaded environment. Absence of light in the complete shaded environment, lack of conversion of light energy into chemical energy, might delay the leaf emergence.

Higher carotenoid content (0.736 mg g^{-1}) was recorded with 70 % shade condition. The lowest carotenoid content (0.369 mg g^{-1}) was observed in a fully shaded environment. Although light is the driving force of photosynthesis for the production of photosynthates, our result showed that plants grown under complete shade level dramatically reduced total chlorophyll content and carotenoid content (Bayat *et al.*, 2018). Similar results were reported by Reginer *et al.* (1988) in velvetleaf (*Abutilon theophrasti*) and common cocklebur (*Xanthium strumarium* L.) about lower chlorophyll content with increased shading.

Table 3: Effect of shade on biochemical properties of purple nutsedge.

Treatments	**SPAD**	**Chlorophyll a mg g^{-1}**	**Chlorophyll b mg g^{-1}**	**Total chlorophyll mg g^{-1}**	**Carotenoids mg g^{-1}**
T1 – 0% shade	35.40	1.623	0.371	1.993	0.567
T2 – 50% shade	30.80	2.271	0.619	2.922	0.696
T3 – 70 % shade	24.30	2.300	0.726	3.027	0.736
T4 – 100% shade	10.53	0.956	0.199	1.155	0.369
SEd	0.396	0.027	0.008	0.039	0.008
CD (p=0.05)	0.831	0.057	0.016	0.083	0.017

C. Effect of shade on tuber production of purple nutsedge

Shading delayed the duration of tuber production and rhizome length which is illustrated in Fig. 3. Under full sunlight (0% shade) plants produced more number of tubers (1.513) within a month followed by 50% shaded environment. There was no tuber formation under 70% shade and complete shaded environments. As a result of these findings, there was a strong correlation between reproductive activity and lighting conditions. The resource partitioning towards reproductive organs is reduced in the shaded environment and there is a delay in tuber formation. Together, the aforementioned processes partitioned resources in such a way that allowed for the most permissible growth under given conditions while penalising tuber production (Mishra *et al.*, 2020). Prolonged vegetative growth and less source to sink relationship might be the reason for delayed reproductive growth. Prolonged vegetative growth is not an advantage for field crops however, it is an advantage to the weeds to delay its offspring production and reduce weed seed bank in the soil. Mack and Pyke (1983) reported that under glasshouse conditions, shading delayed flowering, effectively prolonging the period of vegetative growth in *Phalaris minor*. Studies with peas (*Pisum sativum* L.), lotus (*Nelumbo spp*. Adans.) and *Brassica* spp. (L.) at different shade levels also change the reproduction ability due to altering the GA content under shade (Schulz *et al.*, 2019).

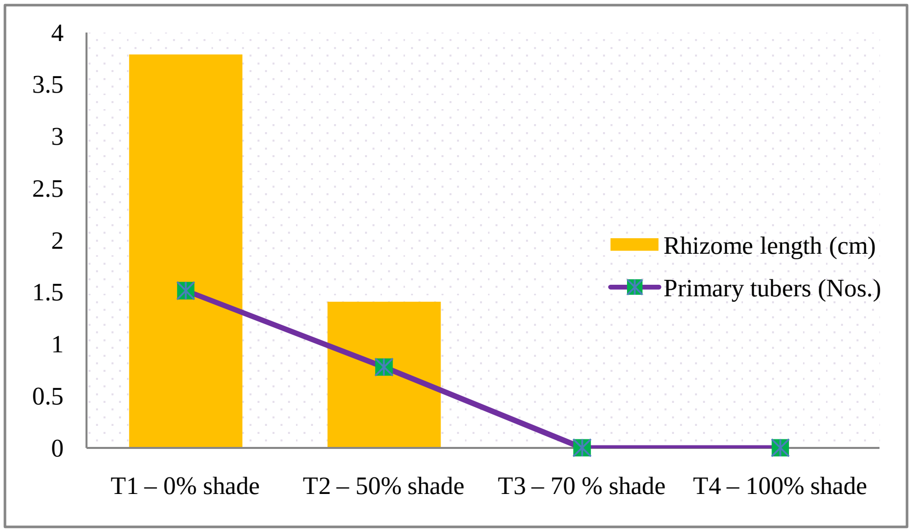

Fig. 3. Effect of shading on reproductive growth of purple nutsedge.

SUMMARY AND CONCLUSION

This research provides information on how purple nutsedge responds to different shaded environments. The plant height and leaf area were more vulnerable for plants growing under a shaded environment compared to full sunlight. Low light intensity causes an increase in leaf area and a decrease in leaf breadth, and these changes may affect the interception, penetration and absorption of herbicides applied to the leaves. As a result of these responses, the effect of competition and defoliation on this species in a cropped field is amplified.

Increased length of the vegetative period dramatically affects the purple nutsedge tuber production. In a low-irradiance environment, purple nutsedge required more time to accumulate more biomass in leaves and transferred to reproductive structures. Purple nutsedge produced less number of tubers under this condition, which could deposit less tubers to the weed seed bank. Purple nutsedge infestations could be reduced by using production strategies such as narrow rows which minimise irradiance availability. Purple nutsedge's vegetative growth and reproductive capacity are severely hampered once a dense canopy has been established. Because, any space in the canopy that allows light penetration results in rapid and prolific weed growth and offspring production, increasing the soil weed seed bank, uniform dense crop canopy is dominant in developing an integrated method to control this weed.

Purple nutsedge grows along with crop plants, other competitive factors such as competition for nutrients and moisture are additional considerations. Several competitive factors acting together may have a greater impact, and a certain amount of shade may be required to control purple nutsedge, as suggested in this study. The current study's findings imply that a specific degree of shade is required to completely control the purple nutsedge once it has been established. Future studies with purple nutsedge should be designed to more precisely resemble the intensity of shade in growing crops. During the growing season, it would also be beneficial to quantify and designate shade intensity under crops.

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Conflict of Interest. There are no conflicts of interest among the authors.

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