PERFORMANCE OF DIFFERENT PLANTING MATERIALS OF TANNIA (*Xanthosoma sagittifolium* (L.) Schott) UNDER SHADE

By

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(2016-11-002)

THESIS

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DECLARATION

I, Nayana V. R (2016-11-002) hereby declare that the thesis entitled **"Performance of different planting materials of tannia (*Xanthosoma sagittifolium* (L.) Schott) under shade"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other university or society.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Tuber crops are second in importance to cereals as a global carbohydrate source. They provide a substantial part of the world's food needs and serve as an important source of animal feed and processed products for human consumption and industrial use. Aroids are a major group of crops coming under tuber crops, which belong to the plant family Araceae. These have modified underground stems for the storage of carbohydrate. Edible aroids include taro (*Colocasia*), tannia (*Xanthosoma*), elephant foot yam (*Amorphophallus*), giant taro (*Alocasia*), and swamp taro (*Cyrtosperma*).

Tannia (*Xanthosoma sagittifolium* (L.) Schott) is a herbaceous perennial plant native to Tropical America; now widely grown in Asia, Africa, and Latin American regions (Wilson, 1984). In India, tannia is grown in Kerala, Tamil Nadu, Maharashtra, West Bengal and North Eastern states generally in homestead gardens (Misra *et al.*, 2005). Because of its resemblance to *Colocasia*, it was called "cocoyam" in the introduced areas, but to distinguish it from the original cocoyam, it has been given the name "new cocoyam''. It is additionally referred as arrow leaf elephant ear, Mafaffa, Tanier, *Yautia*, *Taioba etc.* in different places. In Kerala, it is commonly known as *Seemachempu, Vettuchempu* or *Palchempu.* Tannia is generally produced by small scale farmers, with minimal agricultural inputs. Therefore, it is often called a "poor man's crop" or "woman's crop'' (Onyeka, 2014).

In Kerala, tannia is often grown as a rainfed crop. Irrigated crop can be cultivated throughout the year while rainfed cultivation is more common. Planting is done during April - May with the monsoon onset and harvesting is done by November - December.

It is a staple food in the tropics and subtropics and consumed in various ways. Young leaves and petioles of tannia can be consumed as vegetable just like spinach.

The starch rich underground portion called as mother corm is highly acrid, hence not used for human consumption but generally used as planting material or a potential animal feed. Cormels, the secondary shoots from corms, are the edible part containing 17 - 26 per cent carbohydrate, 1.3 - 3.7 per cent protein and 70 - 77 per cent water (Coursey, 1968) and its nutritional value is comparable to potato. Cocoyams are also considered as a good source of polyphenols and mineral nutrients. In some places, flesh scrapings of corms and cormels are applied in wounds to stop bleeding and also used as anti - tetanus and anti - poison agents against spider, scorpion, and snake bites.

Due to its requirement of low inputs, high photosynthetic efficiency, and high dry matter production capability, substantial yields may be obtained even under poor and marginal soils under harsh climatic conditions. Compared to old cocoyam (*Colocasia*) new cocoyam (*Xanthosoma*) fetches high price in the market, and due to this, its cultivation is catching up especially in the homesteads.

Tannia is observed to be a shade loving crop. Hence, they are often intercropped under perennial crops like coconut, oil palm, cocoa, and rubber. Its increasing acceptability necessitates its cultivation under dense vegetative conditions of multistoried and agroforestry systems with minimal inputs. Sagoe (2006) reported that tannia yield will reduce according to the increase in temperature and solar radiation. Even though response of colocasia to shade is studied by various scientists, details regarding effect of shade on tannia is limited. It is hoped that understanding the response of tannia to different light intensities will help to design an appropriate multistoried system.

Tannia is generally propagated using top of the main corm, but cormels and split corms can also be used. Split corms of 150 - 200g weight or healthy cormels of 50 - 100g weight are often used (KAU, 2016). Cut corm pieces will reduce the amount of planting material needed. The current study has been formulated to evaluate the effect of different shade levels and planting materials on growth and yield of tannia.

Review of literature

2. REVIEW OF LITERATURE

Tannia (*Xanthosoma sagittifolium* (L.) Schott), a herbaceous perennial tuber crop of the tropics belongs to the family Araceae. Although all parts of the plant are edible, it is primarily grown for the edible underground stems. Being a tuber crop, it occupies an important place in the diet of people of the tropics. The fleshy tubers are ideal sources of starch for industrial and food application.

Xanthosoma sagittifolium (L.) Schott is the major edible species coming under *Xanthosoma.* In addition to *Xanthosoma sagittifolium,* four other edible species are also under cultivation in tropics. They are *Xanthosoma atrovirens* Koch and Bouche, *Xanthosoma brasiliense* Engl, *Xanthosoma caracu* Koch and Bouche, *Xanthosoma mafaffa* Schott, and *Xanthosoma nigrum* (Vell.) Mansf. (Tindall, 1983).

Xanthosoma violaceum (L.) Schott or blue taro/blue tannia is another cultivated species having violet petioles and veins, with slender pinkish tinged cormels. However, according to the latest classification this is considered as a synonym for *Xanthosoma sagittifolium* (Tindall, 1983).

Both tannia or new cocoyam (*Xanthosoma*) and taro or old cocoyam (*Colocasia*) are grown for their edible underground stems. They show close resemblance to each other in morphological characters. However there are some major differences (Table 1).

Cocoyams are relatively richer in mineral composition (Table 2). Tannia has relatively larger starch grains which is less digestible than taro. Cormels of tannia are starchier and tasty hence preferred more than corms.

Tannia is considered outstanding among terrestrial crops in its ability to accumulate photosynthates under shaded condition. This makes tannia an ideal crop in the understory of polyculture or agroforestry systems.

In this review, literature on *Xanthosoma* as well as related crops is reviewed because of paucity of enough works in *Xanthosoma.*

Table 1. Major differences between tannia and taro (Onwueme, 1978)

	Tannia	Taro
Scientific name	*Xanthosoma sagittifolium*	*Colocasia esculenta*
Orgin	Tropical America	South Central Asia
Leaf shape	Sagittate /hastate with deep indentation	Peltate with slight indentation
Marginal vein	Prominent marginal veins present	Absence of marginal veins
Plant height	Robust with 2-3 m height	1-2 m height
Cormel size	Larger	Smaller
Cormel shape	Flask shaped cormels	More or less spherical in shape
Habitat	Exclusively upland condition	Both upland and lowland condition
Waterlogging	Susceptible	Tolerant

Table 2. Mineral nutrient composition of Xanthosoma and Colocasia (Njoku and Ohia, 2007)

Composition	***Xanthosoma sagittifolium***	***Colocasia esculenta***
P (mg/100g)	44.39	72.21
K (mg/100g)	3057.16	4276.04
Mg (mg/100g)	313.70	415.07
Ca (mg/100g)	190.93	132.43
Na (mg/100g)	1365.05	1521.34
Zn (mg/100g)	2.49	2.63
Fe (mg/100g)	8.28	8.66

2.1. Botanical description of tannia

Tannia is a herbaceous, perennial having about 2 m or more height. It produces a subterranean main stem called corm, from which swollen secondary shoots, termed cormels, as well as stalked leaves arise. The corm bears up to 10 or more lateral tubers or cormels, 15-25 cm long, flask shaped, broadening towards apex. Leaves are sagittate, erect with stout long winged petioles, 1m or more in length. It has erect, long, winged petioles with large sagittate leaves. Inflorescence is a spadix and emerges between the leaves. The spadix is cylindrical, slightly longer than the spathe, female flowers are arranged on the lower portion, male flowers on the upper portion and sterile flowers in the middle portion. Fruits are rarely produced. Although tannias are perennials, they are often grown as annuals, harvested after one season. Harvesting can be done from 6 month onwards, and if left unharvest most of them will sprout on the receipt of rains becomes watery and less suitable for consumption (Bermejo and Leon, 1994).

2.2. Effect of shade on plant growth and yield characters

2.2.1. Stem and leaf growth

In tannia, plants grown under shade are significantly taller than plants grown in open at all stages of growth (Pushpakumari, 1989). Bai (1981) reported that colocasia plants receiving full sunlight showed maximum height and on par with 25 and 50 per cent shade. In cassava, plant height increased progressively with increase in shade levels (Okoli and Wilson, 1986; Ghosh *et al.*, 2002).

Geetha (2004) reported maximum plant height in cassava, arrowroot, kacholam, patchouli and chilli when grown in shades and minimum when grown in open condition. Roy *et al.* (2013) reported gradual increase in plant height with increase in shade. Pouliot *et al.* (2012) reported that taro plants growing close to the tree canopy of *Parkia biglobosa* showed maximum height.

Xanthosoma produced long petiole under 70 per cent and 50 per cent shade levels compared to plants under full light exposure (Asante *et al.*, 2017). Elephant foot yam grown in open plots resulted in shortest petioles, while the longest petioles were produced under 75 per cent shading (Santosa *et al.*, 2006). Ding *et al.* (2016) observed fast internodal elongation of the middle-upper regions of cassava seedling with low light levels, which resulted in higher plant height under shade.

Increase in collar girth was reported in *Xanthosoma* under low light intensity (Valenzuela *et al.*, 1991). Prameela (1990) noticed increase in collar girth with shade in colocasia, but the sucker number was found to be decreasing. Bai (1981) observed more sucker production in colocasia, turmeric, coleus and ginger under increased shade intensities. In ginger, Vastrad *et al.* (2006) observed decrease in tiller number with increase in shade. Gray and Holmes (1970) observed decrease in stem diameter of potato under shade compared to control but branch number showed no significant difference.

Sun plants have faster leaf production rate and shorter or similar leaf lifespan compared to shaded plants (Poorter, 2001). Fukai *et al.* (1984) stated that cassava plants under full radiance showed the highest leaf number per plant due to increased lateral branching. Shade greatly increased leaf numbers in cassava seedlings (Ding *et al.*, 2016). However, as reported by Santosa *et al.* (2006) shading decreased leaf number in elephant foot yam while leaf lifespan was increased. Ravi *et al.* (2011) stated that shorter leaf lifespan in full light conditions would enhance more leaf production.

Caesar (1980) reported that *Xanthosoma* and Colocasia plants produced less number of leaves under shade. According to Roy *et al.* (2013), taro produced maximum number of leaves in shaded condition and lowest in full sunlight. However, Prameela, (1990) observed no significant difference in leaf numbers between open and shade grown taro plants. This result matches with that reported by Vastrad *et al.* (2006) in ginger.

In taro, Pouliot *et al.* (2012) observed that plants growing closer to the tree canopy of *Parkia biglobosa* produced 15 per cent more leaves than plants growing outside the canopy. Middleton (2001) stated that leaves of shade grown plants would have longer life and lesser plasticity compared to sun grown plants.

Lassoie *et al.* (1983) stated that increased leaf lifespan was an adaptive measure employed by understory plants for gaining maximum access to sunlight. Sreekumari *et al.* (1988) noted that in cassava, shade increased leaf longevity and number of leaves.

2.2.2. Chlorophyll content

Johnston and Onwueme (1998) reported that shade grown tannia produced 1.4 times more total chlorophyll per unit of leaf fresh weight than sun grown plants. Goncalves (2011) reported that *Xanthosoma sagittifolium* grown under half shade will produce dark green leaves.

Pushpakumari (1989) reported that chlorophyll content of tannia, lesser yam, greater yam and elephant foot yam increased with shade intensities and showed maximum at 75 per cent shade level. Valenzuela (1990) stated that for maximizing light interception and photosynthesis plants would allocate more chlorophyll to leaves.

As reported by Olesinski *et al.* (1989) shaded leaves of potato showed low chlorophyll a: b ratio. Prameela (1990) found that chlorophyll a, chlorophyll 'b' and total chlorophyll increased with increase in shade, while chlorophyll 'a' to b ratio decreased with shade in colocasia. Li *et al*. (2010) stated that increase in chlorophyll 'a' content due to shading was less than increase in chlorophyll 'b' content, resulting reduced chlorophyll a/b ratio with shade.

According to Evans and Poorter (2001), greater chlorophyll a : b ratio in open conditions indicates the presence of more chlorophyll 'a' containing photosystem II reaction centre complexes and fewer chlorophyll 'b' containing light harvesting complexes. For increasing the efficiency of light harvesting in low light intensities plants would partition more chlorophyll in to light-harvesting complexes, and hence result in low chlorophyll a/b ratio under shade (Crawford, 1989; Senevirathna *et al*., 2003).

2.2.3. Leaf area and LAI

Shade loving plants acclimatize to low light intensity by the production of larger leaves, and hence have higher LAI (Smith, 1981). This finding was supported by various researchers in different crops. Leaf length and leaf breadth of turmeric and ginger increased with increase in shade intensities (Bhuiyan *et al*., 2012). Srikrishnah and Sutharsan (2015) reported significantly low leaf area in turmeric under open condition, compared to shaded treatments. Fukai *et al*. (1984) observed that low radiation led to leaf with high specific leaf area.

Leaf area index increment is one of the ways of increasing the absorbance of solar radiation by plants (Dalirie *et al.,* 2010). Specific leaf area increased proportionally with shade in sweet potato (Oswald *et al*., 1994). Similar results were observed by Santosa *et al*. (2006) in *Amorphophallus* and Antony (2016) in hybrid napier.

Roy *et al.* (2013) reported that length and breadth of taro leaves increased gradually with increase in shade levels. Valenzuela (1990) suggested that shaded cocoyam produced larger but thin leaves. Tannia under 70 per cent and 50 per cent shade levels produced maximum leaf area compared to those under full irradiance (Asante *et al.*, 2017).

Specific leaf density or specific leaf weight gives leaf fresh weight per unit leaf area. It indicates the thickness of leaves. Plants grown under more light intensities often develop thicker leaves (Nobel, 1980). Shade plants often produce thin leaves with lower fresh weight per leaf area and a higher content of total chlorophyll (Boardman, 1977).

Middleton (2001) stated that leaves under shade would anatomically adapt to shade by producing thinner leaves with poorly developed palisade tissues. Hence pigments in leaf profile can absorb the available light effectively (Olesinski *et al.*, 1989).

Shade grown leaves of cocoyam had significantly higher leaf weight to leaf area ratio than leaves grown in full sun (Schaffer and O'Hair, 1987). According to Olesinski *et al.* (1989), shade resulted in lower specific leaf weight in potatoes. As reported by Johnston and Onwueme (1998), the percentage reduction in leaf fresh weight per unit leaf area due to shade was less in taro and tannia, compared to yam, sweet potato or cassava indicating that both these crops are morphologically well adapted to shade.

2.2.4 Yield and yield attributes

Plants adapted to shade usually have low light compensation point, making them photosynthetically efficient in shade, but tend to be less efficient when exposed to higher light levels (Kubiske and Pregitzer, 1996). High light levels and photoinhibition may even harm shade loving plants resulting in leaf bleaching and scorching (Demmig-Adams and Adams, 1992)

Not all tuber crops are shade tolerant but most aroids are tolerant to shade. Shading in general, affected tuber formation in crops such as cassava, sweet potato, and potato. Pushpakumari (1989) recorded maximum yield of tannia under 25 per cent shade which was almost equal to the yield obtained from 50 per cent. Valenzuela *et al.* (1991) concluded that the larger leaves produced by shade grown plants would lead to a greater light interception and to higher rates of carbon fixation on a per plant basis, thereby producing higher underground yield.

In an agroforestry system, yields of taro close to the tree canopy were almost double that of plants farther away from the canopy (Pouliot *et al.*, 2012). Prameela (1990) observed higher yield of colocasia under 25 per cent shade. Taro from partially shaded areas produced cormels with more length, breadth, and weight (Roy *et al.*, 2013). Fukai *et al.* (1984) showed that tuber number was sensitive to solar radiation.

Miura and Osawada (1981) reported that in elephant foot yam, dry weight of corm under open condition was considerably lower than that of shaded plants. They concluded that increase in corm weight under shade might be due to three reasons a) increased photosynthetic and decreased respiration rates b) decrease in leaf temperature resulted by shading, and c) decreased leaf degeneration rate. Geetha (2004) reported that higher yields in arrowroot under 50 per cent shade was due to increased dry matter production under shade which might be due to increased photosynthetic surface of shaded plants.

Aresta and Fukai (1984) observed that 32 per cent reduction in solar input resulted in 50 per cent reduction in root elongation rate. *Amorphophallus konjac* under 50 per cent shading yielded the highest (Douglas *et al.*, 2005) while *A. mulleri* produced largest corms under 75 per cent shading (Santosa, *et al.*, 2006).

Gray and Holmes (1970) reported that a short period of shading during initial days of tuber initiation caused 30 per cent more potato tubers. Kuruppuarachchi (1990) observed that potato planted in subabul avenues, had increased yield during the initial seasons, but decreased in subsequent seasons due to increase in shading.

According to studies done by Oswald *et al.* (1994), shade decreased assimilate production and partitioning in sweet potato resulting in considerable yield loss. Sale (1976) reported 25-40 per cent decrease in potato tuber yield in shaded plants compared to unshaded. Increasing shading intensity consistently decreased dry matter production and tuber weight and finally decreased tuber yield in potato. According to Mwanga and Zamora (1988) in sweet potato, compared to full sunlight, shading led to significant reduction in total number and dry matter yield of tuber.

Prakash (1996) reported that under shaded condition, coleus shoot characters are negatively correlated to yield. Chapman and Cowling (1965) reported that exposure of maximum leaves to full sunlight would increase the yield of sweet potato. When grown as intercrop in coconut garden, tuber yield of cassava was significantly reduced (Sreekumari *et al.*, 1988). In cassava, shading resulted in late tuber bulking, decreased number of tubers, tuber weight and yield (Okoli and Wilson, 1986).

Ramanujam *et al.* (1984) reported that shade grown cassava plants utilized most of its photosyntates for shoot growth leaving little for root development. Under the partial shade of coconut gardens, cassava tuber yield was very poor compared to open (Raveendran, 1996).

2.2.5. Nutritional quality

Shading has some effects on nutritional quality. However, the effects depend upon the crops involved. Plants adapted to shade had lower non-structural carbohydrate than those grown in full light intensity (Kephart and Buxton, 1996). Buxton (2001) reported that increased concentration of nitrogenous compounds could be seen in shading, with less concentration of soluble carbohydrates.

Pushpakumari (1989) noticed decrease in starch content of elephant foot yam tuber with increase in shade, while tannia produced maximum starch under 50 per cent, which was on par with open and 25 percent. Rogers and Iosefa (1993) noted that shade grown taro plants produced corms of better cooking and taste quality.

Hozyo and Kato (1976) observed that sunlight exposed parts of sweet potato had decreased starch content. According to Li and Guo (2015), shade decreased starch and dry matter content of potato tubers but increased the protein content.

