CROP - WEATHER RELATIONS ON YIELD AND QUALITY OF *IRUVELI* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]

By

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(2017-11-013)

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KERALA, INDIA
2019

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THESIS

Submitted in partial fulfillment of the requirement for the degree of

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(Agronomy)

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DEPARTMENT OF AGRONOMY
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR – 680656
KERALA, INDIA
2019

DECLARATION

I, Sabika K. P. (2017-11-013) hereby declare that the thesis entitled **"Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]"** 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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Certified that the thesis entitled **"Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]"** is a record of research work done independently by **Ms. Sabika K. P.** (2017-11-013) under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associate ship or fellowship to her.

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Dedicated to the eternal memory of Dr. Sunil K. M., the then Assistant Professor (Agrl. Meteorology), KVK Palakkad and member of my advisory committee

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And He is with you wherever you are

- *Qur'an 57:4*

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1. INTRODUCTION

Rise in world population, inadequate supply of drugs, high cost of modern medical treatments, side effects of synthetic drugs and development of resistance against many synthetic drugs have increased emphasis on the use of plant materials as the source of medicine for wide variety of human ailments. Among the ancient civilizations, India has been known as a rich repository of medicinal plants. Our country is considered as the botanical garden of the world due to its varied agro climatic conditions and topography. The forests in India are the principle emporium of medicinal plants, which are largely collected as raw material for the manufacture of drugs. Increased demand for the raw drugs resulted in the over harvesting of plants from the wild, which led to the loss of biodiversity and extinction of many species. In this context, medicinal plants require domestication to meet the increasing demand of quality crude drugs.

Plectranthus belonging to the family Lamiaceae is a large widespread genus, with a variety of medicinal uses. The genus consists of about 300 species found in Tropical Africa, Asia and Australia. *Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma, which was earlier known as *Coleus vettiveroides* is one important species among them. The plant is endemic to South India and is now extinct in the wild. It is a small profusely branched succulent plant which has deep straw coloured roots.

Major economic part of *Iruveli*is the root, which is used against skin diseases, rheumatism, bronchitis and chronic allergies. It is also used as stimulant and carminative. *Iruveli* is most commonly used against ailments like vomiting, diarrhoea, leucoderma, fever, chronic liver diseases etc. It is used against indigestion and urinal disorders and is a chief ingredient of many ayurvedic preparations like *Iruvelikashayam, devashtagandha, snanachoornam* etc. (Warrier *et al*., 1995). About 40 herbal drugs are which contain *Plectranthus vettiveroides*

solely or as an ingredient currently available in the global/local markets. About 50 tonnes of the plant biomass is required annually for ayurvedic preparations.

Growing environment not only affects plant growth but also influences production of secondary metabolites responsible for the medicinal property of plants. In medicinal plant cultivation, both yield and quality are equally important, and therefore, it is necessary to identify optimum growth factors that can ensure high yield and quality. Environmental factors such as temperature, light and atmospheric CO_2 concentrations can influence the levels of secondary metabolites in plants. Several environmental factors affecting growth, photosynthesis and other parts of the primary metabolism, will also influence secondary metabolism.

Light is a physical factor which can stimulate growth and development of plants. According to Kumar (2013), light intensity had profound influence on biometric characters, yield and oil content of *Plectranthus vettiveroides*. Both deficient and excessive light intensities may be injurious to plants and it will affect plant growth, development and yield. Studies on growth response to varied light intensities are useful to determine the favourable conditions for the cultivation of crop.

Time of sowing is crucial for the vegetative growth and ultimate expressions of yield in any crop. Early or late sowing may hamper the growth, yield as well as quality of the crop. Time of planting controls the phenological development along with efficient conversion of biomass into economic yield (Khichar and Niwas, 2006).

Competition from weeds is one of the major factors adversely affecting the growth and yield of medicinal plants. Mulching is one of the important agronomic practices beneficial in conserving soil moisture, suppressing weeds, improving soil fertility and modifying soil physical environment. Mulching also has significant influence on plant biometric and quality characters of the growing crops.

The available literature on the studies of scientific cultivation of *Plectranthus vettiveroides* is very less. By considering the above facts, the experiment entitled "Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]" was taken up with the main objective to study the effect of variations in intensity of light, time of planting and mulching on yield and quality of *Iruveli* (*Plectranthus vettiveroides*).