Hernández *et al*. (2015) reported increased lycopene concentration in tomato when produced under shade. Thangam and Thamburaj (2008) observed increase in acidity and decrease in ascorbic acid and TSS content of tomato under shade. Grapes grown under open condition resulted in high TSS, high reducing and non-reducing sugars. High light intensity increased vitamin C content and decreased nitrate levels in pea seedlings (Liu *et al*., 2013). In pineapple, acidity increased, while sugar and ascorbic acid content decreased with increase in shade levels (Radha, 1979).

Ten leafy vegetables harvested at low light intensity showed increased phenolic content and protein levels (Colona *et al*., 2016). Broccoli sprouts grown under light were found to have high glucosinolates, vitamin C and phenolic contents (Pérez-Balibrea *et al*., 2008). According to Blair *et al*. (1983), protein content was higher in shaded plants than plants grown under full irradiance. Ajithkumar and Jayachandran (2003) reported that oil content of ginger increased with increase in shade levels. In a study in maize, Yang *et al*. (2016) reported that starch content decreased and protein content increased by shading.

22.6. Antinutritional factors

Oxalate is an important antinutritional factor in tannia and other aroids. Along with itching, stinging and irritation, the dietary oxalate has been known to form complexes with calcium, magnesium and iron. This will lead to the formation of insoluble oxalate salt and resulting in kidney stones (Onwuka, 2005).

According to Moreau and Savage (2009), under shade, plants will tend to accumulate more insoluble oxalates. Antony (2016) reported increase in oxalate content of hybrid napier with increase in shade. Harvesting at low light intensity resulted in increased nitrate levels in leafy vegetables (Colona *et al.*, 2016). In colocasia, Prameela (1990) observed increased oxalate content when grown in open condition.

2.3. Effect of planting material on plant growth characteristics

According to Dev (2014), corms of higher weight would have larger reserved food material and water content enabling the plants to withstand adverse situations, resulting in less mortality and heavy plant growth.

Gebre *et al.* (2015) reported that in taro maximum sprouting and number of shoots could be seen when planted with large sized sets due to more number of potential buds and food reserves in large sized corms. Nath *et al.* (2007) reported that in *Amorphophallus,* it was beneficial to use seed corms for planting, as it gave almost 100 per cent early sprouting and 40 per cent more yield than cut pieces. He also noted that the cut pieces were prone to high microbial attack. Nedunchezhiyan *et al.* (2011) reported that for elephant foot yam, cormels serve as good source of planting material.

In potato, cut tubers resulted in the highest leaf area. The wounded surface increase enzyme activities and makes it physiologically more active (Tanka and

Uritani, 1979). According to Tsedalu *et al.* (2014) planting with corms recorded highest plant height, number of suckers, number of leaves, and leaf area in taro. Maximum leaf length and width was observed in taro by planting with cormels resulting in higher photosynthetic area (Fajinmi, 2015). According to Tsedalu *et al.* (2014), planting of corms in taro resulted 50 per cent earlier emergence and maximum marketable tubers. Biometric observations like plant height, leaf number, and leaf area was maximum in plants produced from corms.

2.4. Effect of planting material on yield characteristics

In general, yield of tubers are significantly affected by the planting material used (Sikder *et al.*, 2014). Several researchers have reported the influence of set size on yield in tuber crops (Siddique *et al.*, 1988; Saravaiya *et al.*, 2010). Splitting of tubers will help in reducing the planting material size and hence the bulkiness (Nakasha *et al.*, 2017).

Fajinmi (2015) reported higher yield in *Xanthosoma mafafa* when planted with cormels of 120 g compared with corm of 200 g and split corm of 60 g. In colocasia, planting with primary corms produced maximum cormel yield, corm and cormel weight, but cormels as planting material produced the lower yield (Faisal *et al.*, 2009).

Cut tubers and whole tubers produced no significant difference on growth and yield of potato (Babaji *et al.*, 2008; Jaiswal and Saini, 1991). In potato, cut tubers on planting mostly produced tubers of smaller size and whole tubers produced large tubers on harvest (Kabir *et al.*, 2004). Nakasha *et al.* (2017) reported that in safed musli cut tubers produced higher number of tubers. According to them cut tubers would develop specialized roots earlier than whole tubers, which would make penetration easy and fast.

Planting of turmeric with mother rhizomes produced maximum yield, gross, and net returns (Manhas *et al*., 2010; Temteme *et al*., 2017) and maximum curcumin content (Deshmukh *et al*., 2005) over the primary and secondary finger planting material. Neeraja *et al*. (2016) also recorded lowest curcumin and oleoresin contents when planted with single noded cuttings and maximum in mother rhizomes.

In *Xanthosoma*, Cunliffe (1917) observed that by using main corm sections, yield was higher than planting with small, medium, or large cormels. According to Beale *et al*. (1981), in *Xanthosoma*, planting with cormels out yielded crown and cut section planting.

Materials & methods

3. MATERIALS AND METHODS

The experiment entitled "Performance of different planting materials of tannia (*Xanthosoma sagittifolium* (L.) Schott) under shade" was conducted at the Agronomy farm, Department of Agronomy, College of Horticulture, Vellanikkara during June 2017 - January 2018. The materials used and methodology adopted for the investigation are detailed in this chapter.

3.1. General details

Location

The experiment was conducted at the Agronomy farm, Department of Agronomy, College of Horticulture, Vellanikkara, Thrissur, Kerala. The field was situated geographically at 13° 32' N latitude and 76° 26' E longitude, at an altitude of 40.3 m above mean sea level.

Climate and weather conditions

The area experiences tropical humid climate. The mean weekly averages of important meteorological parameters observed during the experimental period are presented in Appendix 1.

Soil

The soil of the experimental site was well - drained sandy clay loam and acidic with a pH of 4.65. The physico - chemical properties are given in Table 3.

Season

Planting was done during June 2017, by the onset of monsoon and harvesting was done during January 2018.

Table 3. Physico-chemical properties of soil

Particulars	**Value**	**Method used**
1. Physical properties		
Particle size composition		
Coarse sand (%)	31.90	Robinson international pipette method (Piper, 1942)
Fine sand (%)	27.30	
Silt (%)	18.64	
Clay (%)	22.16	
2. Chemical properties		
pH	4.65	1: 2.5 soil water ratio (Jackson, 1958)
Organic carbon (%)	1.13	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	189.00	Alkaline permanganate method (Subbaiah and Asija, 1956)
Available P (kg/ha)	10.08	Ascorbic acid reduced molybdo phosphoric blue colour method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965)
Available K (kg/ha)	259.84	Neutral normal ammonium acetate extraction and estimation using flame photometry (Jackson, 1958)

3.2. Experimental details

Treatment details

Main plot: Shade levels

S1: 25% shade

S2: 50% shade

S3: Open (0% shade)

Sub plot: Planting materials

P1: Planting with top of corm (200 g)

P2: Planting with cormels (75 g)

P3: Planting with split corm (150 g)

Design	: Split plot
Replication	: 3
Spacing	: 90 cm × 90 cm
Variety	: Local
Plot size	: 3.6 m × 3.6 m
Planting season	: June 2017 - January 2018

The layout of the experiment is depicted in Fig.1.

Land preparation and planting

The site was ploughed thoroughly and made in to fine tilth. Pits were made at spacing of 90 cm × 90 cm. Planting was done using locally available variety collected from farmers field.

Shade provision

Nets of 25 per cent and 50 per cent shade were used for providing corresponding shade levels, while open plot was left unshaded. The sides of shaded plots were also covered with corresponding shade nets leaving 1 m from ground level.

Manures and fertilizers

Fertilizer application and manuring were carried out according to the KAU package of practices recommendation (KAU, 2016). Dolomite was applied at the rate of 1 kg/pit during the time of land preparation, as tannia being identified as Mg indicator plant. About 2 kg cattle manure was applied per pit at the time of planting. For tannia, NPK recommended rate was 80:50:150 kg/ha. Full P was applied as basal. 75 per cent of nitrogen was met by incorporating 20 kg/ha of green manure cowpea on the interspaces at 45 - 60 DAP. While 25 percent nitrogen and full potassium were applied in three splits on 2, 4, 6 months after planting along with weeding and earthing up.

Weed management

Weed management was done along with earthing up and fertilizer application at 1, 2, 4, and 6 month of planting.

Harvesting

Harvesting was done at seven and half months after planting, when yellowing and drying of aerial portion started.

3.3. Observations recorded

From each plot, four plants were selected at random as the sampling unit for taking observations. Observations were recorded at 60, 90, 120 and 150 DAP and at harvest.

3.3.1. Observations on crop

Days to emergence: Number of days taken for sprouting of 50 per cent of the total number of setts planted in each plot.

Petiole length: Length of petiole was calculated by measuring the length from collar region to the blade joint.

Plant height: The plant height was measured from collar region near to ground to the tip of top most leaf.

Collar girth: The girth of collar region of all the tillers were taken and average was worked out.

Number of leaves per plant: By counting the number of leaves from all the tillers and taking the average.

Leaf area: Leaf area per plant was calculated by using the formula developed by Valenzuela *et al*. (1991) as given below and expressed in $dm^{2.}$

Leaf area (dm^2) = 69.27 + 0.87 (leaf length × leaf width) × number of leaves

Leaf area index (LAI): Leaf area index (LAI) was recorded by using the formula given by Watson (1947) as given below.

Leaf area index =Leaf area/Land area

Specific leaf density: It was calculated as the ratio of leaf dry weight to leaf area as mentioned by Valenzuela (1990).

Specific leaf density= Leaf dry weight/Leaf area

Lifespan of leaves: Number of days taken by a fully opened leaf to become completely yellow.

Chlorophyll content of leaves: Total chlorophyll content was estimated by DMSO method by Hiscox and Israelstam (1979).

Number of cormels per plant: By counting the number of cormels obtained from a plant.

Fresh weight of cormels: Total weight of cormels from the observational plants were recorded and divided by number of cormels and expressed in gram/cormel

Dry weight of cormels: Cormels from the observational plants were taken, cut and dried in oven for 80°C and dry weight was noted. The weight was then divided by number of cormels and expressed in gram/cormel.

Fresh weight of corm: Fresh weight of harvested corms of the sample plants were noted, and then average was recorded in g.

Dry weight of corm: Corm dry weight of sample plants were taken after cleaning, cutting and oven drying at about 80° C in hot air oven and finally recording the average in g.

Cormel yield per hectare: From the yield of four plants, cormel yield per plot was calculated in kg and from this value, the yield per ha was calculated (t/ha).

Corm yield per hectare: From the yield of four plants, the corm yield per plot was noted in kg and from this value, yield per ha was calculated (t/ha).

Shoot - Storage organ ratio: Fresh weight of shoot and fresh weight of storage organ (both corm and cormels) were noted separately at the time of harvest and shoot - storage organ ratio ratio was calculated.

Corm - Cormel ratio: Fresh weight of corm and fresh weight of cormels of observation plants were taken separately at the time of harvest and the ratio was calculated.

Length of cormels: The length of cormel was calculated by taking measurement from apical to distal portion of tuber.

Girth of cormels: The girth was taken by measuring the circumference of the thickest portion of tuber.

Incidence of pest and diseases: Pest and disease incidence was observed and recorded.

3.3.2. Chemical analysis

3.3.2.1. Soil analysis

The pH, organic carbon, and major nutrient contents (N, P, and K) of the soil were estimated before and after the experiment following common methods as indicated in Table 3. Soil samples were collected, dried, powdered and sieved through

0.5mm sieve for organic carbon analysis and samples passed through 2 mm sieve was used for analysis of available N, available P, and available K. Soil pH was analyzed in soil: water suspension of 1: 2.5.

3.3.2.2. Crop analysis

Crude protein content of corms and cormels

For this, first nitrogen content of corms and cormels was determined by distillation and titration method (Jackson, 1958). Afterwards, the crude protein content was calculated from nitrogen content by multiplying it with 6.25 (Simpson *et al.*, 1965).

Starch content of corms and cormels

Starch content of corms and cormels was determined by potassium ferricyanide method as described by Murthy and Padmaja (2002). For this 1 g of sample was weighed and 20 ml of 80 per cent ethanol was added and left overnight to extract the sugars. The extracted sugars were separated from the residue by filtration with Whatman No.1 filter paper. The residue was washed with 20 ml distilled water first and transferred back into the conical flask using 20 ml of 2N HC1. This was then hydrolyzed on hot plate at 100° C for 30min, till the residue was reduced to 5 ml. Then the volume of starch residue was raised to 50 ml using distilled water and added 1 drop HCl. Then 10 ml of 1per cent potassium ferricyanide was pipetted and 5 ml NaOH (2.5 N w/v) was added and mixed. The contents were boiled and 1 drop of dilute methylene blue was added. The solution immediately turned blue green. The starch hydrolase was taken in a 2 ml pipette and added drop by drop. The end point was noted by the change of color to golden yellow.

Starch content (%) =

$$\frac{Titre\ value\ of\ ferricyanide \times Vol.of\ starch\ hydrolase \times Morris\ factor \times 100}{Titre\ value\ of\ starch\ hydolase \times weight\ of\ sample \times 1000}$$

Oxalate content of corms and cormels

Determination of oxalate content was done as per the method given by Oke (1966). Weighed 2 g of the sample, and it was digested with 10 ml of 6 M HCl for one hour and made up to 250 ml in a volumetric flask and filtered. The pH of the filtrate was adjusted by adding 3 - 4 drops of methyl red indicator first followed by adding con. NH_4OH solution until the colour of solution changed from salmon pink to faint yellow. Thereafter, the filtrate was treated with 10 ml of 5 per cent $CaCl_2$ solution to precipitate the insoluble oxalate. The suspension was then allowed to stand for 24 hrs, after which the supernatant was filtered and precipitate completely dissolved in 10 ml of 20per cent (v/v) H_2SO_4. The total filtrate resulting from the dissolution in H_2SO_4 was made up to 300 ml. An aliquot of 125 ml of the filtrate was heated until near boiling point and then titrated against 0.05 M standardized $KMnO_4$ solution to a faint pink colour which persisted for about 30 seconds after which the burette reading was taken. The oxalate content was calculated from the titer value.

$$\text{Oxalate content (g/100g)} = 0.05\ N\ \text{KMnO}_4\ used(ml) \times 0.00225 \times \frac{250}{50} \times \frac{100}{2}$$

3.4. Economic analysis

For economic analysis, prevailing labour charges in the locality, cost of inputs and extra treatment costs were considered and gross expenditure was computed and expressed in rupees per hectare. The current price of tannia in the local market was utilized for computing gross returns and expressed in rupees per hectare. The Benefit: Cost ratio was worked out according to the given formula below.

BCR= Gross returns/Gross expenditure

3.5. Statistical analysis

The data collected were subjected to analysis of variance as per the design adopted in the experiment by using the statistical package 'OP Stat' (Sheoran *et al.*, 1998).

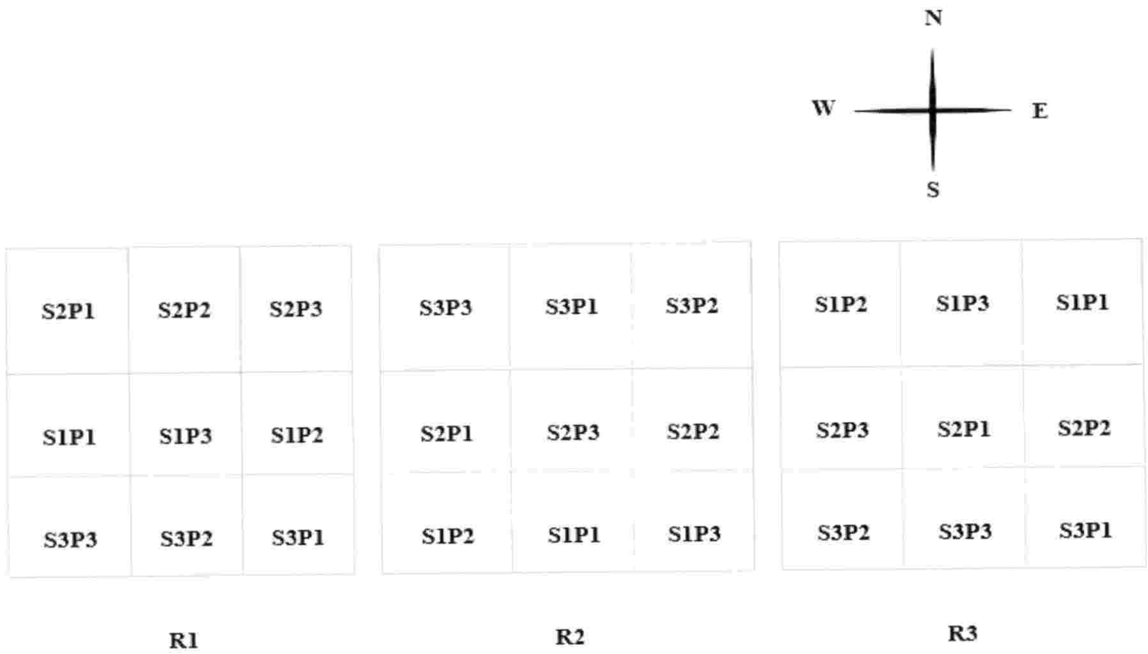

Fig.1. Layout of the experimental field

Main plot: Shade levels

S1: 25% shade

S2: 50% shade

S3: Open (0% shade)

Sub plot: Planting materials

P1: Planting with top of corm (200 g)

P2: Planting with cormels (75 g)

P3: Planting with split corm (150 g)

Plate I: Planting materials

P1: Top of corm (200g)

P2: Cormels (75 g)

P3: Split corm (150g)

Plate II. 1. General field view

Plate II. 2. 25 per cent shaded plots at 90 DAP

Plate II. 3. Open plots at 90 DAP

Field view at 120 DAP

Plate III. 1. 25 per cent shaded plot

Plate III. 2. 50 per cent shaded plot

Plate III. 3. Open plot

Results

4. RESULTS

The results of the study entitled ''Performance of different planting materials of tannia (*Xanthosoma sagittifolium* (L.) Schott) under shade" conducted at the Department of Agronomy, College of Horticulture, Vellanikkara during June 2017 - Jan. 2018 are presented in this chapter after subjecting them to appropriate statistical analysis.

4.1. Biometric observations

4.1.1 Days to emergence

The data regarding the days to emergence is presented in Table 4. Shade had no effect on the days taken for emergence. However, the planting materials used significantly influenced the days of emergence. Top of corm has shown early emergence within 15 days, while split corm has taken maximum days for emergence, about 25 days.

4.1.2. Plant height

The effect of treatments on plant height is presented in Table 5. Plant height continued to increase up to 120 DAP and then maintained almost the same height at 150 DAP. Shade produced significant difference in plant height at all the growth stages. At 60 DAP, tallest plants were observed in 25 per cent shade (86.80 cm). At 90 DAP, 50 per cent shade showed higher plant height (132.46 cm), while at 120 and 150 DAP, 25 per cent shade and 50 per cent shade were on par in terms of plant height. With 50 and 25 per cent shade, plant height were 137.44 cm and 132.45 cm, respectively at 120 DAP, and 135.19 cm and 132.14 cm respectively at 150 DAP.