2. *Review of literature*

2. REVIEW OF LITERATURE

From the pre historic period itself plants has been used for medicinal purpose. Around 28 percent of the total plant species discovered is reported to have medicinal properties. Indian vaids have been using plants or plant derived drugs for treating various types of ailments from 4000 years back. Nowadays in India, about 7500 species of medicinal plants are being used in different traditional systems of medicines like Ayurveda, Siddha, Unani, Homeopathy, folklore etc. WHO has reported that around 80 percent of the world population depends upon plants and plant derived drugs for treating their primary health care needs.

Plectranthus is an important genus belongs to the family Lamiaceae, subfamily Nepetoideae and the tribe Ocimeae (Cantino *et al.,* 1992). *Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma (Syn. *Coleus vettiveroides*) is an important herbaceous medicinal plant which belongs to the family Lamiaceae. It is a profusely branched succulent aromatic herb, used as diuretic and antipyretic. *Iruveli* can be also used for the treatment of burning sensation, leprosy, skin diseases, ulcers, vomiting and diarrhoea.

The vernacular names of *Plectranthus vettiveroides* are as follows:

Language	Name
Hindi	Valak
Sanskrit	Valakam,Hriberam
Kannada	Muchivala,Lavanchi
Malayalam	Iruveli
Tamil	Kuruver, Vettiver
Telungu	Kuriveru,vettiveru
Sinhala	Iriweria

2.1 Botanical Name Change

Jacob (1941) originally described and authenticated the plant as *Coleus vettiveroides*. Later the plant name was changed to *Plectranthus vettiveroides* (K.C.Jacob) N.P. Singh & B. D. Sharma, by N. P. Singh and B. D. Sharma during 1981 and was published in Journal of Bombay Natural Historical Society (Nisheedha *et al.*, 2016).

2.2 Habitat

In the global scenario the cultivation of *Iruveli* is limited to tropical India (Lukhoba *et al*., 2006). *Iruveli* is extinct in wild and thus cannot be found in natural habitats (Shivananda *et al*., 2007). This is due to many reasons like unavailability of copious water and open sunshine in the natural condition. Saraswathy *et al*. (2011) reported that *Iruveli* has been cultivating in the North Arcot, Coimbatore, Madurai, Thanjavur, Tirunelveli and Chengalpattu districts in Tamil Nadu from early 20^{th} century. Later surveys (Nisheedha *et al*., 2016) revealed that it has also been cultivated by a few number of families in Chidambaram district of Tamil Nadu as a part of their religious beliefs and customs.

According to Nair *et al*. (1986), in Kerala the cultivation is limited to herbal gardens of Arya Vaidya Sala, Kottakal, Medicinal Plants Gardens of Kerala Agricultural University, and near the vicinity of the clinics of many Ayurveda and Siddha vaidyas which is sold and used by the physicians. Nisheedha *et al.* (2016) reported that the plant is conserved at Saraswathy Thangavelu Centre of JNTBGRI Thiruvananthapuram also.

2.3 Morphology

Plectranthus vettiveroides is a small profusely branched succulent perennial aromatic herb with quadrangular stem, and deep straw coloured aromatic roots. The leaves are hairy and glandular with broadly ovate shape and dentate margins. The reticulate veins are prominent in the margin. Flowers are blue in colour and blooms in terminal racemes (Prajapati *et al.,* 2003).

The plant grows up to 1m tall. It also has a lateral spread of 60-80 cm in both east-west and north south directions. *Iruveli* is a profusely branching herb with average 20-22 branches per plant and 20-22 leaves per branch (Shivananda *et al.,* 2007). Roots are fibrous 30-90 cm long, form a tuft, slender, very thin, easily cut-off, strongly aromatic, straw colour when fresh, changing dark brown on drying (Nisheedha *et al*., 2016) .

Shivananda *et al*. (2007) reported that rooting pattern differ according to texture of soil. If they grow on sandy soil with copious water availability, the roots will be profuse with thin long tertiary roots, while in case of loamy soil the primary and secondary roots will be prominent. Flowers are having the characters of Lamiaceae family. They have blue coloured, bilabiate, corolla arranged in whorls. The fruits are tiny nutlets (Saraswathy *et al*., 2011).