Among the different planting materials used, top of corm recorded higher height at all the growth stages. At 60 DAP, top of corm (84.29 cm) produced taller plants which was significantly superior to the other two planting materials. The second best at 60 DAP was planting with cormels (80.81 cm). At 90 DAP too, plant height was significantly superior with top of corm (122.25 cm), followed by split corm

Table 4. Effect of shade levels and planting materials on days to emergence

Treatments	Days to emergence
Shade levels	
25 per cent	20.00
50 per cent	20.44
Open	20.78
SEm±	0.86
CD (0.05)	NS
Planting materials	
Top of corm	15.00
Cormels	21.22
Split corm	25.00
SEm±	0.34
CD (0.05)	1.05

(116.39 cm), and cormels (116.23 cm) which were on par. At 120 DAP, top of corm and split corm were on par showing higher values (126.63 cm and 126.23 cm respectively). At 150 DAP, no significant differences in height were noted between the planting materials.

Significant interaction was noted between shade levels and planting materials at 60, 90 and 150 DAP (Table 5 a.). At 60 DAP, planting of top of corm under 50 per cent shade showed the higher plant height (93.79 cm) on par with planting of cormels under 25 per cent shade (92.18 cm). At 90 DAP, plant height produced by top of corm under 50 per cent shade (140.54 cm) and cormels under 50 per cent shade (133.73 cm) were on par. At 150 DAP, cormel planting in 50 per cent shade produced maximum height on par with the treatment combinations, split corm under 25 per cent shade, and top of corm under 25 per cent and 50 per cent shade.

4.1.3. Petiole length

The data pertaining to the petiole length are given in Table 6. Petiole lengths at different growth stages were significantly influenced by shading except at 60 DAP. During other growth stages, petiole lengths increased with an increase in shade intensity. At 90 DAP, petiole lengths were significantly high in 50 per cent shade (91.43 cm), followed by 25 per cent shade (82.99 cm). At 120 DAP and 150 DAP, 50 per cent shade produced petioles with lengths of 93.03 cm and 95.78 cm respectively which were on par with 25 per cent shade (86.86 cm and 89.23 cm respectively). At all the stages, lower petiole length was seen in open grown plants.

Planting materials significantly influenced petiole length except at 90 DAP. At 60 DAP, petiole length was higher in planting with top of corm (50.38 cm) on par with planting with cormels (47.94 cm). At 120 DAP, petiole length recorded in planting with top of corm (86.28 cm) was significantly superior, followed by split corm which was on par with planting with cormels. Planting with top of corm showed the highest length (87.22 cm) at 150 DAP which was on par with planting using split corm (84.75 cm).

Table 5. Effect of shade levels and planting materials on plant height

Treatments	Plant height (cm)			
Shade levels	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
25 per cent	86.80	121.85	132.45	132.14
50 per cent	83.28	132.46	137.44	135.19
Open	72.00	100.57	105.69	97.49
SEm±	0.52	2.14	1.41	1.69
CD (0.05)	2.08	8.63	5.70	6.79
Planting materials				
Top of corm	84.29	122.25	129.63	123.42
Cormels	80.81	116.23	119.72	118.64
Split corm	76.98	116.39	126.23	122.76
SEm±	0.56	1.41	1.18	1.45
CD (0.05)	1.73	4.40	3.68	NS

Table 5 a. Interaction effect of shade levels and planting materials on plant height

Treatments (Shade levels × Planting materials)	Plant height (cm)		
	60 DAP	90 DAP	150 DAP
25 % shade × Top of corm	87.19	121.16	135.175
25 % shade × Cormels	92.18	118.22	124.19
25 % shade × Split corm	81.03	126.17	137.05
50 % shade × Top of corm	93.79	140.54	133.6
50 % shade× Cormels	73.31	133.73	140.75
50 % shade × Split corm	82.75	123.10	131.22
Open × Top of corm	71.90	105.06	101.47
Open × Cormels	76.96	96.75	90.99
Open × Split corm	67.15	99.91	100.02
SEm±	0.94	3.71	2.66
CD (0.05)	3.19	8.81	9.26

Table 6. Effect of shade levels and planting materials on petiole length

Treatments	Petiole length (cm)			
Shade levels	**60 DAP**	**90 DAP**	**120 DAP**	**150 DAP**
25 per cent	49.70	82.99	86.86	89.23
50 per cent	49.32	91.43	93.03	95.78
Open	44.63	67.25	66.32	65.88
SEm±	1.26	0.74	1.74	1.87
CD (0.05)	NS	2.99	7.01	7.55
Planting materials				
Top of corm	50.38	82.96	86.28	87.22
Cormels	47.94	79.09	79.06	78.93
Split corm	45.33	79.62	80.86	84.75
SEm±	0.97	1.29	1.00	2.01
CD (0.05)	3.03	NS	3.11	6.26

Table 6 a. Interaction effect of shade levels and planting materials on petiole length

Treatments (Shade levels × Planting materials)	Petiole length (cm)	
	60 DAP	90 DAP
25 % shade × Top of corm	49.55	81.08
25 % shade × Cormels	52.67	82.75
25 % shade × Split corm	46.89	85.14
50 % shade × Top of corm	55.70	90.21
50 % shade× Cormels	45.30	94.92
50 % shade × Split corm	46.95	89.17
Open × Top of corm	45.89	77.58
Open × Cormels	45.84	59.61
Open × Split corm	42.17	64.55
SEm±	1.87	1.97
CD (0.05)	6.60	6.39

The treatments produced significant interaction effect on petiole length during initial stages, 60 DAP and 90 DAP (Table 6 a.). At 60 DAP, 50 per cent shade with top of corm showed the highest petiole length (55.70 cm) which was on par with top of corm under 50 per cent (52.67 cm) and 25 per cent shade (49.53 cm).

4.1.4. Collar girth

The data on collar girth are given in Table 7. Shade levels influenced collar girth at all the stages. Collar girth increased during the growth stages from 60 to 90 DAP. At 60 and 120 DAP, collar girth of plants in 25 and 50 per cent shade plots were on par. At 90 and 150 DAP, collar girth in 50 per cent shaded plots were significantly higher than other two treatments. At all the growth stages, the least girth was observed in open condition.

Planting materials produced significant effect on collar girth only at 90 DAP. At 90 DAP, higher collar girth was shown by planting with cormels (23.73 cm). It was followed by planting with split corm and top of corm.

Significant interaction was observed between main plot and sub plot with regards to collar girth (Table 7 a.). At 60 DAP, collar girth was the highest in combination of top of corm and 50 per cent shade (17.98 cm) on par with split corm under open condition (17.39 cm), top of corm and cormels under 25 per cent shade (16.50 and 16.33 cm respectively). At 90 DAP, planting of cormels under 25 per cent shade resulted in maximum collar girth and interaction effect of 50 percent shade with top of corm, cormels, and split corm were on par with it. At 150 DAP, combination of cormels and 50 per cent shade resulted in higher collar girth (28.63 cm) which was significantly superior to other treatments.

4.1.5. Number of leaves

The data pertaining to the number of leaves are given in Table 8. Shade significantly influenced the leaf number at all the stages. At all the stages, 50 per cent shade recorded higher number of leaves but open condition and 25 per cent shade were on par.

Table 7. Effect of shade levels and planting materials on collar girth

Treatments	Collar girth (cm)			
	60 DAP	90 DAP	120 DAP	150 DAP
Shade levels				
25 per cent	15.64	22.63	26.17	23.15
50 per cent	16.03	24.38	25.54	25.89
Open	15.20	21.24	20.85	17.30
SEm±	0.15	0.38	0.37	0.22
CD (0.05)	0.62	1.53	1.47	0.88
Planting materials				
Top of corm	15.74	21.89	24.28	21.76
Cormels	15.90	23.73	24.21	22.31
Split corm	15.22	22.63	24.06	22.27
SEm±	0.32	0.24	0.85	0.30
CD (0.05)	NS	0.73	NS	NS

Table 7 a. Interaction effect of shade levels and planting materials on collar girth

Treatments (Shade levels× Planting materials)	Collar girth (cm)		
	60 DAP	90 DAP	150 DAP
25 % shade × Top of corm	16.50	21.88	23.65
25 % shade × Cormels	16.33	24.96	19.38
25 % shade × Split corm	14.09	21.07	26.44
50 % shade × Top of corm	17.98	24.63	25.15
50 % shade× Cormels	15.91	24.25	28.63
50 % shade × Split corm	14.20	24.25	23.89
Open × Top of corm	12.74	19.17	16.47
Open × Cormels	15.47	21.97	18.93
Open × Split corm	17.39	22.58	16.50
SEm±	0.27	0.66	0.38
CD (0.05)	1.78	1.48	1.70

Influence of planting materials on leaf number was evident at all the stages. Planting with top of corm recorded maximum number of leaves at all the stages and was significantly superior to other two planting materials. The next better treatment in terms of leaf number was planting with cormels, which was on par with split corm at all the stages.

Significant interaction was noted at 60, 120 and 150 DAP (Table 8.a.). At 60 DAP, planting of split corm under 50 per cent shade has shown the highest leaf area and it was on par with combinations top of corm under both open and 25 per cent shade, and cormels under open condition. At 120 DAP, interaction of top of corm under both open and 50 per cent shaded condition, split corm under 50 per cent shade and top of corm and 25 per cent shade produced higher and statistically similar number of leaves. At 150 DAP, top of corm in combination with 50 per cent shade and open condition and 50 per cent shade in combination with split corm produced maximum number of leaves.

4.1.6. Leaf area per plant

The data regarding leaf area per plant is shown in Table 9. Leaf area was maximum at 90 DAP, and then declined. Shade influenced leaf area significantly at all the stages. At all the stages, higher leaf area was recorded in 50 per cent shade, but 25 per cent shade and open were on par except 90 DAP.

Planting materials significantly affected leaf area at all the stages. Planting with top of corm produced higher leaf area at all the stages which was significantly superior to other two types of planting materials. Cormels and split corms were comparable at all the stages with regard to leaf area per plant.

Interaction between shade levels and planting materials was significant only at 60 DAP (Table 9 a.). At 60 DAP, the highest leaf area was observed from the combination of top of corm with 50 per cent shade (111.01 dm^2). Among all the treatment combinations, split corm planting under open condition produced lower

Table 8. Effect of shade levels and planting materials on number of leaves

Treatments	Number of leaves			
	60 DAP	90 DAP	120 DAP	150 DAP
Shade levels				
25 per cent	4.82	5.87	6.1	5.45
50 per cent	7.59	7.64	8.74	8.00
Open	5.95	6.25	7.63	6.63
SEm±	0.32	0.30	0.42	0.44
CD (0.05)	1.28	1.22	1.68	1.79
Planting materials				
Top of corm	7.84	8.94	10.05	8.75
Cormels	5.35	5.67	6.37	5.81
Split corm	5.17	5.12	6.06	5.53
SEm±	0.41	0.40	0.46	0.44
CD (0.05)	1.26	1.25	1.42	1.37

Table 8 a. Interaction effect of shade levels and planting materials on number of leaves

Treatments (Shade levels× Planting materials)	Number of leaves		
	60 DAP	120 DAP	150 DAP
25 % shade × Top of corm	6.61	8.43	6.83
25 % shade × Cormels	4.21	5.44	5.33
25 % shade × Split corm	3.62	4.42	4.18
50 % shade × Top of corm	8.95	10.68	9.99
50 % shade× Cormels	5.63	6.00	5.43
50 % shade × Split corm	8.20	9.55	8.58
Open × Top of corm	7.94	11.03	9.42
Open × Cormels	6.23	7.66	6.67
Open × Split corm	3.68	4.20	3.82
SEm±	0.55	0.72	0.77
CD (0.05)	2.34	2.67	2.60

Table 9. Effect of shade levels and planting materials on leaf area

Treatments	Leaf area (dm^2)			
	60 DAP	**90 DAP**	**120 DAP**	**150 DAP**
Shade levels				
25 per cent	56.20	102.98	96.34	72.30
50 per cent	82.46	144.15	139.42	120.64
Open	58.66	89.61	81.61	52.72
SEm±	1.63	2.61	4.05	4.56
CD (0.05)	6.55	10.52	16.33	18.40
Planting materials				
Top of corm	88.42	143.34	135.46	101.03
Cormels	56.14	101.51	90.95	68.33
Split corm	52.76	91.89	90.96	76.30
SEm±	3.27	9.45	8.09	6.51
CD (0.05)	10.19	29.43	25.20	20.27

Table 9 a. Interaction effect of shade levels and planting materials leaf area at 60 DAP

Planting materials / Shade levels	Leaf area (dm^2)		
	Top of corm	Cormels	Split corm
25 % shade	78.08	48.07	42.45
50 % shade	111.01	52.69	83.69
Open	76.17	67.66	32.15
SEm±	2.82		
C.D.(0.05)	18.22		

leaf area per plant (32.15 dm^2) on par with split corm and 25 per cent shade (42.45 dm^2), and cormels and 25 per cent shade (48.07 dm^2).

4.1.7. Leaf area index

The data on LAI are presented in Table 10. At all the stages, the LAI of tannia was below 2 indicating the absence of mutual shading or leaf overlapping. Shade significantly affected leaf area index of the plants during all the stages. Just like leaf area, LAI has also shown similar trends. At all the stages, higher LAI was observed in 50 per cent shade. Except at 90 DAP, LAI of 25 per cent shade and open were on par.

The effect of planting material on LAI was significant at all the stages. Higher leaf area index was observed in planting with top of corm, while cormels and split corm were on par to each other.

Significant interaction was noted between main plots and subplots with regard to LAI only at 60 DAP (Table 10 a.). Just like leaf area, LAI of top of corm combined with 50 per cent shade (1.37) was significantly superior to other combinations.

4.1.8. Specific leaf density

The effect of shade and planting materials on specific leaf density is given in Table 11. Shade levels affected specific leaf density at all the stages except 150 DAP. Maximum specific leaf density was observed in open condition at all the stages which was significantly superior to other two treatments. The specific leaf densities of plants from 25 per cent and 50 per cent shaded plots were on par at 60 and 120 DAP. At 90 DAP, 50 per cent shade has shown the lowest specific leaf density.

At 60 and 120 DAP, planting materials influenced specific leaf density. Planting with split corm had greater specific leaf density at 60 DAP, followed by planting with cormels. At 120 DAP, maximum specific leaf density was in cormel planted plots.

Table 10. Effect of shade levels and planting materials on leaf area index

Treatments	Leaf area index			
	60 DAP	90 DAP	120 DAP	150 DAP
Shade levels				
25 per cent	0.67	1.27	1.19	0.89
50 per cent	1.02	1.78	1.72	1.49
Open	0.73	1.11	1.01	0.65
SEm±	0.03	0.03	0.05	0.06
CD (0.05)	0.12	0.13	0.20	0.23
Planting materials				
Top of corm	1.09	1.77	1.67	1.25
Cormels	0.67	1.25	1.12	0.84
Split corm	0.65	1.13	1.12	0.94
SEm±	0.04	0.12	0.10	0.08
CD (0.05)	0.14	0.36	0.31	0.25

Table 10 a. Interaction effect of shade levels and planting materials leaf area index at 60 DAP

Shade levels \ Planting materials	Top of corm	Cormels	Split corm
25 % shade	0.96	0.53	0.51
50 % shade	1.37	0.65	1.03
Open	0.94	0.84	0.40
SEm±	0.05		
C.D.(0.05)	0.25		

Table 11. Effect of shade levels and planting materials on specific leaf density

Treatments	Specific leaf density(mg/cm^2)			
	60 DAP	90 DAP	120 DAP	150 DAP
Shade levels				
25 per cent	5.29	5.02	5.05	4.88
50 per cent	5.25	4.42	6.02	4.87
Open	7.57	8.79	7.17	5.12
SEm±	0.24	0.09	0.25	0.41
CD (0.05)	0.96	0.35	1.02	NS
Planting materials				
Top of corm	4.99	6.06	4.80	4.76
Cormels	5.54	6.82	7.69	5.00
Split corm	7.57	5.35	5.75	5.10
SEm±	0.26	0.40	0.28	0.38
CD (0.05)	0.82	NS	0.87	NS

Table 11 a. Interaction effect of shade levels and planting materials on specific leaf density

Treatments (Shade levels × Planting materials)	Specific leaf density (mg/cm^2)		
	60 DAP	**90 DAP**	**120 DAP**
25 % shade × Top of corm	5.29	5.53	4.56
25 % shade × Cormels	4.38	5.32	5.09
25 % shade × Split corm	6.20	4.22	5.49
50 % shade × Top of corm	4.03	6.15	4.34
50 % shade× Cormels	5.78	4.39	8.78
50 % shade × Split corm	5.93	2.71	4.93
Open × Top of corm	5.67	6.49	5.49
Open × Cormels	6.46	10.76	9.21
Open × Split corm	10.59	9.13	6.82
SEm±	0.41	0.38	0.44
CD (0.05)	1.54	1.66	1.64

Significant interaction was noted between shade and planting materials at 60, 90, and 120 DAP (Table 11 a.). At 60 DAP, combination of open and split corm resulted in maximum specific leaf density, while at 90 DAP, combination of open and cormels, produced higher specific leaf density on par with open in combination with split corm. At 120 DAP, higher specific leaf density was in the combination of cormels with open which was on par with cormels and 50 per cent shade.

4.1.9. Lifespan of leaves

At all the stages, leaf lifespan was affected by shade levels and the data are given in Table 12. Under shade, the lifespan of leaves was more compared to open condition. In shade, at different growth stages, lifespan of leaves varied from 76-81 days, while in open condition the lifespan was about 68 days.

Planting materials produced no significant effect on leaf lifespan. In addition, no significant interaction was noticed between shade and planting material in terms of leaf lifespan at any of the stages.

4.1.10. Chlorophyll content

The data pertaining to chlorophyll 'a' and 'b' content of leaves are shown in Table 13 and 14 respectively. Chlorophyll 'a' and 'b' contents were recorded at 60, 90, 120, and 150 DAP. At all the growth stages, shade significantly affected chlorophyll 'a' and 'b' content of leaves. At 60 DAP and 90 DAP, both chlorophyll 'a' and 'b' content were higher in 50 per cent shade on par with 25 per cent shade.

At 120 DAP, maximum content of chlorophyll 'a' and 'b' was obtained from plants grown under 25 per cent shade on par with 50 per cent shade. At 150 DAP, chlorophyll 'a' content was higher in 25 per cent shade and chlorophyll 'b' content was higher at 50 per cent and, on par with 50 per cent and 25 per cent shade respectively. Under open condition, at all the growth stages, chlorophyll 'a' content was lower than shaded plants.

Planting materials influenced chlorophyll 'a' content only at 90 DAP. At 90 DAP, planting with cormels produced maximum chlorophyll 'a' content.