2.4 Phytochemical constituents

Waldia *et al.* (2011) made a study in Indian Plectranthus species and reported that the major chemical constituents include essential oils, diterpenoids, triterpenoids, flavones and fatty acids. The essential oil is found to be brightly coloured (orange red) and was highly viscous with a pleasant odour.

According to Abdel-Mogib *et al.,* (2002) the essential oil content of *Plectranthus* genus is more than 0.5 percent. Saraswathy and Lavanya (2013) investigated the root essential oil of *Iruveli* using GC-MS analysis and characterized 36 compounds. The oil was rich in oxygenated hydrocarbons and saturated hydrocarbons, including aldehydes, ketones and hydroxy groups. The analysis showed that the plant contains mainly androstan-17-one, 3-ethyl-3-hydroxy-, (5α)- (25%) and -(-) spathulenol (9%). The other compounds were α-bisabolol (7%), Z-valerenyl acetate (7%), 8(Z)-triene (6%), 1H-cycloprop(E)azulen-7-ol, decahydro-1,1,7-trimethyl-4-methylene (5%), myrtenol (2%), 1-naphthalenol (2%), caryophyllene oxide (2%), abieta-9(11),8(14),12-trien-12-ol (2%). All other compounds were found to be less than 2%.

HPTLC studies of *Plectranthus vettiveroides* using different extracts indicated the presence of carbohydrates, steroids, proteins, amino acids, phenolic compounds, tannins and alkaloids in different extracts (Beesha and Padmaja, 2013). On Phytochemical screening by Gopalakrishnan and Dhanapal (2014) of methanolic extract showed presence of triterpenoids, phenolic compound, proteins, flavonoids, alkaloids and tannins. Presence of mono, di and sesqui tepenoides and phenolics were also reported by Rohini and Padmini (2016) in the roots of *Iruveli*.

2.5 Medicinal Uses and Economic importance

Plectranthus vettiveroides is a medicinal plant with very high importance in traditional systems of medicine. Its ethno botanical use has been reported in monumental scriptures like Amarakosham written by Amarasimhan written in early 1-6 century AD (Nambiar and Raveendran, 2008). *Iruveli* is used as single or one of the active ingredients in more than 78 herbal medicines (Nisheedha *et al.,* 2016).

As per Sivarajan and Balachandran (1986), in Kerala *Iruveli* has been traditionally used for treating children's cough and cold. According to Joy *et al.* (2001) *Iruveli* has immense scope for cultivation in Kerala, as there is high demand in the ayurvedic industry for treating skin diseases and leprosy. Chopda and Mahajan (2009) reported it as a traditional wound healing plant used in Maharashtra. Use of whole plant extract of *Plectranthus vettiveroides* for treating leucoderma was reported by Chandrasekar *et al.* (2016).

Mishra (2009) reported the use of *Iruveli* as traditional medicine for curing fever. Anbarasu *et al.* (2011) investigated the antipyretic anti inflamatory and analgesic properties of *Nilavembukudineerchoornam*, a classical siddha medicine used in the treatment of Chikunguniya where *Iruveli* is an important component. Singh and Rawat (2017) revealed that the whole plant extract of *Plectranthus vettiveroides* had been used by traditional healers in south India and thus could be used as component in traditional formulations for management of dengue fever. Ramanathan *et al*. (2019) also evaluated *Nilavembukudineer* capsule containing the extract of *Plectranthus vettiveroides* and reported as highly effective medicine in treating fever.

According to Mondal and Kolhapure (2004) extracts of iruvli has been used as ingredient in hand sanitizers. Safeer *et al.* (2013) observed that *Iruveli* has been used as antibacterial, deodorant, cooling agent, against eye burning, head ache and fever. Saraswathy and Lavanya (2013) observed inhibition of seven clinical isolates of bacteria. The anti-bacterial activity of coleus species had also been revealed by Tarh *et al.* (2015). Whole plant extract with 50% methanol could inhibit four different strains of bacteria.

It has been reported that the methanol extract of *Plectranthus vettiveroides* significantly reduced the blood glucose level and thus poses anti diabetic activity (Gopalakrishnan and Dhanapal, 2014). Priya *et al.* (2017) investigated and reported that, the herbal drugs containing *Iruveli* can effectively inhibit the growth

of bacteria *Candida albiscans* in intestine which assimilate the glucose, and thus effectively regulate blood glucose level.

Ganapathy *et al*. (2015) studied the in vitro antioxidant and anti cancerous property of the hydro alcoholic extracts of the roots of the species. The hydro alcoholic extract exhibited high phytotoxicity and antioxidant properties even at very low concentration.

In 1981, Cramer reported that decoction using *Iruveli* and onion is used in veterinary medicine to treat dysentery and diarrhoea of cattle. Rajalekshmi *et al*. (2009) investigated that triazole treatment to *Plectranthus vettiveroides* has altered morphological characteristics of the plant including root length plant height and leaf area and also has increased photosynthetic pigment which is highly promising in the medicinal potentiality of the plant. *Iruveli* has also been used for producing many house hold products like bathing soap and agarbathies (Safeer *et al*., 2013). *Iruveli* is also effective in hair growth (Dharmapalan *et al.,* 2011).

2.6 Cultivation

Desai and Thirumala (2014) suggest that *Plectranthus vettiveroides* are best grown in sandy loam soil along river banks in plains. The rooting pattern is different in light and heavy textured soils. In sandy soils, thin and long tertiary roots are prominent with less prominent primary and secondary roots. But if is grown on loamy soils, the primary and secondary roots will grow profusely than tertiary roots.

Mamatha *et al*. (2014) investigated the optimum nutrient condition for *Iruveli* and was found that the maximum plant height obtained was at 200:25:100 kg/ha and maximum root weight was obtained at application rate of 100:50:50 kg NPK/ha.

In a study to find out the influence of growing media on the growth of *Iruveli*, it was found that the maximum biomass content was obtained at the ratio of 50% sand and 50% soil mixture along with FYM at10t/ha (Mamatha and Shivananda, 2012).

Mamatha (2009) based on field experiment concluded that soft wood stem cutting had used for planting *Iruveli* in nursery. Forty five days old rooted plantings was used to plant at raised beds. They were planted at a spacing of 60cm X 60cm. weeding has to be done at 30 days after transplanting and subsequently at 30 days interval till harvest.

Another experiment to find the influence of nutrient source and light intensity on yield and quality of *Iruveli* (Kumar 2013). In that, planting was done on sandy soil and fresh shoot cuttings was used and was planted at a spacing of 30cm X 30 cm.

Based on experiments Safeer *et al*., (2013) developed agrotechniques for *Iruveli*. According to them, planting of 15 cm long shoot tip cuttings in sandy soil at a spacing of 35 cm x 35cm and harvesting at 70 days is ideal.

The fertilizer dose of 20 kg N, 50 kg P_2O_5 and 20 kg K_2O/ha and irrigating twice daily was also found to be better for growth of *Iruveli* (Nisheeda *et al*., 2016).

Ideal time for harvesting in *Iruveli* is within 70 - 90 days of planting. After 90 days, the root growth will be arrested and there will be deterioration in the quality of oil. It was also observed that there optimum yield of 4-6t/ha root would be obtained on harvesting at 70 -90 days (Krishnan and Sreekumar, 2011). They also recommended that *Iruveli* can be cultivated as an intercrop in coconut plantations.

Subramanian *et al*. (2002) has studied the scope of micro propagation methods of *plectanthus vettiveroides* and revealed that it can be successfully propagated through clonal propagation. On an average 60-70 plantlets could be produced from one nodal explant and the propagation success rate was 80%.

Although *Iruveli* has got good resistance against pests and diseases, some pest were identified in the crop. Estelitta *et al.* (1992) reported bacterial wilt caused by *Pseudomonas solanacearum* as a major disease of *Iruveli*. The common pests and diseases identified includes *Pycnarmon cribrata* (leaf folder), *Nupserha vexator* (stem borer), Mealy bug, Spittle bug, White grub, Root knot and Fusarium wilt disease (Krishnan and Sreekumar, 2011).

2.7 Influence of weather parameters on crop growth and quality of medicinal plants and aromatic plants

Weather is one of the most important factors that affect the growth, distribution, survival and quality of medicinal plants. Hang *et al.* (2005) reported that better meteorological conditions, such as sufficient sunshine, stable and suitable temperature, moderate rainfall and rational distribution are essential for the growth of medicinal plants in terms of dry matter production and accumulation of active constituents.