Table 12. Effect of shade levels and planting materials on leaf lifespan

Treatment	Leaf lifespan (days)
Shade levels	
25 per cent	76.44
50 per cent	80.89
Open	67.78
SEm±	1.94
CD (0.05)	7.83
Planting materials	
Top of corm	73.44
Cormels	75.11
Split corm	76.56
SEm±	0.97
CD (0.05)	NS

While chlorophyll 'b' content was significant at all stages except 150 DAP Table 14. At 60 DAP, chlorophyll 'b' content was significantly high when top of corm was used as planting material; at 90 and 120 DAP, higher chlorophyll 'b' content was noted in planting with cormels.

Significant interaction was noticed between main plots and sub plots with regard to chlorophyll 'a' at 90, 120 and 150 DAP (Table 13 a.). At 90 DAP, cormel planting in 50 per cent shade produced higher chlorophyll 'a' content on par with cormels combined with 25 per cent shade. At 120 DAP, cormels combined with 50 per cent shade recorded the maximum chlorophyll 'a' content on par with 25 per cent shade in combination with both cormels and split corm. At 150 DAP, planting of cormels under 50 percent shade, top of corm and split corm in combination with 25 per cent shade and top of corm under 50 per cent shade recorded the highest chlorophyll 'a' content.

Chlorophyll 'b' content was found to be significant at 60, 90, and 120 DAP (Table 14 a.). At 60 DAP, maximum content of chlorophyll 'b' was from 50 per cent shade – top of corm interaction. At 90 and 120 DAP, the combination of cormels and 50 per cent shade, resulted in maximum chlorophyll 'b' content.

Shade significantly affected total chlorophyll content at all the stages and the data are presented in Table 15. At 60 DAP, 50 per cent shade recorded higher total chlorophyll, and at the remaining stages both 50 and 25 percent shade have shown higher values. Planting materials did not affect total chlorophyll at any of the stages. Significant interaction was noted between shade and planting materials on total chlorophyll content at 120 DAP (Table 15 a.). Combination of cormels with 25 and 50 per cent shade, top of corm under 50 per cent shade and split corm under 25 per cent shade resulted in higher total chlorophyll content.

Table 13. Effect of shade levels and planting materials on chlorophyll 'a' content

Treatments	Chlorophyll 'a'(mg/g)			
	60 DAP	90 DAP	120 DAP	150 DAP
Shade levels				
25 per cent	1.43	1.55	1.64	1.38
50 per cent	1.47	1.59	1.60	1.35
Open	1.11	1.10	1.13	0.97
SEm±	0.03	0.05	0.05	0.02
CD (0.05)	0.13	0.19	0.19	0.09
Planting materials				
Top of corm	1.33	1.32	1.43	1.28
Cormels	1.30	1.55	1.53	1.24
Split corm	1.38	1.37	1.41	1.18
SEm±	0.05	0.06	0.04	0.03
CD (0.05)	NS	0.18	NS	NS

Table 13 a. Interaction effect of shade levels and planting materials on chlorophyll 'a' content

Treatments (Shade levels× Planting materials)	Chlorophyll 'a' (mg/g)		
	90 DAP	120 DAP	150 DAP
25 % shade × Top of corm	1.38	1.51	1.49
25 % shade × Cormels	1.75	1.72	1.30
25 % shade × Split corm	1.52	1.67	1.35
50 % shade × Top of corm	1.52	1.46	1.33
50 % shade× Cormels	1.91	1.81	1.49
50 % shade × Split corm	1.35	1.54	1.24
Open × Top of corm	1.04	1.31	1.03
Open × Cormels	1.00	1.05	0.94
Open × Split corm	1.25	1.01	0.94
SEm±	0.08	0.08	0.04
CD (0.05)	0.34	0.22	0.17

Table 14. Effect of shade levels and planting materials on chlorophyll 'b' content

Treatments	Chlorophyll 'b' (mg/g)			
	60 DAP	**90 DAP**	**120 DAP**	**150 DAP**
Shade levels				
25 per cent	0.34	0.31	0.41	0.34
50 per cent	0.39	0.32	0.40	0.36
Open	0.28	0.17	0.27	0.26
SEm±	0.02	0.01	0.01	0.01
CD (0.05)	0.09	0.03	0.05	0.03
Planting materials				
Top of corm	0.38	0.23	0.35	0.33
Cormels	0.32	0.33	0.39	0.32
Split corm	0.31	0.25	0.34	0.32
SEm±	0.01	0.01	0.01	0.01
CD (0.05)	0.04	0.03	0.03	NS

Table 14 a. Interaction effect of shade levels and planting materials on chlorophyll 'b' content

Treatments (Shade levels× Planting materials)	Chlorophyll 'b' (mg/g)		
	60 DAP	90 DAP	120 DAP
25 % shade × Top of corm	0.36	0.29	0.38
25 % shade × Cormels	0.35	0.36	0.43
25 % shade × Split corm	0.31	0.28	0.41
50 % shade × Top of corm	0.48	0.26	0.37
50 % shade× Cormels	0.36	0.47	0.48
50 % shade × Split corm	0.33	0.23	0.33
Open × Top of corm	0.30	0.14	0.29
Open × Cormels	0.25	0.15	0.25
Open × Split corm	0.29	0.24	0.27
SEm±	0.04	0.01	0.02
CD (0.05)	0.07	0.05	0.06

Table 15. Effect of shade levels and planting materials on total chlorophyll content

Treatments	Total chlorophyll (mg/g)			
	60 DAP	90 DAP	120 DAP	150 DAP
Shade levels				
25 per cent	1.48	1.69	1.89	1.52
50 per cent	1.70	1.81	1.98	1.60
Open	1.22	1.25	1.34	1.11
SEm±	0.05	0.10	0.11	0.05
CD (0.05)	0.21	0.39	0.44	0.20
Planting materials				
Top of corm	1.54	1.51	1.69	1.43
Cormels	1.40	1.75	1.81	1.40
Split corm	1.47	1.48	1.71	1.40
SEm±	0.11	0.10	0.06	0.07
CD (0.05)	NS	NS	NS	NS

Table 15 a. Interaction effect of shade levels and planting material on total chlorophyll content at 120 DAP

Shade levels \ Planting materials	Total chlorophyll (mg/g)		
	Top of corm	Cormels	Split corm
25 % shade	1.70	1.92	2.05
50 % shade	1.94	2.23	1.77
Open	1.42	1.29	1.30
SEm±	0.19		
CD (0.05)	0.36		

4.2. Observations after harvest

4.2.1. Corm fresh weight

The data on individual corm fresh weight are presented in Table 16. Shade produced significant effect on corm fresh weight. Fresh weight of individual corms ranged from 452.17 g to 658.91 g. Maximum corm fresh weight was noticed in 50 per cent shade on par with 25 per cent shade.

Planting with top of corm was the best treatment in terms of corm yield, followed by planting with cormels on par with split corm.

Among the treatment combinations (Table 16 a.), maximum fresh weight was recorded in top of corm with 50 per cent shade on par with top of corm under open condition.

4.2.2. Dry weight of corm

The effect of treatments on corm dry weight are presented in Table 16. Among different shade levels, 50 per cent shade recorded the maximum corm dry weight (115.56 g) at harvest. Corm dry weight of open condition (95.21 g) and 25 per cent shade (91.59 g) were on par to each other.

Planting materials significantly affected corm dry weight at harvest. The highest dry weight was observed when top of corm was used as planting material (119.82 g), followed by split corm (98.41 g) and cormels (84.12 g).

Combined effect of shade and planting material was significant with respect to corm dry weight (Table 16 a.). Maximum corm dry weight (143.91 g) was from 50 per cent shade in combination with top of corm as planting material.

4 .2.3. Corm yield

The data regarding corm yield are shown in Table 16. Corm yield followed the same trend as corm fresh weight. The highest corm yield was noticed in 50 per cent shade (6.80 t/ha) followed by 25 per cent shade (6.42 t/ha).

Among the subplot treatments, planting of top of corm resulted in maximum corm yield (8.13 t/ha) which was significantly superior to other planting materials used.

Table 16. Effect of shade levels and planting materials on corm fresh weight, dry weight and yield

Treatments	Corm fresh weight (g)	Corm dry weight (g)	Corm yield (t/ha)
Shade levels			
25 per cent	519.91	91.59	6.42
50 per cent	550.77	115.56	6.80
Open	503.24	95.21	6.21
SEm±	5.27	1.18	0.07
CD (0.05)	21.26	4.77	0.26
Planting materials			
Top of corm	658.91	119.82	8.13
Cormels	462.83	84.12	5.71
Split corm	452.17	98.41	5.58
SEm±	6.10	2.55	0.08
CD (0.05)	18.99	7.94	0.24

Table 16 a. Interaction effect of shade levels and planting materials on corm fresh weight and dry weight

Treatments (Shade levels × Planting materials)	Fresh weight of corm (g)	Dry weight of corm (g)	Corm yield (t/ha)
25% shade × Top of corm	483.97	119.14	5.97
25% shade × Cormels	651.25	70.15	8.04
25% shade × Split corm	424.50	85.48	5.24
50% shade × Top of corm	740.68	143.91	9.14
50% shade× Cormels	454.00	101.99	5.60
50% shade × Split corm	457.63	100.77	5.65
Open × Top of corm	752.08	96.42	9.28
Open × Cormels	283.25	80.23	3.50
Open × Split corm	474.38	108.99	5.86
SEm±	9.13	3.80	0.11
CD (0.05)	35.53	12.14	0.44

Significant interaction was noticed between the shade levels and planting materials used (Table 16 a.). At harvest, maximum corm yield was obtained from top of corm under open (9.28 t/ha) which was on par with top of corm under 50 per cent shade (9.14 t/ha).

4.2.4. Number of cormels

The data on the number of cormels are presented in Table 17. Number of cormels increased with increase in shade intensity. Number of cormels was maximum in 50 per cent shade (10.29) followed by 25 per cent shade (9.61) and open condition (9.36).

Significant differences were noticed among sub plot treatments with regard to cormel numbers (Table 17 a.). Top of corm recorded the maximum number of cormels (10.63) which was on par with split corm (9.67). Between sub plots and main plots no significant interaction was noticed in terms of cormel number.

4.2.5. Length of cormels

The effect of treatments on cormel length are presented in Table 17. Shade levels significantly affected cormel length. Longer cormels (16.83 cm) were from 25 per cent shade followed by 50 per cent shade (14.96 cm).

Planting with split corm produced cormels of maximum length (14.67) which was on par with planting with top of corm (14.46).

Significant interaction was noted in terms of cormel length between main plots and sub plots (Table 17 a.). The combination, 25 per cent shade with top of corm produced maximum cormel length (19.75 cm) and was superior to other treatment combinations. Twenty five percent shade combined with top of corm planting (18.13 cm) was the next best treatment combination with regard to cormel length.

4.2.6. Girth of cormels

The data on girth of cormels are presented in Table 17. Among the main plot treatments, maximum girth was observed in 50 per cent shade (16.95 cm) on par with 25 per cent shade (15.19 cm).

Table 17. Effect of shade levels and planting materials on number, length, and girth of cormels at harvest

Treatments	Number of cormels	Length of cormels (cm)	Girth of cormels (cm)
Shade levels			
25 per cent	9.61	16.83	15.19
50 per cent	10.29	14.96	16.95
Open	9.36	9.32	13.19
SEm±	0.17	0.33	0.39
CD (0.05)	0.68	1.34	1.83
Planting materials			
Top of corm	10.63	14.46	15.22
Cormels	8.96	11.99	14.16
Split corm	9.67	14.67	15.95
SEm±	0.21	0.24	0.24
CD (0.05)	0.66	0.75	0.74

Table 17 a. Interaction effect of shade levels and planting materials on length and girth of cormels

Treatments (Shade levels× Planting materials)	Length of cormels (cm)	Girth of cormels (cm)
25% shade × Top of corm	19.75	16.47
25% shade × Cormels	12.62	12.23
25% shade × Split corm	18.13	16.97
50% shade × Top of corm	16.50	16.48
50% shade× Cormels	11.89	16.82
50% shade × Split corm	16.50	17.55
Open × Top of corm	7.13	13.58
Open × Cormels	11.47	12.65
Open × Split corm	9.37	11.87
SEm±	0.58	0.08
CD (0.05)	1.49	2.50

The lowest girth was observed in cormels produced in open plots (13.19 cm).

The highest cormel girth was obtained in planting with split corm (15.95 cm) which was on par with planting with top of corm (15.22 cm).

Significant interaction was noted between various shade levels and planting materials (Table 17 a.). The highest girth was observed in split corm in 50 per cent shade, which was on par with split corm and 25 per cent shade, cormels under 50 per cent shade, top of corm under 50 per cent and 25 per cent shade.

4.2.7. Fresh weight of cormels

The data on cormel fresh weight are presented in Table 18. Shade significantly influenced individual fresh weight of cormels at harvest. Fresh weight of cormels was noted maximum for 25 per cent shade (108.26 g/cormel), on par with that of 50 per cent shade (103.61 g/cormel).

Among different planting materials, top of corm (103.58 g/cormel) and split corm (97.17 g/cormel) recorded the highest fresh weight per cormel.

Significant interaction was observed between main plot and sub plot treatments (Table 18 a.). The highest cormel fresh weight was noted in the combinations of 25 per cent shade with top of corm (114.66 g/cormel), cormels (105.45 g/cormel) and split corm (104.68 g/cormel) and combinations of 50 per cent shade with top of corm (109.58 g/cormel) and split corm (105.72 g/cormel).

4.2.8. Dry weight of cormels

The data on the effect of treatments on cormel dry weight are given in Table 18. Individual dry weight of cormel was the highest in 25 per cent shaded plots (64 g/cormel), on par with 50 per cent shade (60.74 g/cormel).

Planting materials produced no significant difference in individual cormel dry weight.

Significant interaction was noted between various treatment combinations (Table 18 a.) and the highest cormel dry weight was noted in combination of 25 per cent shade with top of corm (69.45 g/cormel) and with split corm (67.47 g/cormel) on par with combination of 50 per cent shade and split corm (69.22 g/cormel).

4.2.9. Cormel yield

Cormels are the most important economic part from tannia. The influence of treatments on cormel yield are presented in Table 18. The highest cormel yield was noticed in plots provided with 50 per cent shade (13.47 t/ha) and 25 per cent shade condition (12.66 t/ha). Yield from unshaded plots were (8.38 t/ha) significantly lower. Among the different planting materials, top of corm produced maximum yield (13.59 t/ha), followed by split corm (11.40 t/ha). The lowest yield was reported in cormel planting (9.51 t/ha).

Significant interaction between shade levels and planting material was found in cormel yield (Table 18 a.). Planting of top of corm under 50 per cent shade resulted in maximum cormel yield (14.85 t/ha) on par with planting of top of corm at 25 per cent shade (14.83 t/ha) and 50 per cent shade with split corm (13.71 t/ha). Among all the combinations, the lowest yield was from planting of cormels under open condition (4.47 t/ha).

4.2.10. Shoot: storage organ ratio

The data on shoot: storage organ ratio are presented in Table 19. Among the shaded treatments open condition recorded the lowest shoot: storage organ ratio (0.11) and 50 per cent shade recorded the highest value (0.21)

Among different planting materials, maximum ratio was noticed with cormel (0.18), followed by split corm and top of corm.

Shade and planting material combination significantly influenced shoot: storage organ ratio in plants (Table 19 a.). The lowest ratio was obtained when top of corm was planted under open condition (0.07) which was on par with open and split corm (0.08), 25 per cent shade and top of corm (0.12).

Table 18. Effect of shade levels and planting materials on cormel fresh weight, cormel dry weight and yield

Treatments	Fresh weight of cormels (g/cormel)	Dry weight of cormels (g/cormel)	Cormel yield (t/ha)
Shade levels			
25 per cent	108.26	64.00	12.66
50 per cent	103.61	60.74	13.47
Open	70.68	39.27	8.38
SEm±	2.38	0.96	0.20
CD (0.05)	9.60	3.85	0.82
Planting materials			
Top of corm	103.58	54.11	13.59
Cormels	81.80	54.30	9.51
Split corm	97.17	55.60	11.40
SEm±	2.52	1.32	0.37
CD (0.05)	7.86	NS	1.14

Table 18 a. Interaction effect of different shade levels and planting materials on cormel fresh weight, dry weight and yield

Treatments (Shade levels× Planting materials)	Cormel fresh weight (g/cormel)	Cormel dry weight (g/cormel)	Cormel yield (t/ha)
25% shade × Top of corm	114.66	69.45	14.83
25% shade × Cormels	105.45	55.08	12.22
25% shade × Split corm	104.68	67.47	10.93
50% shade × Top of corm	109.58	50.97	14.85
50% shade × Cormels	95.52	62.03	11.85
50% shade × Split corm	105.72	69.22	13.71
Open × Top of corm	86.51	41.89	11.10
Open × Cormels	44.43	45.80	4.47
Open × Split corm	81.11	30.11	9.57
SEm±	4.13	2.96	0.56
CD (0.05)	14.85	6.92	1.8

4.2.11. Corm: cormel ratio

The data on corm: cormel ratio are presented in Table 19. Corm: cormel ratio decreased with increase in shade levels. A higher corm: cormel ratio indicates among the total storage organ, cormel portion is more over corm portion. Lowest corm: cormel ratio was noted with 50 per cent shade (0.48) and the highest under open (0.90).

Planting with cormels and split corm were on par to each other and recorded the lowest value (0.60 and 0.63 respectively).

Interaction effect of shade and planting material significantly affected corm: cormel ratio (Table 19 a.). Lower values were noted in the combination of split corm with 50 per cent shade (0.35) and 25 per cent shade (0.39) and cormels under 50 per cent shade.

4.3. Plant analysis

4.3.1. Crude protein content of corms

The influence of shade and planting materials on crude protein content of corms is given in Table 20. Corm protein content varied significantly with shade levels. Higher protein content was observed from open conditions (8.57 %). Corm protein content of 50 per cent shade and 25 per cent shade was on par.

Planting materials were also found influencing the protein content in corms. Planting material with split corm recorded the highest protein content (8.14 %) and was superior to others. Lower corm protein content was seen in top of corm which was on par with protein content of cormels.

Interaction effect of shade and planting material was significant (Table 20 a.). Maximum protein content in all the treatments was reported in split corm and open combination (9.84 %) which was on par with open and cormel interaction (9.30 %).