Halva *et al*. (1993) studied the effects of various combinations of day and night temperatures and day lengths on growth of annual herb Dill (*Anethum graveolens*) in environmentally controlled chambers. The concentration of essential oil was highest in highest temperature tested and in longest photoperiod. Time to maturity was also accelerated by high temperature treatment. Hikosaka *et al.* (1999) reported that optimum temperature for photosynthesis is determined by the temperature during early stages of growth. When there is an increase from the optimum level of temperature the rate of photosynthesis will be affected.

The production of secondary metabolites is highly influenced by outside environmental parameters. In a study conducted by Castrillo *et al.* (2001) to assess the chlorophyll content in eleven cultivated and wild species of lamiaceae family, in most of the species the chlorophyll a/b ratio was depend only on the shade level and not on cultivated or wild origin.

Chang *et al.* (2008) studied the effect of solar irradiance on basil (*Ocimum basilicum* L.) and found that on shading, the photo synthates assimilation will reduce, thus eventually reduce the production of secondary metabolites. Here the maximum shading treatment, that is 75 per cent shading resulted in the production of shorter plants, less number of shoots, smaller leaf area, decreased photosynthetic rate and reduced total volatile oil content. Between the four treatments, the complete irradiation produced the maximum amount of volatile oil.

Ghasemzadeh *et al*. (2010) reported that the difference in light intensities can significantly fluctuate the amount of total phenol, flavonoid contents and antioxidant activities of ginger. Kumar (2013) investigated the effect of light intensity on the growth and yield of *Iruveli*. The treatments included open condition, 75% light and 50% light. He could obtain maximum growth and herbage yield under 75% light intensity.

According to Rezai *et al*. (2018) difference in light intensities in the growing period of sage plant (*Salvia officinalis*) had significant effect in the rate of photosynthesis and essential oil content. They grown the plants under shade treatments of 0%, 30%, 50%, or 70% shade levels for five months and observed morpho chemical changes. Leaf size was observed to be the highest under 50% shade level. The highest photosynthesis activity was achieved under full sunlight. Decreasing light intensity led to an increase in chlorophyll content. The essential oil content was found to be the highest in 30% shading.

In another field study to assess the effect of shade in *Jeffers oniadubia*, a spring flowering herbaceous perennial, Rhie *et al*. (2014) observed increase in shoot-to-root ratio with increased shading, mainly due to decreased root dry weight under shading. But the photosynthetic rate was found to be higher in highest shading mainly due to increase in chlorophyll content.

Yan *et al.* (2016) made a conclusion that, under different degrees of shade there was difference in content of components of turmeric volatile oil. The increase in shade was found to be conducive for increase in active components. In *Andrographis paniculata,* Omar *et al.* (2016) observed higher plant height under 50 percent shade compared to open condition. However, total phenolics were higher under open condition. Liphan, and Detpiratmongkol, (2017) in *Andrographis paniculata* recorded highest herbage yield in terms of leaf dry weight, root weight and leaf area under 20% shading compared to open condition.

2.8 Effect of time of planting on growth, herbage yield and quality in medicinal and aromatic plants

Effect of planting time of peppermint (*Mentha piperita*) was analyzed and the essential oil content was significantly higher in spring planted crops in comparison to the autumn planted ones (Marotti *et al*., 1994). Ram *et al.* (1997) compared the essential oil content of three varieties of geranium planted in six different dates starting from September at monthly interval. They concluded that the cultivar borboun planted in October had maximum essential oil yield with superior quality (25% citranellol and 20% geraniol). Gill and Randhawa (1997) studied the influence of planting dates on quality of French basil. According to them, the specific gravity of herb oil, cineole and methyl chavicol contents not affected by different transplanting dates. However, the linalool content in herb oil increased with delay in planting.

Peppermint (*Mentha piperita)* planted on 15th January recorded significantly higher plant height, number of branches, leaf stem ratio and herbage yield when different planting dates (January 15th, January 30th, February 14th, March 1st) were compared on yield and quality (Sharma and Kanjilal (1999), However, the quality of oil measured by the menthol content was not affected by planting time. Similarly, Sharma and Kanjilal (2000) observed that the best planting time for patchouli (*Pogostemon patchouli*) as February compared to March, where the essential oil yield reached up to 26.6 kg/ha. According to Tiwari *et al.* (2000) July Ist week planting is better for *Plumbago zeylanica* with respect to maximum plant height, number of branches, root fresh and dry weight per plant and root yield. The performance of *Andrographis paniculata* was found to be different to different dates of planting and planting and the second fortnight of July was ideal for obtaining higher herbage yield. Maheshwari *et al.* (2002).

In a field experiment on turmeric with five planting dates (February 15, March 15, April 15, May 15 and June 15) and observing the emergence, growth pattern and yield suggest that it should be planted in the month of April (Ishimine *et al*., 2004). In the experiment with four sowing date, fennel, goat pea and black cumin had got highest dry weight seed production in October whereas green cumin performed well in December (Mohsenzadeh, 2008). Sadeghi *et al.* (2009) evaluated the effect of sowing dates on yield and yield components of Basil (*Ocimum basilicum* L.) under dry farming conditions. They observed higher values for plant height, above ground biomass, number of umbels per plant, number of seeds per umbel and higher seeds for crop planted on early days of March.

The study on date of planting of German chamomile (*Matricaria chamomilla* L.) grown in four dates (15 April, 1 May, 15 May, 30 May) showed that delay in planting date cause increase in temperature and produce more oxygenated compounds, which eventually decrease the essential oil content. Therefore the April planted crop got the highest yield (Mohammad *et al*., 2010).

Akshay *et al.* (2014) revealed that the date of planting had a significant influence on the synthesis of secondary metabolites in medicinal and aromatic plants. Saini *et al*. (2018) studied the influence of dates of planting (September 20, October 5, October 20,) in patchouli (*Pogostemon cablin* Benth.) in two consecutive years. Significant plant spread, herbage yield and essential oil content was obtained at plants grown in October 20. Kodori *et al.* (2014) studied the influence of planting dates in *Aloe vera* plant. The two planting dates were October 2009 and February 2009 and according to the results the February planted crops got highest yield, plant survival, gel yield and leaf number.

A field experiment was conducted by Khalil *et al.*, (2013) to study the effects of sowing date on yield, yield components and pigment of safflower (*Carthamus tinctorius*). They could observe significant effects of sowing dates on seed yield, dry weight and pigment yield. Decrease of seeds number/head and seed weight in delayed sowing dates was attributed to unfavorable climatic conditions during flowering and seed filling stages of the plant.

Ghobadi *et al*. (2016) studied the influence of planting dates on the yield and growth characteristics of the saffron plant. The treatments consisted of four planting dates (June 10th, September 7th and 27th, and October 12th). The results revealed that the flower and stigma yield was higher in June 10th panting and was 50% higher as compared with other planting dates. A similar result was obtained in other parameters like flower length and number of buds leaf dry weight and length.

Karami *et al.* (2017) investigated influence of seasonal variation on the percentage of seed oil and total phenolic content in seeds and leaf of safflower. They evaluated two sowing dates and the highest amount of seed oil and total phenolics was found in summer planted crop compared to spring planted. Upon studying the effect of different dates of planting for *Indigofera tinctoria* over three

consecutive years, Sindhu *et al*. (2018) concluded that August or September planting is ideal for better herbage yield and quality.

Hassan *et al*. (2019) studied effect of planting date on Dill plant **(***Anethum greveolens*) and according to them September planting is ideal for vegetative growth, fresh biomass yield and vitamin C content, and the October planning is ideal for carbohydrate and chlorophyll contents.

2.9 Effect of time of mulching on growth, herbage yield and quality in medicinal and aromatic plants

A mulch is any material that is spread over the ground as a layer. Coming to the etymology, the word "Mulch" is derived from German word "Molsch", which means soft to decay (Jacks *et al*., 1955). Based on the mulching material, mulch can be divided into organic or inorganic. Organic mulches are either plant or animal origin, which could be incorporated into the soil during or after the crop period. But in case of inorganic mulches, it has to be removed after the cropping season (Monks and Bass, 1999).