Table 19. Effect of shade levels and planting materials on shoot: storage organ and corm: cormel ratios at harvest

Treatments	Shoot: storage organ ratio	Corm: cormel ratio
Shade levels		
25 per cent	0.14	0.60
50 per cent	0.21	0.48
Open	0.11	0.90
SEm±	0.02	0.02
CD (0.05)	0.06	0.10
Planting materials		
Top of corm	0.11	0.75
Cormels	0.18	0.60
Split corm	0.17	0.63
SEm±	0.01	0.03
CD (0.05)	0.04	0.09

Table 19 a. Interaction effect of shade levels and planting materials on shoot: storage organ and corm: cormel ratios at harvest

Treatments (Shade levels× Planting materials)	Shoot: storage organ ratio	Corm: cormel ratio
25% shade × Top of corm	0.12	0.79
25% shade × Cormels	0.15	0.57
25% shade × Split corm	0.17	0.39
50% shade × Top of corm	0.15	0.57
50% shade× Cormels	0.22	0.47
50% shade × Split corm	0.26	0.35
Open × Top of corm	0.07	0.77
Open × Cormels	0.19	0.69
Open × Split corm	0.08	1.06
SEm±	0.03	0.06
CD (0.05)	0.07	0.18

4.3.2. Crude protein content of cormels

The effect of shade and planting materials on crude protein content of cormels is given in Table 20. Shade produced no significant difference in crude protein content of cormels. Crude protein content of cormels ranged from 2.19 to 4.92 per cent. In general, crude protein content was lower in cormels compared to corms. Crude protein content of corms raged from 5.47 to 9.30 per cent.

Significant variation was seen in crude protein content of cormels among various planting materials used. Planting with split corm produced the highest cormel protein content (4.38 %), followed by cormels on par with top of corm.

Interaction between shade and planting material influenced cormel protein content significantly (Table 20 a.). Among the combinations, split corm under open condition resulted in maximum protein content of cormels (4.92 %) on par with top of corm under 25 per cent shade (4.65 %), cormels under 50 per cent shade (4.38 %) and split corm under 25 per cent shade (4.38 %).

4.3.3. Starch content of corms

The data on starch content of corms are presented in Table 21. The effect of different shade levels on starch content of corms was significant. Starch content of corms at harvest was maximum in 50 per cent shade (56.61 %) on par with starch content of unshaded plots (55.92 %).

Regarding planting materials, planting with top of corm (56.98 %) recorded the highest corm starch content among different planting materials.

Significant interaction was noted between main plot and subplot treatments in case of corm starch content (Table 21 a). Higher starch content of corms were reported in the combination of open condition with top of corm (57.72 %) and split corm (56.02 %), 50 per cent shade with top of corm (56.98 %), cormel (56.25 %) and split corm (56.61 %) and 25 per cent shade with top of corm (56.26 %).

Table 20. Effect of shade levels and planting materials on crude protein content of corm and cormels

Treatments	Crude protein content (%)	
	Corms	Cormels
Shade levels		
25 per cent	6.20	4.19
50 per cent	6.61	3.47
Open	8.57	3.95
SEm±	0.13	0.15
CD (0.05)	0.53	NS
Planting materials		
Top of corm	6.24	3.50
Cormels	6.99	3.74
Split corm	8.14	4.38
SEm±	0.22	0.10
CD (0.05)	0.68	0.31

Table 20 a. Interaction effect of shade levels and planting materials on crude protein content of corm and cormels (%)

Treatments (Shade levels× Planting materials)	Crude protein content (%)	
	Corm	Cormels
25% shade × Top of corm	6.56	4.65
25% shade × Cormels	5.47	3.55
25% shade × Split corm	6.56	4.38
50% shade × Top of corm	5.61	2.19
50% shade× Cormels	6.20	4.38
50% shade × Split corm	8.02	3.83
Open × Top of corm	6.56	3.65
Open × Cormels	9.30	3.28
Open × Split corm	9.84	4.92
SEm±	0.23	0.27
CD (0.05)	1.23	0.61

4.3.4. Starch content of cormels

The data on starch content of cormels are presented in Table 21. The highest starch content was recorded in 50 per cent shade (64.64 %) on par with 25 per cent shade (63.14 %). The lowest starch content among the three shades was noticed in open condition.

Starch content of cormels ranged from 57.5 to 68.32 per cent. In general, starch content of cormels was higher than that of corms (47.44 to 57.72 %).

Among the different type of planting materials used, planting with top of corm (65.07 %) resulted in higher starch content in cormels.

Combination of shade and planting material significantly affected starch content of cormels (Table 21 a.). Higher starch content of cormels was observed in planting with top of corm under 50 per cent shade (68.32 %), and planting of split corm (66.23 %) and top of corm (64.29 %) under 25 per cent shade.

4.3.5. Oxalate content of cormels and corms

The data regarding oxalate content is given in Table 22. No significant differences were noticed on oxalate content of cormels and corms due to the treatments. Oxalate content of corms were slightly higher than cormels. Oxalate content in corms ranged from 0.15 to 0.16 g/100 g and that of cormels from 0.12 to 0.15 g/100 g. However, shade levels and planting materials did not affect the content.

4.4. Soil analysis

4.4.1. Soil pH

The data on soil pH after the experiment is given in Table 23. Soil pH decreased after cultivation compared to the initial value. Soil pH before the experiment was 4.65. However, various the treatments produced no significant effect on soil pH. It ranged from 4.38 to 4.55. Interaction was also absent between treatments.

4.4.2. Organic carbon

The data on soil organic carbon content was given in Table 23. Similar to soil pH, soil organic carbon was also not significantly different. However, compared to the initial

Table 21. Effect of shade levels and planting materials on starch content of corms and cormels

Treatments	Starch content (%)	
	Corm	Cormels
Shade levels		
25 per cent	52.43	62.69
50 per cent	56.61	63.96
Open	55.92	59.71
SEm±	0.49	0.61
CD (0.05)	1.97	2.46
Planting materials		
Top of corm	56.98	65.07
Cormels	52.75	59.55
Split corm	55.41	61.74
SEm±	0.38	0.83
CD (0.05)	1.20	2.57

Table 21 a. Interaction effect of shade levels and planting materials on corm and cormel starch content

Treatments (Shade levels× Planting materials)	Starch content (%)	
	Corm	Cormels
25% shade × Top of corm	56.26	64.29
25% shade × Cormels	47.44	57.54
25% shade × Split corm	53.60	66.23
50% shade × Top of corm	56.98	68.32
50% shade× Cormels	56.25	63.39
50% shade × Split corm	56.61	60.19
Open × Top of corm	57.72	62.60
Open × Cormels	54.01	57.72
Open × Split corm	56.02	58.81
SEm±	0.85	1.23
CD (0.05)	2.33	4.36

Table 22. Effect of shade levels and planting materials on oxalate content of corm and cormels after harvest

Treatments	Oxalate content (g/100 g)	
	Corm	Cormels
Shade levels		
25 per cent	0.15	0.12
50 per cent	0.16	0.13
Open	0.15	0.15
SEm±	0.005	0.009
CD (0.05)	NS	NS
Planting materials		
Top of corm	0.15	0.12
Cormels	0.15	0.14
Split corm	0.15	0.13
SEm±	0.011	0.007
CD (0.05)	NS	NS

value soil organic carbon (1.13 %), the content increased after cultivation (1.05 to 1.40 %).

The main plot and subplot interaction was significant. Among the combinations, maximum organic carbon content was observed in planting of top of corm in 50 per cent shade, on par with planting of cormels in 50 per cent shade (Table 23 a.).

4.4.3. Available N, P, and K

Compared to the initial values of available soil N, P, and K, their values increased after the harvest and the data are represented in Table 23. Among the different shade levels, available N after harvest was higher in 25 per cent shaded plots. Available nitrogen content in open plots were on par with 25 per cent shade and 50 per cent shade.

Available soil nitrogen left behind after harvest was maximum with cormels, followed by planting with split corm and top of corm which was on par. Interaction between shade and planting material was absent.

Shade levels produced significant effect on soil available P and K content after harvest Table 23. Higher available soil P content was observed in open condition on par with 50 per cent shade. Planting material produced no significant effect on soil available P after harvest.

In open conditions, available soil K was maximum (Table 23), followed by 50 per cent shade and 25 per cent shade. Planting materials produced no significant effect on soil available K. Interaction was also not significant.

4.5. Pest and disease incidence

No serious pest or disease incidence was observed in the crop.

Table 23. Effect of shade levels and planting materials on soil pH, organic carbon, available N, P, and K after harvest

Treatments	Soil pH	Soil organic carbon (%)	Available soil N (kg/ha)	Available soil P (kg/ha)	Available soil K (kg/ha)
Shade levels					
25 per cent	4.47	1.21	262.67	15.31	280.62
50 per cent	4.43	1.32	242.64	18.31	324.18
Open	4.54	1.28	251.84	21.01	575.36
SEm±	0.04	0.02	3.62	0.77	7.88
CD (0.05)	NS	NS	14.61	3.10	31.78
Planting materials					
Top of corm	4.38	1.25	241.93	17.12	398.00
Cormels	4.52	1.30	266.22	19.72	385.32
Split corm	4.55	1.26	249.01	17.82	396.85
SEm±	0.07	0.01	2.95	1.21	12.02
CD (0.05)	NS	NS	9.19	NS	NS
Pre experiment	4.65	1.13	189.00	10.08	259.84

Table 23 a. Interaction effect of shade levels and planting materials on soil organic carbon

Shade levels \ Planting materials	Soil organic carbon (%)		
	Top of corm	Cormels	Split corm
25% shade	1.05	1.31	1.27
50% shade	1.40	1.35	1.21
Open	1.31	1.23	1.30
SEm±	0.04		
CD (0.05)	0.08		

4.6. Economic analysis of treatments

The data related to economic analysis are presented in Table 24. In terms of gross returns, 50 per cent shaded condition produced maximum returns, followed by 25 per cent shade. Among the three planting materials, top of corm produced maximum returns in all the shade levels.

The highest B: C ratio was obtained from combination of 50 per cent shade with top of corm (4.86), followed by 25 per cent shade and top of corm (4.45). The lowest B: C ratio was noted in cormel planting under open condition (1.32).

Table 24. Economic analysis of treatments

Treatments	Total cost (Rs./ha)	Gross return (Rs./ha)	B:C ratio
25 percent shade			
Top of corm	1,46,591	6,52,946	4.45
Cormels	1,58,933	5,38,530	3.39
Split corm	1,58,936	4,92,005	3.10
50 per cent shade			
Top of corm	1,46,591	7,12,236	4.86
Cormels	1,58,933	5,79,113	3.64
Split corm	1,58,936	5,51,294	3.47
Open			
Top of corm	1,72,091	4,36,844	2.54
Cormels	1,84,433	2,42,967	1.32
Split corm	1,84,436	3,50,682	1.90

*Labour charges (Men- Rs 550/day and women Rs. 450/day)
*Cost of corms – Rs. 10/kg
*Cost of cormels – Rs. 40/kg

Discussion

5. DISCUSSION

An experiment was conducted to assess the performance of different planting materials of tannia (*Xanthosoma sagittifolium* (L.) Schott) under various shade levels. The results obtained from the experiment, presented in the previous chapter, are discussed below.

5.1. Effect of shade levels on growth characters of tannia

The growth characters at different stages of tannia clearly reveled the influence of shade on its growth. In tannia, plant height was measured from the base to tip of the top most leaf. From 60 to 120 DAP, plant height went on increasing but thereafter decreased slightly at 150 DAP (Fig. 2 and Table 5). At all the stages, taller plants were produced in shaded plots and shorter plants in open plots. At 60 DAP, 25 per cent shade and at 90 DAP, 50 per cent shade recorded maximum plant height. At the remaining two stages, 25 per cent shade and 50 per cent shade were on par in terms of plant height. Influence of shade on plant height has been reported by Puspakumari (1989) in tannia under intercropped situation, Prameela (1990) in colocasia and Babu (1993) in ginger.

Petiole length was measured from the base to the point of leaf blade joint. In the case of petiole length also, shaded plots recorded higher values at all the stages except at 60 (Fig. 3 and Table 6). At 90 DAP, petiole length of 50 per cent shade was higher while at 120 and 150 DAP, 50 per cent shade and 25 per cent shade were on par to each other. The presence of shade might have compelled the plant to become taller to receive more light (Roy *et al.*, 2013) which may be the reason for higher petiole length in shade.

Collar girth increased from 60 to 120 DAP, but slightly decreased at 150 DAP (Fig. 4 and Table 7). At 60, 90 and 150 DAP, maximum girth was noted in 50 per cent shade, but at 120 DAP, 25 and 50 per cent shade were on par. Among the three shade levels, the lowest collar girth at all the stages was noted in open condition. This can be attributed to the increased vigor of plants under shade. Similar result was recorded in colocasia by Prameela (1990) under shade.

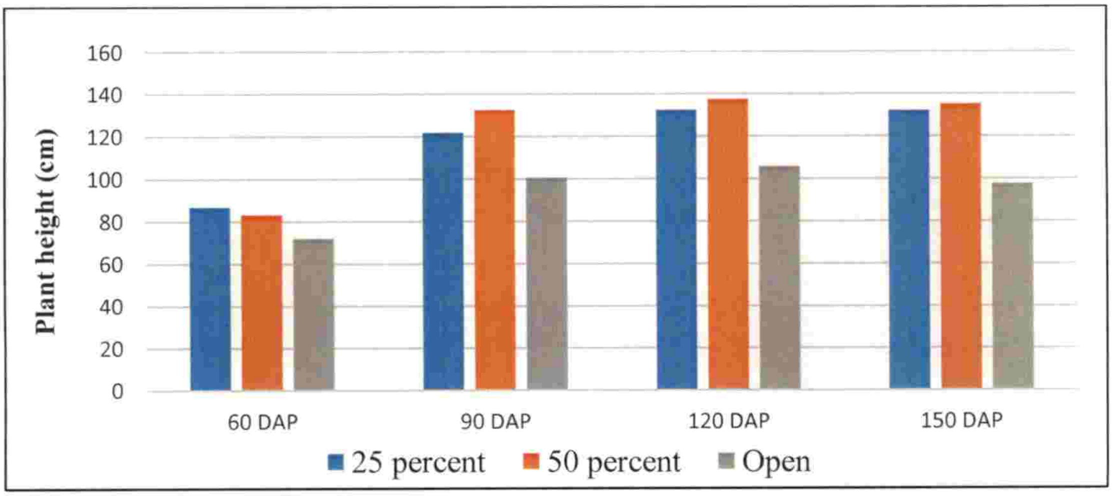

Fig. 2. Effect of shade levels on plant height (cm) at different growth stages

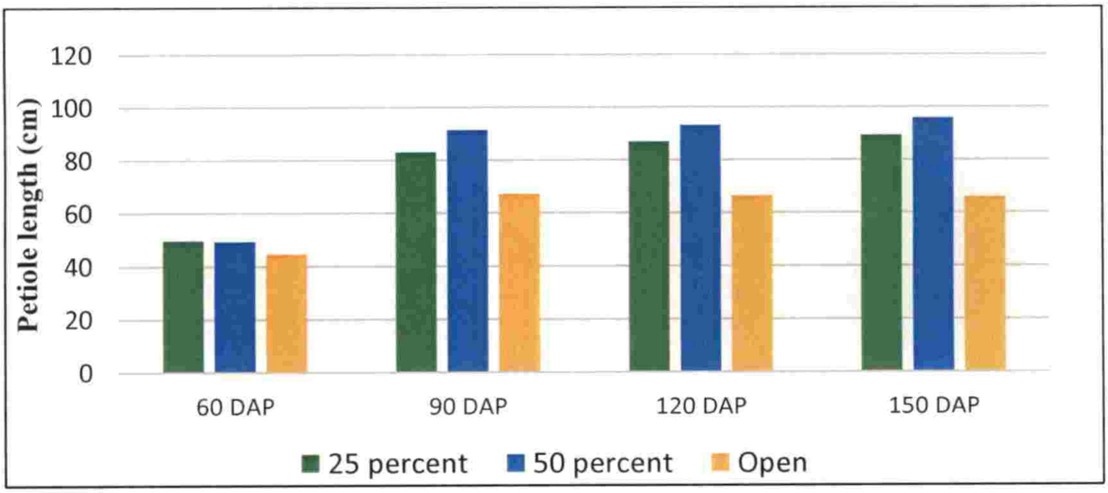

Fig. 3. Effect of shade levels on petiole length (cm) at different growth stages

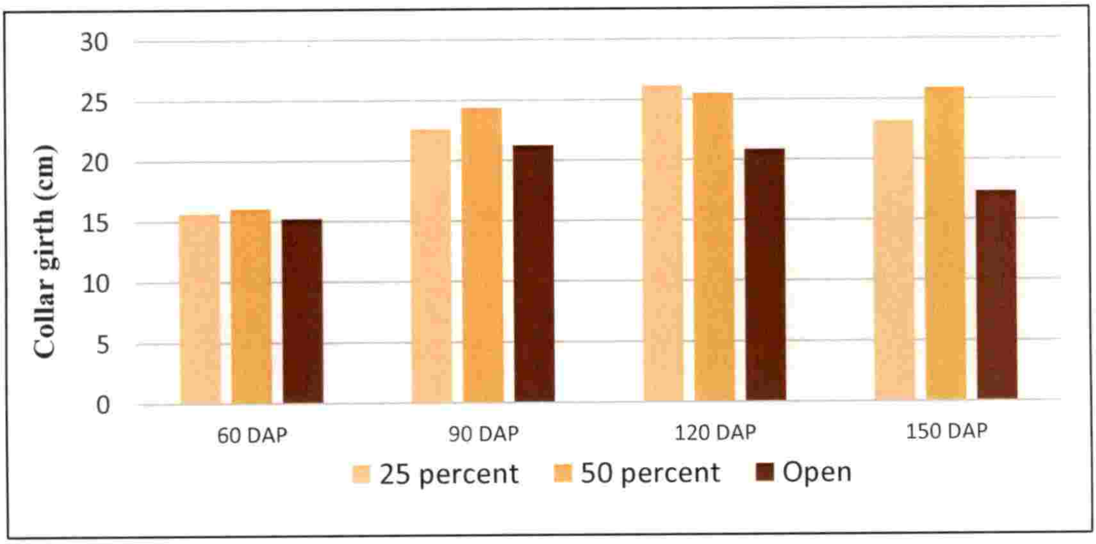

Fig. 4. Effect of shade levels on collar girth (cm) at different growth stages

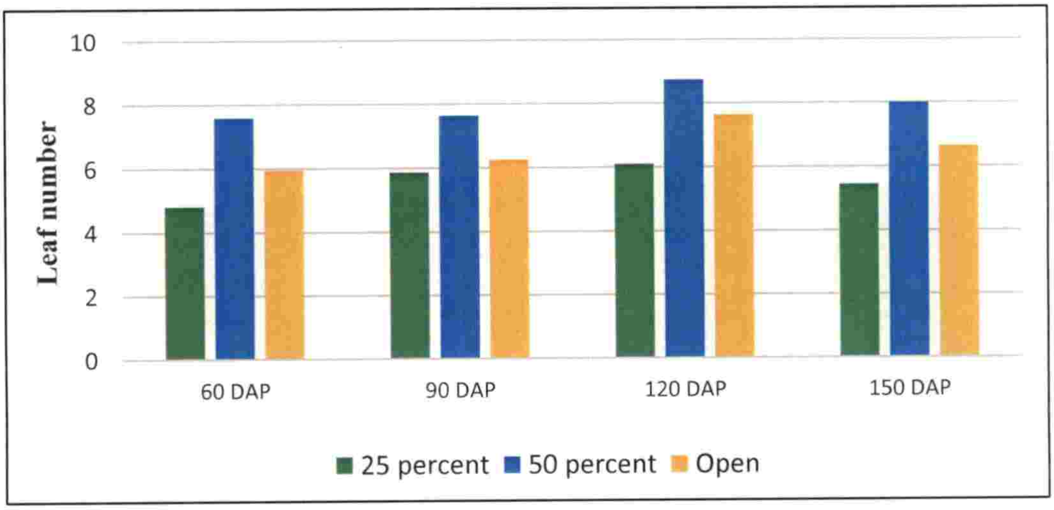

Fig. 5. Effect of shade levels on number of leaves at different growth stages

With regard to leaf number, maximum number of leaves was observed in 50 per cent shade (Fig. 5 and Table 8). As reported by Babu (1993) lower light intensities help in preventing leaf damage by scorching and hence help in retention of more leaf under shade.

Leaf area per plant and LAI were significantly high in 50 per cent shaded plots (Fig. 6; Table 9; Fig. 7; and Table 10). Similar observations were noted by Prameela (1990) in colocasia and Suja (2001) in white yam. High leaf area and LAI under shaded condition might be because of higher sensitivity of leaves of shade loving plants to heavy irradiance which might cause destruction of photosynthetic pigments and tissues in open condition (Srikrishnah and Sutharsan, 2015). Smith (1981) reported that plants would acclimatize to low light levels by producing more photosynthetic surface.

Lifespan of leaves had showed a decreasing trend with the increasing light intensity. The lifespan of leaves was found to be more under shaded condition and less in open condition (Fig. 8 and Table 12). Inaba and Chonan (1984) reported that under full sunlight, leaves of elephant foot yam showed a shorter lifespan than those grown under 50 per cent shade.

Except final stage, at all other stages, specific leaf density was significantly affected by shade. Specific leaf density is the measure of leaf thickness. At all the stages, higher leaf thickness was observed in open condition. In terms of leaf thickness, 25 per cent shade and 50 per cent shade were on par at 60 and 120 DAP (Fig. 9 and Table 11). Middleton (2001) stated that shade loving plants would anatomically adapt to shade by producing thinner leaves with poorly developed palisade tissues. Hence pigments in leaf profile can absorb the available light effectively (Olesinski *et al.*, 1989).

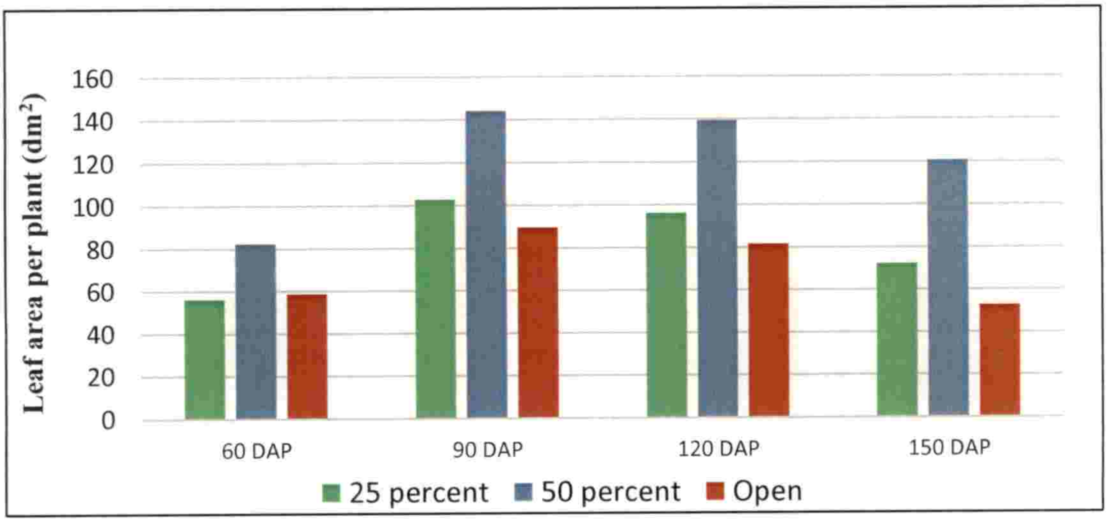

Fig.6. Effect of shade levels on leaf area per plant (dm^2) at different growth stages

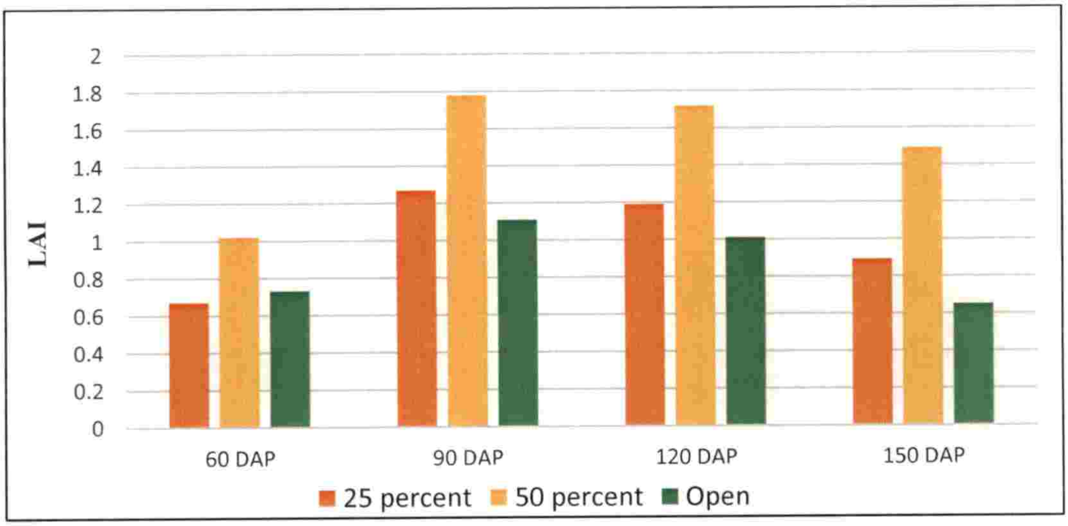

Fig. 7. Effect of shade levels on LAI at different growth stages

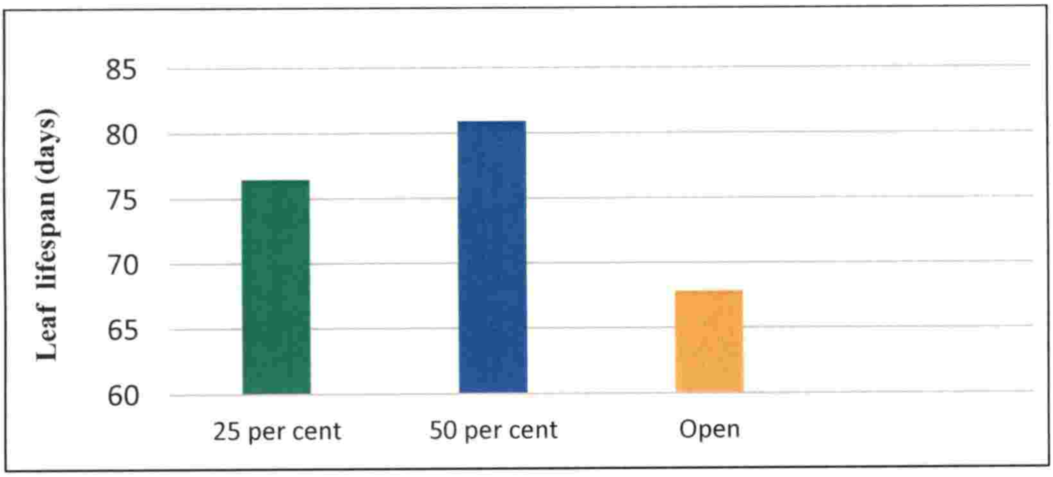

Fig. 8. Effect of shade levels on leaf lifespan of Xanthosoma

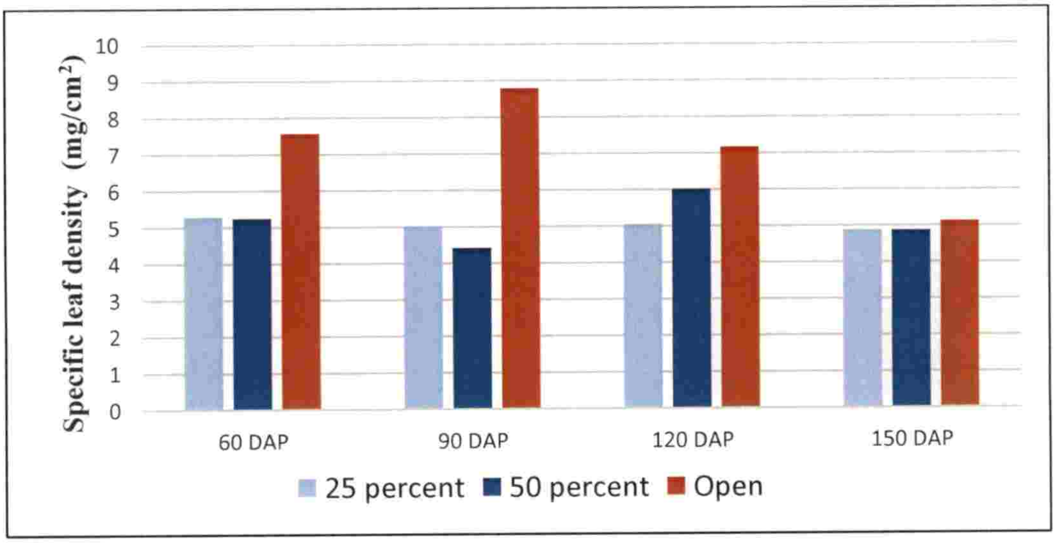

Fig. 9. Effect of shade levels on specific leaf density (mg/cm^2) at different growth stages

Many plants acclimatize photosynthetically to reduced light through phenotypic plasticity and the extent varies for each of the morphological characters (Pierson *et al.*, 1990). Under reduced light, plants have increased plant height, leaf length and leaf width but reduced number of tillers and leaves in order to allow better access to sunlight (Antony, 2016). Gobbi *et al.* (2009) are of the opinion that under reduced light, plants distribute most of their resources for increasing the canopy height aiming at better accessibility to PAR for balancing photosynthesis and respiration.

Chlorophyll 'a' and 'b' contents were high under shade than open (Fig. 10 and Fig. 11). At all the stages 50 per cent shade and 25 per cent shade were on par in terms of chlorophyll 'a' and 'b' contents and lower values were noted in open condition. This is in agreement with the results obtained by Prameela (1990) in colocasia, Babu (1993) in ginger, and Puspakumari (1989) in tannia. Under shaded conditions, an increased chlorophyll content in leaves would help in harnessing the available incident light more effectively (Johnston and Onwueme, 1998).

5. 2. Effect of shade levels on yield characters of tannia

Fresh weight per cormel and dry weight per cormel, from 25 and 50 per cent shade were statistically at par and significantly superior to open (Fig. 12 and Table 18). Number of cormels were high under 50 per cent shade, while cormel length was seen higher in 25 per cent shade (Fig. 13 and Table 17). Shaded plots also resulted in higher cormel girth and yield. Cormel yield from 50 per cent shaded plots were 37 per cent and from 25 per cent shaded plots were 33 per cent higher over open plots (Fig. 14 and Table 18) can be attributed to the higher number of cormels in the case of heavy shaded plots over low shade. Lower values on fresh weight and dry weight of corm and cormels, number, length and breadth of cormels were noticed in open plots.

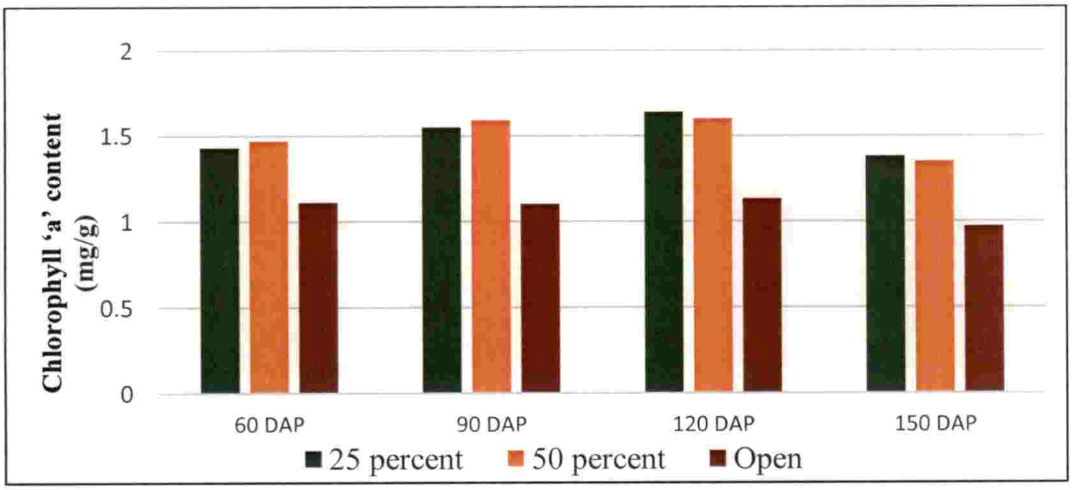

Fig. 10. Effect of shade levels on chlorophyll 'a' content at different growth stages

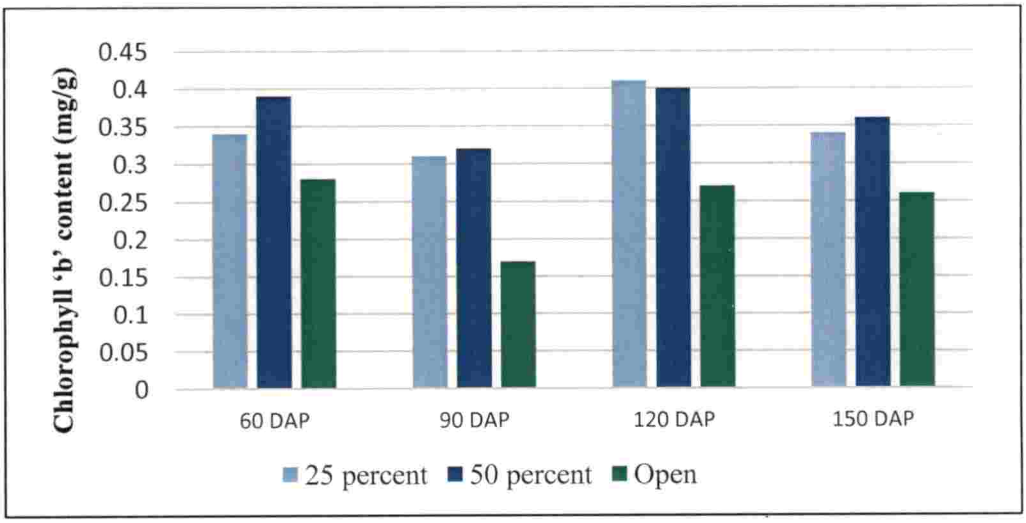

Fig. 11. Effect of shade levels on chlorophyll 'b' content at different growth stages

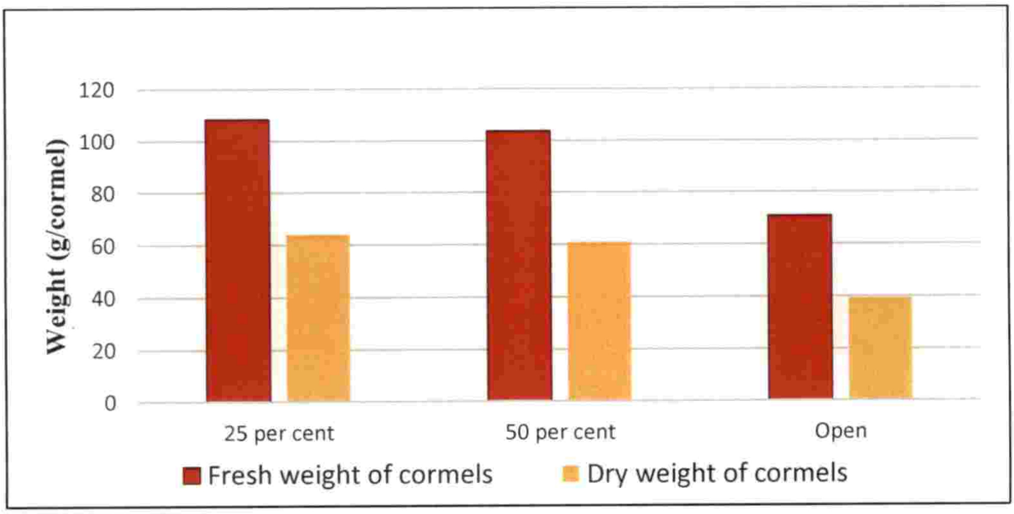

Fig. 12. Effect of shade levels on fresh weight and dry weight per cormel

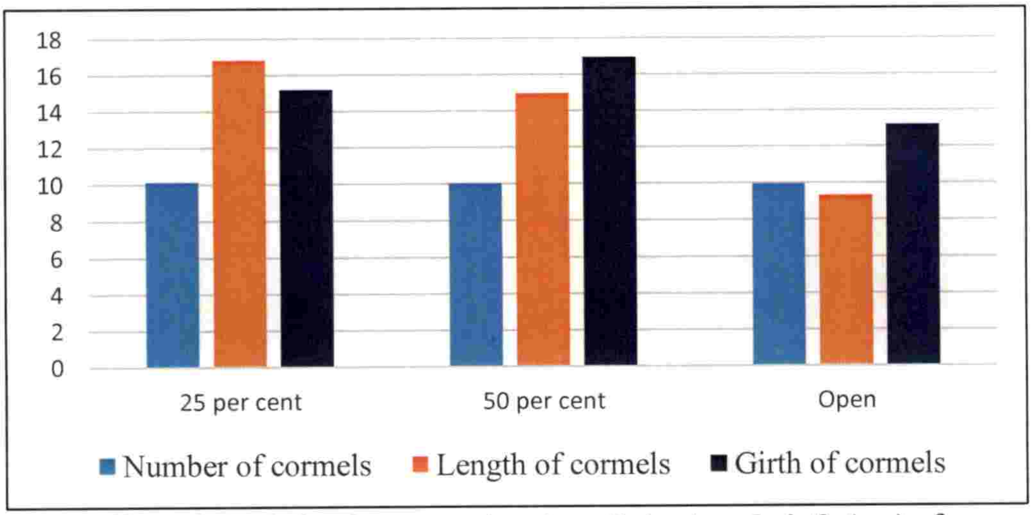

Fig. 13. Effect of shade levels on number, length (cm) and girth (cm) of cormels

Under open condition, small sized tubers of limited number were produced which resulted in low yield in open grown plants. This is in conformity with the findings of Puspakumari (1989) and Valenzuela (1991) in tannia.