Agele *et al.* (2000) in a field experiment on tomato found that mulches enhanced the soil hydrothermal regime and thereby improved the vegetative and flowering properties of the crop. This in turn increased the fruit yield over the control.

Crops planted in the mulched plots had got improved plant height, number of leaves, pod length and pod diameter and reduced weed density and could produce higher yield (Usman *et al.*, 2005).

Mulches has got the property of modifying the microclimate of the crop differently depending upon the mulch materials (Munn, 1992). Sharma and Kathiravan (2009) report that mulch will smother the weed population by acting

as a physical barrier and hinder the photosynthetic activity of weeds. Thus the competition between the crops and weeds would be reduced considerably and creates a favorable condition for crop growth. Kumar *et al.* (2014) reported that the contents of organic carbon, available nitrogen, phosphorus and potassium had increased significantly by mulching as compared to non-mulched plots.

The practice of mulching is highly desirable in crop production as it can reduce soil moisture loss through transpiration, control weed population, maintain soil temperature in an optimum level and enhance microbial growth and activity (Govindappa *et al.,* 2015). Adekiya *et al.,* (2017) stated that mulching reduced bulk density of the soil and thus improved physical properties and moisture content compared with control.

Organic mulching

Organic mulches are mainly originated from plant and animal products like straw, leaf residues, compost, wood shavings, animal manure, grass clippings and also newspapers (Kumar and Lal, 2012).

Application of crop residues would improve the quality and productivity of soil (Lal and Stewart, 1995). Bhardwaj (2013) also suggested plant residues as the most frequently used organic mulch materials. He concluded that the organic mulches had significant influence in reduction of nitrate leaching, provide organic matter to soil, improve nitrogen balance of the soil, adjust soil temperature to optimum level, also increasing biological activity.

Mulumba and Lal (2008) conducted a long term field plot experiment to find the effect of organic mulch on the soil physical properties. Fields were set up with different rates of mulches without cultivation of crops for a period of 11 years. The results demonstrated that mulching increased available water capacity by 18-35%, total porosity by 35-46% and soil moisture retention up to 70%.

In a field study, conducted by Ram *et al.* (2003) to observe the effect of organic mulching on N-use efficiency and essential oil yield in a multi-harvested geranium crop using two treatments paddy straw at 7 t/ha and open condition, the results revealed that application of paddy straw mulch increased the herb and essential oil yields in geranium by 23% and 27%, respectively, over the non-mulched control at initial crop harvest. Corresponding values at regenerated crop harvest were 18.7% and 19.2%. Nitrogen uptake by plants of initial and regenerated crops was also found to be increased in paddy straw mulched crop. The use of organic mulching did not had significant effect on quality of essential oil of geranium in terms of its major constituents, citronellol and geraniol.

Jodaugiene *et al.* (2014) stated that organic mulches could decrease weed density by up to 10.3 times compared with non mulched soil. Also increasing mulch thickness was correlated with weed inhibition. The mulch layer of 10 cm thickness could decrease the weed density by 2.9 times as compared to 5 cm layer.

Gill and McSorley (2012) observed that the organic mulches are the cultural practice for controlling both weeds and insect pests. Mulching in cowpea resulted in decrease in number of surface arthropods and also mortality of 28 per cent population of weedy plant snapdragon.

Ren *et al.* (2018) identified the effects of different mulching materials in physical, chemical properties of soil and the microbial biomass and concluded straw mulching as best compared to plastic mulching. According to them the ground surface mulching cultivation could buffer soil temperature and preserve soil moisture content. They also reported that available nitrogen, phosphorus and potassium in soil increased significantly, which further improved soil fertility. At the same time, the mulching cultivation technology decreased the concentrations of NO_3^{-1}, phosphorous and K^{+1} loss from soil. Straw mulching increased the content of soil microbial biomass carbon and nitrogen.

Muhammad *et al.* (2009) reported that organic mulches were efficient in improving soil physical properties, reducing nitrate leaching, controlling erosion, nutrient cycling and increasing biological activity.