Increase in biomass production under shade could be substantiated by high level of chlorophyll content (Sreekala, 1999), increased leaf area, and low leaf temperature (Miura and Oswada, 1981). The reduced cormel length and girth in open plots can be attributed to the reduced moisture and increased soil hardness in open conditions, which might have made the root penetration difficult.

Shoot: storage organ ratio increased with increase in shade levels. A high shoot: storage organ ratio means that the plant would allocate much of its photosynthates for the production of foliage. In the case of tuber crops a low ratio is desirable. The lowest ratio was observed under open condition and highest under 50 per cent shade (Fig. 15 and Table 19). This might be due to greater plant biomass production of shade loving plants under low light intensity.

Corm: cormel ratio was high in open condition (Fig. 15 and Table 19) which can be attributed to the low yield of cormels compared to corm in open condition.

5.3. Effect of shade levels on qualitative characters of tannia

Compared to cormels, crude protein content was more in corms. Higher protein content of corm was recorded in open condition (Fig. 18 and Table 20). Higher crude protein content in the open was reported by Murthy and Sahu (1987) in rice and Bellaloui *et al*. (2012) in soybean. This might be due to the decreased nitrate reductase activity in shaded plants (Ghosh *et al*., 2002).

Starch content of corms was lower than that of cormels, and it was noted that starch content of corms and cormels were higher in plants grown under shade (Fig. 18 and Table 21). The probable reason for higher starch under shade could be the higher

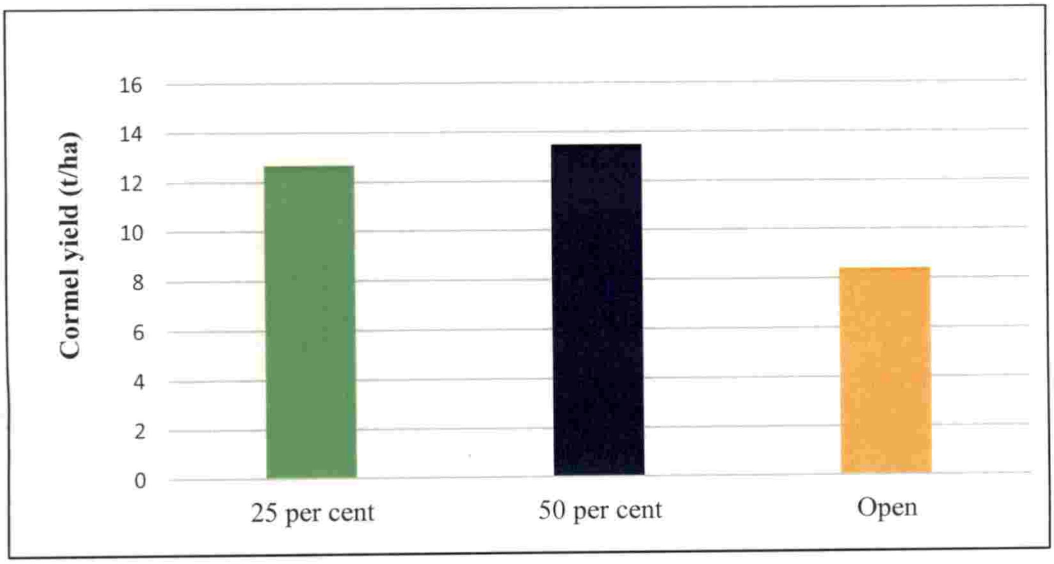

Fig. 14. Effect of shade levels on cormel yield (t/ha)

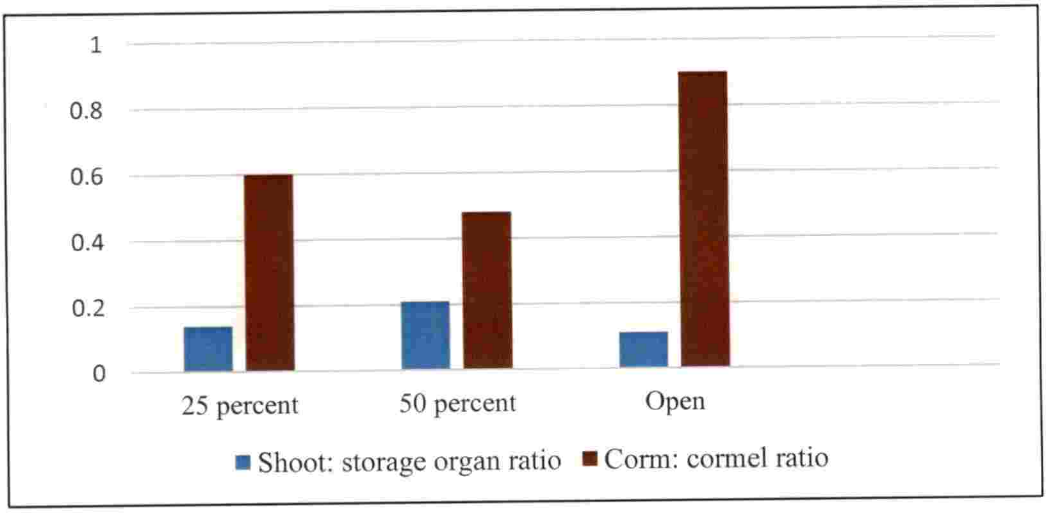

Fig. 15. Effect of shade levels on corm: cormel ratio and shoot: storage organ ratio

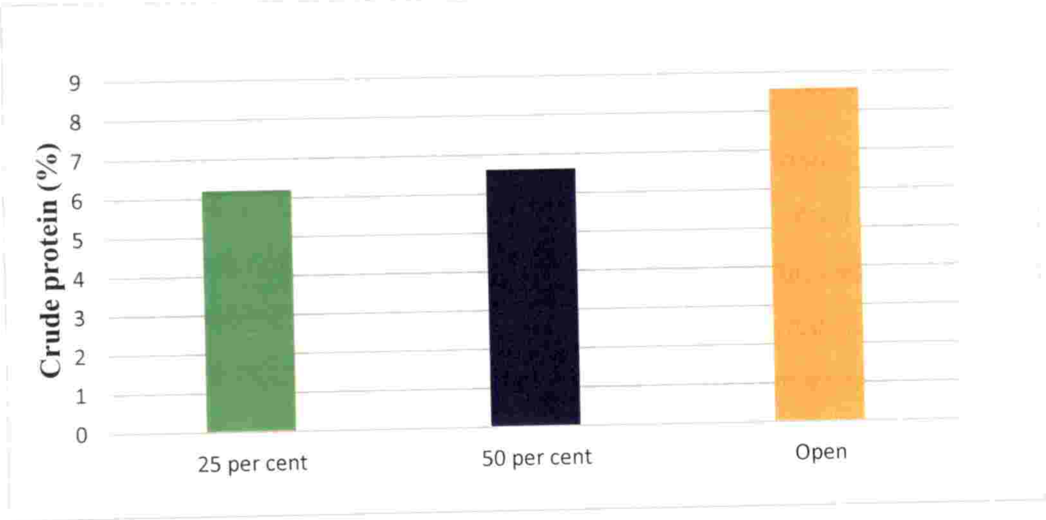

Fig. 16. Effect of shade levels on crude protein content (%) of corms

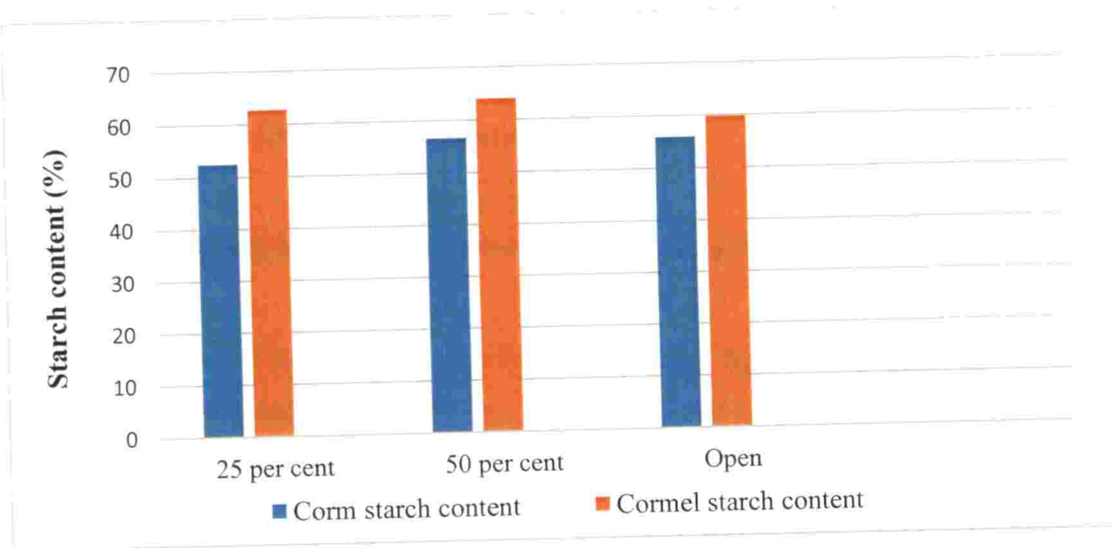

Fig. 17. Effect of shade levels on starch content (%) of corms and cormels

rate of photosynthesis and carbohydrate translocation to economic part by shade loving plants under low irradiance (Susan, 1989).

5.4. Effect of shade levels on soil characters

Shade produced no significant influence on soil pH and organic carbon content. However, compared to initial values, soil pH decreased after cultivation probably because of the addition of acid forming fertilizers. Organic carbon, and available N, P, K content were increased after cultivation. This could be attributed to the addition of organic manures and fertilizers, and that plants could not remove them fully from the soil.

In the case of available nitrogen left behind, maximum amount was observed in 25 per cent shaded plots on par with open condition. Heavy uptake by plants for vegetative growth might be the reason for low nitrogen in 50 per cent shaded plots. Available P and K content after harvest was found to be high in open plots. Significant reduction in potassium content of soil with increase in shade intensity was reported by Anita (2002). This can be substantiated by the observations on low vegetative growth, and yield of tannia under full light conditions.

5.5. Effect of planting materials on growth characters of tannia

The days to emergence was significantly affected by planting materials used (Fig. 18). Top of corms achieved early emergence, followed by cormels. Similar results were reported by Tsedalu *et al.* (2014) in colocasia. According to Osei and Mintah (2003) buds on cormels were more dormant than buds on corms. More days were taken by split corm and Bazel (2006) reported that the cut open edges of corm would invite rotting and might lead to reduced emergence rate and emergence percentage.

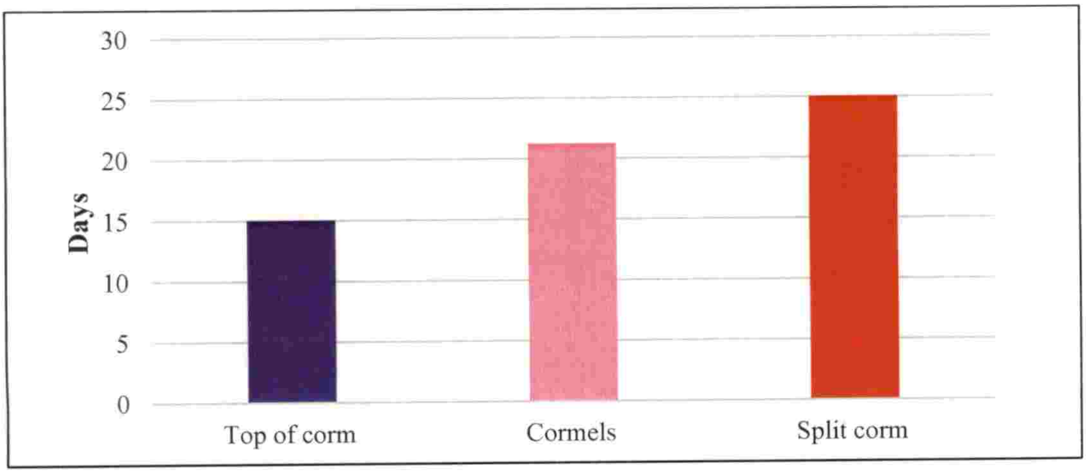

Fig. 18. Effect of planting materials on days to emergence

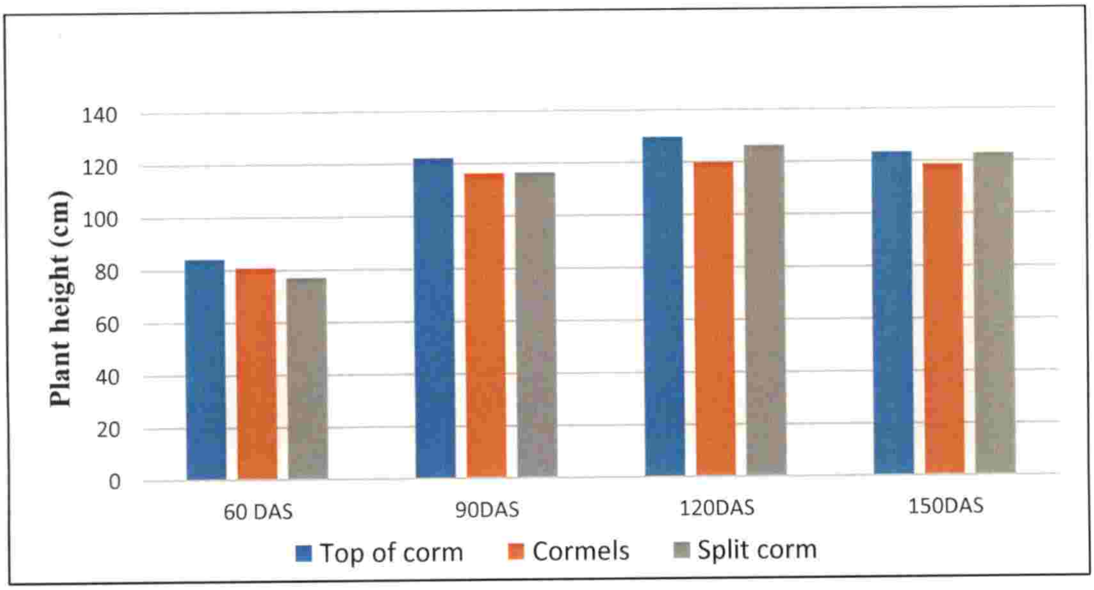

Fig. 19. Effect of planting materials on plant height (cm) at different stages

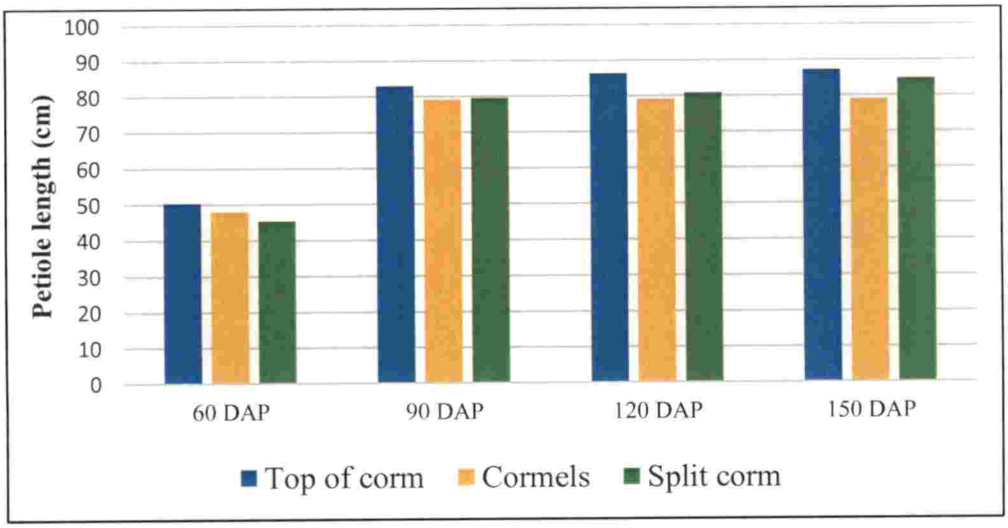

Fig. 20. Effect of planting materials on petiole length (cm) at different stages

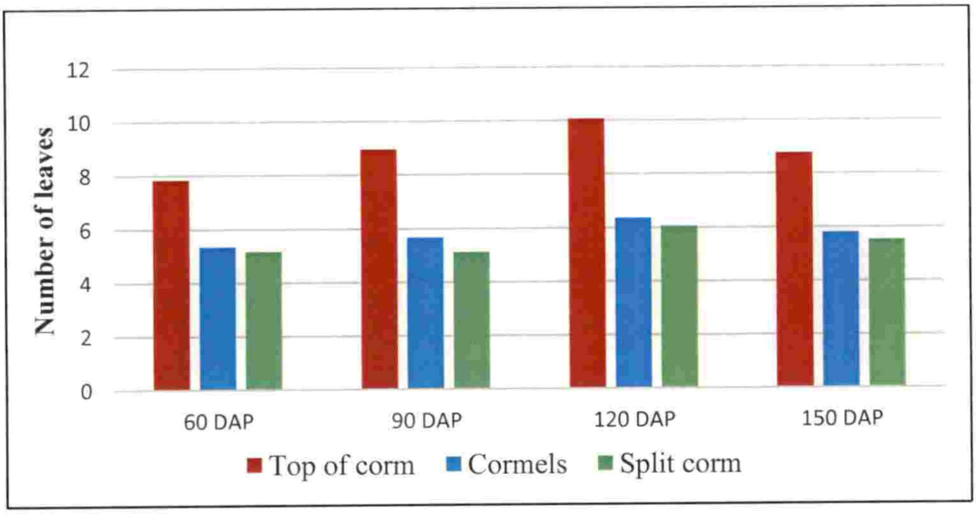

Fig. 21. Effect of planting materials on number of leaves at different stages

Higher plant height (Fig. 19) and petiole length (Fig. 20) were noted in planting with top of corm. Similar results were reported by Onwueme and Charles (1994), Suja (2001) in white yam, and Tsedalu *et al*. (2014) in colocasia. This might be due to the early emergence and establishment of plants produced from top of corm, which would give them a competitive advantage.

Collar girth was found to be affected by planting materials used only at 90 DAP. Superior girth was shown by plants emerged from cormels. This might be due to the fact that cormels produced stout tillers of less number, while top of corm produced more number of tillers of lower thickness.

Number of leaves was affected by planting materials used. Plants produced from top of corm produced greater number of leaves (Fig. 21). The reason may be the presence of higher number of potential buds and more assimilates in the case of top of corm (Gebre *et al*., 2015).

Leaf area and LAI were higher in planting with top of corm, while cormels and split corms were on par to each other (Fig. 22; Table 9 and Fig. 23; Table 10). Nakasha (2017) reported that the increase in leaf number was directly related to leaf area of plant which in turn is related to net plant productivity and thus tuber growth.

5.6. Effect of planting materials on yield characters of tannia

Number of cormels was high in the case of top of corm followed by split corm (Fig. 24 and Table 17). In the case of length and girth of cormels, top of corm and split corm were on par to each other (Fig. 24 and Table 17). When planted with cormels, lower number of tubers with less length and breadth were noted. This can be attributed to the low weight and low number of buds in cormels compared to top of corm and

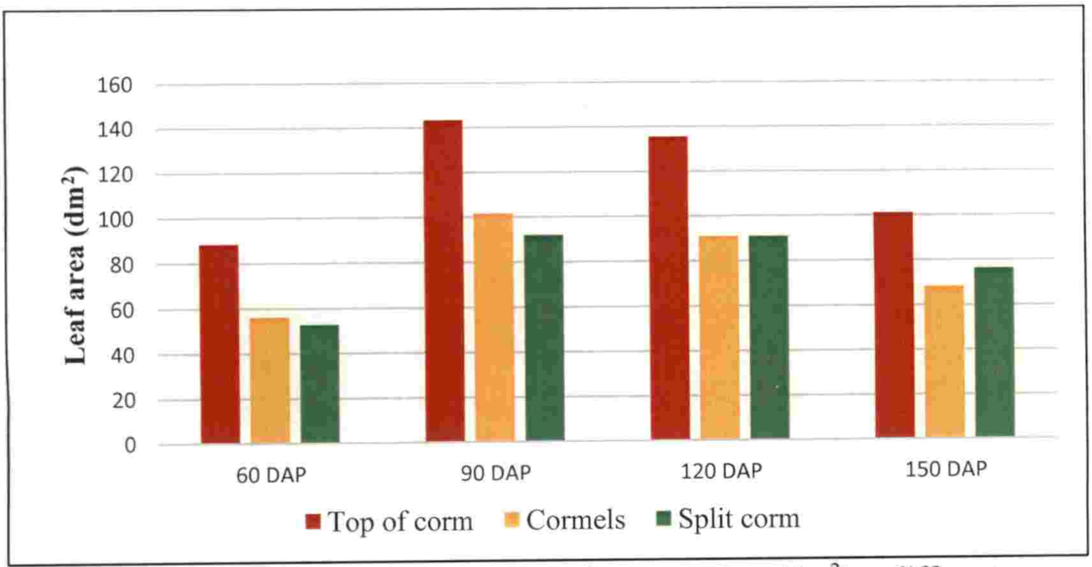

Fig. 22. Effect of planting materials on leaf area per plant (dm^2) at different stages

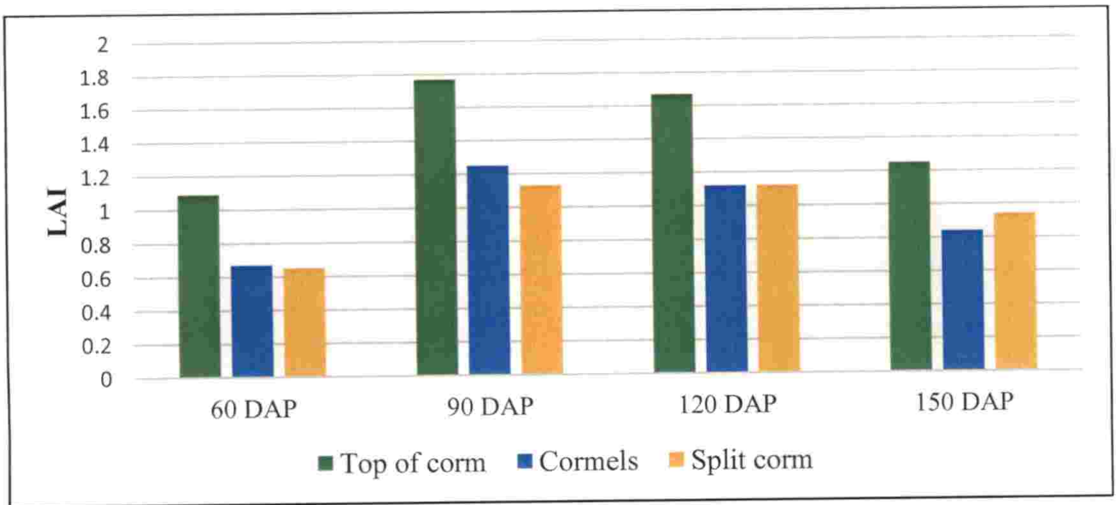

Fig. 23. Effect of planting materials on leaf area index at different stages

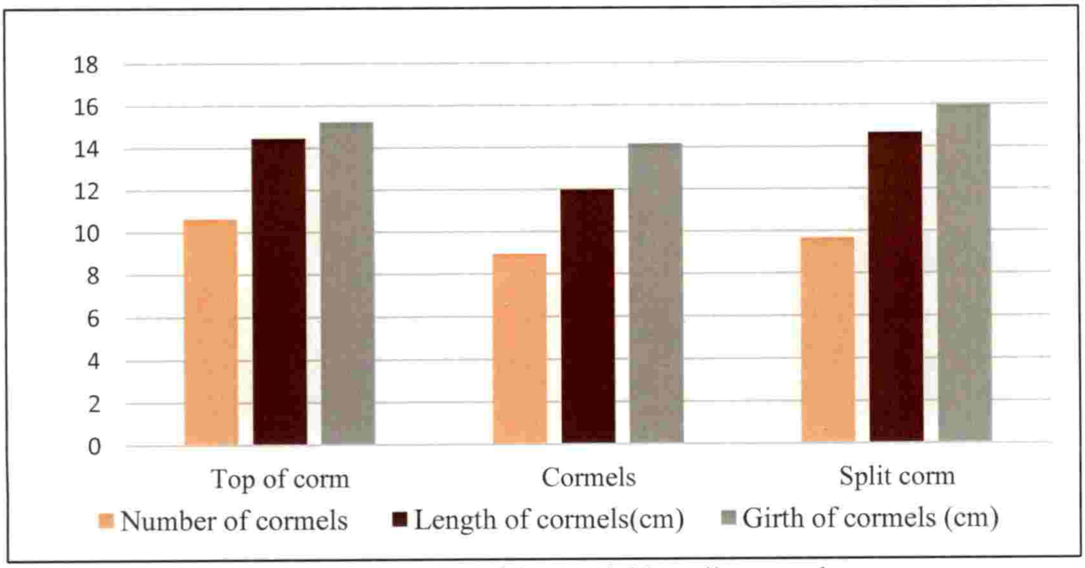

Fig. 24. Effect of planting materials on yield attributes at harvest

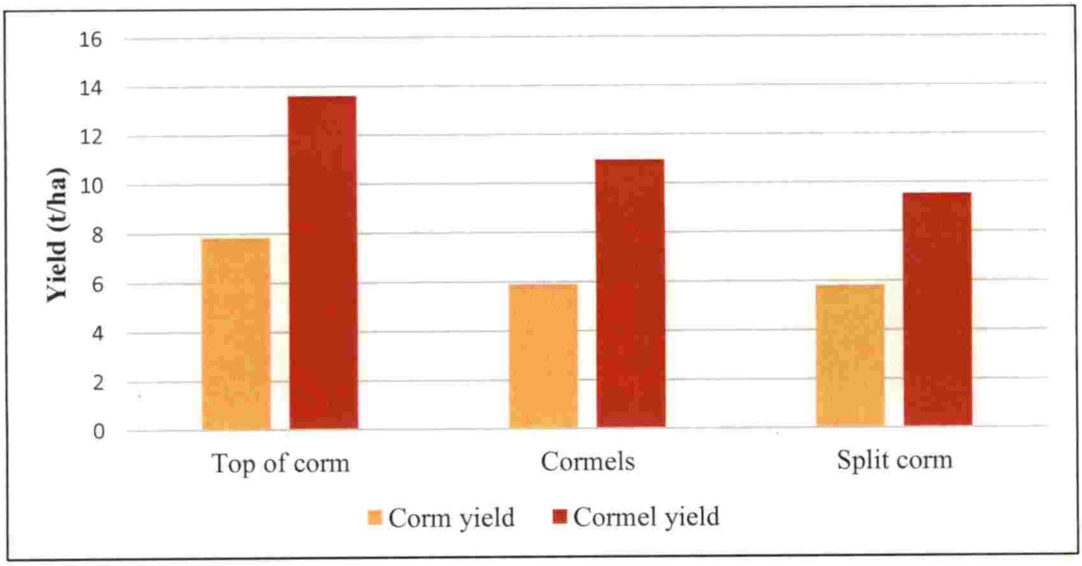

Fig. 26. Effect of planting materials on corm and cormel yield at harvest (t/ha)

split corms. Michael *et al.* (2012) reported that large size seed tubers, with their relatively larger food reserves, produced large plants which established faster and produced vigorous stems, increasing the efficiency of biomass partitioning to the tubers.

Individual fresh weight of cormels was not affected by planting material used, but cormel yield was higher in planting with top of corm (Fig. 26). This might be due to higher number of cormels in top of corm planting. Moreover, higher corm fresh weight, corm dry weight, corm yield, and cormel dry weight were observed in planting with top of corm. In good growing conditions, heavy head-setts would result in higher yields (Lebot, 2009). Similar observations were reported by Strange and Blackmore (1990) in potato. Higher number of leaves, leaf area per plant, and LAI in case of top of corm would result in large photosynthetic surface helping in accumulating more dry matter to tubers.

5.7. Effect of shade levels and planting material on economics of cultivation

Benefit: cost ratio of 4.86 was obtained when top of corm was used under 50 per cent shade closely followed by top of corm under 25 per cent shade (4.45) showing the better effects of top of corm as a planting material and its suitability under shaded condition (Table 24). With decrease in size of planting material, cost of cultivation decreased, but maximum profit was realized from planting material having more weight (Manhas *et al.*, 2010).

Cormels are the economically important part of tannia which fetches good price in the market. Corms, in general, are not good for human consumption, and therefore command very low price. The use of corms as planting material is, therefore, advantageous.

Summary

6. SUMMARY

The present investigation entitled "Performance of different planting materials on tannia (*Xanthosoma sagittifolium* (L.) Schott) under shade" was conducted during June 2017-Jan 2018 at the Department of Agronomy, College of Horticulture, Vellanikkara with the objective of studying the effect of different shade levels and planting materials on growth and yield of tannia. Three shade levels (25 % shade, 50 % shade and open condition) were selected as main plot treatments and three planting materials (top of corm, cormels, and split corm) were selected as subplot treatments. The effect of these treatments and their combinations were studied by laying the experiment in split plot design with three replications. The findings from the study are summarized below.

Overall performance of the crop in terms of growth and yield was better under shade levels compared to open. Hence, the crop can be classified as a shade loving crop.

Shading affected both biometric and yield characters of tannia. Shade resulted in production of taller plants with longer petioles. Among the shade levels, 50 per cent shade recorded higher number of leaves, lamina area, and LAI at all the stages. Full light condition decreased leaf life span.

Shade produced positive effects on chlorophyll content and negative effects on specific leaf density. With increase in shade level chlorophyll 'a', chlorophyll 'b' and total chlorophyll increased.

The yield performance of various planting materials used were better under shaded situation than open condition. For estimating yield, both corm and cormels were considered. Higher corm fresh weight (550.77 g), dry weight (115.56 g), and corm yield (6.80 t/ha) was observed in 50 per cent shade. In the case of cormel characters also 50 per cent and 25 per cent shade were the better.

Cormels are the main economic part of tannia. In cormel characters also, 50 per cent shade and 25 per cent shade were better. Number of cormels produced per plant was higher in 50 per cent shaded plots (10.29), while cormels with better length was produced from 25 per cent shade (16.83 cm). Cormel yield from 50 per cent shaded condition were 37 per cent higher and at 25 per cent shade, 33 per cent higher than open plots.

Among the different planting materials, top of corm has taken lower days for emergence (15 days), while split corm took more days (25 days).

Biometric characters like plant height, petiole length, leaf number, leaf area, and leaf area index were higher in plants produced with top of corm.

Yield characters, including number of cormels (10.63), corm yield (8.13 t/ha) and cormel yield (13.59 t/ha) were also higher in top of corm planting. Compared to cormels 30 per cent yield increase was observed with top of corm planting. Cormel length and girth were seen higher in both top of corm and split corm.

The starch content of cormels (59.55 to 65.07 %) was higher compared to corms (52.43 to 56.98 %), but crude protein was higher in corms (5.47 to 9.30 %). Shade increased cormel starch content. And it was also seen that crude protein content of corms was decreased due to shade. Oxalate content, the anti-nutritional content in aroids was seen more in corms over cormels, but different treatments do not affected its values.

Among the treatment combinations, planting of top of corm in combination with shaded condition and split corm in combination with 50 per cent shade resulted in higher yield of cormels per hectare.

Higher B: C ratio was observed in planting of top of corm under 50 per cent shade, followed by top of corm in 25 per cent shade.

From the results, it is advisable to cultivate tannia in 25 - 50 per cent shade using top of corm as planting material. In the absence of enough planting materials split corm can be an ideal substitute.

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Appendices

Appendix 1. Weekly weather data during experimental period

Std. Week No.	Date	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)			Wind speed (Km/hr)	Mean Sunshine hours	Rainfall (mm)	Rainy days (No.)
				Morning	Evening	Mean				
19	06/5-13/5	35.5	24.7	85	58	72	1.8	6.8	15.2	1
20	14/5-20/5	35.0	25.8	88	57	72	1.8	6.6	16.2	1
21	21/5-27/5	33.9	25.2	87	61	73	1.8	3.4	26.2	2
22	28/5-03/6	31.1	24.0	94	76	85	1.4	2.9	113.2	7
23	04/6-10//6	30.8	24.1	92	75	84	0.9	1.3	60.6	5
24	11/6-17/6	30.2	23.9	97	79	88	0.8	0.9	151.2	5
25	18/6-24/6	31.7	23.6	94	78	86	4.1	4.1	104.4	6
26	25/6-01/7	29.4	22.4	96	83	90	1.3	1.3	291.8	7
27	02/7-08/7	30.1	22.7	96	77	86	0.9	1.8	77.1	7
28	09/7-15/7	30.3	22.9	94	75	85	0.5	1.5	97.5	4
29	16/7-22/7	30.9	22.1	95	77	86	1.4	2.1	171.1	6
30	23/7-29/7	31.6	23.0	93	68	31	1.6	5.2	30.3	5
31	30/7-05/8	31.2	23.9	94	75	85	1.7	5.1	87.1	2
32	06/8-12/8	29.9	23.6	95	73	84	1	3.5	80.8	4
33	13/8-19/8	31.0	23.4	96	79	88	0.8	3.5	83.8	3
34	20/8-26/8	30.1	23.1	97	76	86	0.8	2.1	97.7	3
35	27/8-02/9	29.4	23.1	95	80	88	1	2.9	143.6	6
36	03/9-09/9	31.7	23.6	94	77	86	0.7	4.4	56.5	5
37	10/9-16/9	32.4	23.0	96	78	87	0.7	3.9	91.9	4
38	17/9-23/9	30.6	22.2	95	71	83	1	4.2	211.5	5
39	24/9-30/9	31.2	22.9	94	70	82	0.2	4.1	39.0	2

Std. Week No.	Date	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)			Wind speed (Km/hr)	Mean Sunshine hours	Rainfall (mm)	Rainy days (No.)
				Morning	Evening	Mean				
40	01/10-07/10	31.4	22.8	95	72	84	0.1	4.1	61.1	2
41	08/10-14/10	31.9	22.8	93	71	82	0.1	4.5	14.6	3
42	15/10-21/10	30.9	22.2	95	79	87	0.1	3.9	56	3
43	22/10-28/10	32.0	21.5	91	64	78	0.3	6	50.5	2
44	29/10-04/11	33.5	22.7	83	50	70	1.4	7.4	29.9	2
45	01/11-07/11	32.3	21.9	85	61	73	2.2	5.7	3.5	1
46	12/11-18/11	32.8	20.8	93	57	75	0.6	6.7	0	0
47	19/11-25/11	33.8	21.6	92	55	73	1.6	6.8	25.5	2
48	26/11-02/12	32.0	22.5	82	61	71	5	4.3	11.5	2
49	03/12-09/12	32.8	21.0	89	58	73	1.8	7.3	0	0
50	10/12-16/12	32.7	21.4	87	56	72	1.8	5.1	0	0
51	17/12-23/12	32.3	21.5	67	42	54	9.2	9.1	0	0
52	24/12-31/12	32.8	20.3	68	36	52	7	9.4	0	0
1	01/1-07/1	33.2	19.8	75	41	58	3.9	8.8	0	0
2	08/1-14/1	32.7	21.8	73	39	56	6.7	7.4	0	0
3	15/1-21/1	33.8	20.7	63	33	48	6.9	8.6	0	0
4	22/1-28/1	34.1	21.4	68	39	53	4.3	8.1	0	0

PERFORMANCE OF DIFFERENT PLANTING MATERIALS OF TANNIA (*Xanthosoma sagittifolium* (L.) Schott) UNDER SHADE

By

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ABSTRACT OF THE THESIS

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ABSTRACT

An experiment was conducted for studying the response of different shade levels and planting materials on tannia (*Xanthosoma sagittifolium* (L.) Schott), an aroid tuber crop. The experiment was done in split plot design with the shade levels of 25 and 50 per cent and open as main plots and top of corm, cormels, and split corm as planting materials in sub plots. Shading and planting materials affected both growth and yield of tannia.

Shade caused taller plants with longer petioles. Leaf numbers, lamina area, and LAI were higher with 50 per cent shade. Open condition decreased leaf life span but increased lamina thickness. Corm yield was higher in 50 per cent shade (6.80 t/ha). Higher number of cormels (10.29) were also obtained from plots with 50 per cent shade. Both 25 and 50 per cent shade recorded highest cormel yield (13.47 t/ha and 12.66 t/ha, respectively). Shoot: storage organ ratio (0.11) was significantly low in open plots, while low corm: cormel ratio (0.48) was noted in 50 per cent shade.

Among planting materials, top of corm has taken less days for emergence (15 days) followed by cormels (21days). Top of corm was superior in terms of leaf numbers, leaf area, and LAI. Yield characters including number of cormels (10.63), corm yield (8.13 t/ha), and cormel yield (13.59 t/ha) were also high in top of corm planting.

Crude protein content was low in cormels compared to corms. However, starch content was much higher in cormels. Shade increased starch content of cormels, but decreased corm protein content. Higher crude protein content of corm (8.14 %) and cormels (4.38 %) was observed with split corm planting, but higher starch content of corms (56.98 %) and cormels (65.07 %) were noted with top of corm. Oxalate content was unaffected because of treatments but higher in corms than cormels.

Higher benefit - cost ratio of 4.86 was observed with planting of top of corm under 50 per cent shade followed by it under 25 per cent shade (4.45). It is concluded

that tannia is a shade loving crop, which can be cultivated under 25 to 50 per cent shade using top of corm as planting material. In the absence of enough planting materials, split corm is an ideal substitute.