In a field study by Patra *et al.* (1993), it was observed that mulching with paddy straw and citronella (*Cymbopogon winterianus*) distillation waste could increase the herbage yield, essential oil content and N use efficiency in Japanese mint (*Mentha arvensis*). Plant dry weight was increased by 17 and 31% with paddy straw and citronella distillation waste, respectively over no mulched crop. Mulched plots have been observed to contain 2 to 4% higher moisture over the un mulched soils. Nitrogen uptake by plants increased by 18 and 25% compared to no mulched, with using paddy straw and citronella distillation waste, respectively.

Kumar *et al.* (2014) conducted an experiment to assess the effect of mulches in stevia cultivation and observed that the use of leaf mulch as a soil cover is effective in increasing crop yield and fertility of soil All the mulched plots considerably increased dry leaf yield, total dry biomass organic carbon (O C), available nitrogen (N), phosphorus (P) and potassium (K), bacterial and fungal population compared to non-mulched plots.

Palada *et al.* (2000) compared different mulches for growing sweet basil under drip irrigation system and revealed that yield from plots under organic mulches were higher than the plots using synthetic mulches. Mulches also lowered irrigation water use and increased water use efficiency as compared with open plots. Soil temperature was reduced to the range of 1 - 6 ºC in organic mulched plots.

Shukla *et al.* (2000) reported that paddy straw mulching in aonla can increase the plant height, canopy spread and stock girth of the plant and total nitrogen content in the soil.

Duppong *et al.* (2004) conducted an experiment to study crop performance, weed suppression, and environmental conditions associated with the use of several organic mulches in the production of two herbs, catnip and St. John's wort. Plant height and total yield of both the herbs were highest in the flax straw mulched treatment. The active components, nepetalactone in catnip and pseudohypericin–hypericin in St. John's wort, was found in higher concentrations in the flax straw treatment.

Singh *et al.* (2002) conducted an experiment to assess the effect of organic mulch on growth, herbage yield, oil yield and quality of patchouli (*Pogostemon cablin*), and revealed that application of 5 t ha^{-1} waste material of palmarosa as organic mulch, produced maximum herbage and oil yield. Singh (2012) studied the influence of organic mulching and nitrogen application on essential oil yield and nitrogen use efficiency of rosemary. He proved that mulching with lemon grass spent material increased the herb and essential oil yields by 16.2 per cent and 24.2 per cent, respectively, compared to that of the non mulched treatment.

Mulch type had influence in the shoot growth and yield of American apple (*Podophyllum peltatum*), but mulching depth did not had significant effect on the same (Cushman *et al.,* 2005).

Organic mulching had got high economic benefit also. It could enhance soil nutrient status after decaying, which was additional benefit over inorganic mulching. Polythene mulches were more expensive than organic mulch. Organic mulches were cheaper, had very good accessibility and multiple benefits (Kader *et al.,* 2017). Sathiyamurthy *et al.* (2017) after a field experiment in chilly found that organic mulch had superior performance in plant height, number of fruits and fruit yield than the control treatment.

Mulching with straw significantly reduced the loss of water from the treated plot and conserved 106.9 mm of water in 0-200 cm soil layer (Mupangwa

et al., 2013). Jun *et al.* (2014) made a similar conclusion that presence of straw on the soil surface could modify the temperature, increase soil N, and available P and also increased water use efficiency significantly.

Polythene mulching

Polythene which is used as plastic film has been developed in back 1938 and from 1950s it was used for commercial crop production. (Lament, 1993). In the recent times the use of polythene or plastic mulching materials had increased its pace and is the most accepted mulch for weed control. Colour of the polythene mulch also determine its influence on microclimate. A soil temperature increase of 2.8 ^{o}C was observed at a depth of 2 inch under black polythene compared to bare soil. Plastic mulches have greater permeability to long wave radiation and thus it increases temperature around the plants during night in winter (Bhardwaj, 2013). Black polyethylene mulches are the most widely used mulches for weed control in conventional and organic systems of crop production.

Polythene mulching would reduce the evaporation of water from the soil surface and thus maintained the soil moisture content. Also as light do not enter inside the black polythene weed growth also be suppressed. Haynes (1987) explained that polythene mulch helps in early growth of tomato seedling due to improved soil temperature, soil water balance, increased aeration and nutrient availability compared to the non-mulched soil.

Dudas, and Jurica, (2009) conducted an investigation to study the effects of black, white and transparent mulch films on the yield and quality parameters of medic *Ocimum basilicum.* The highest yield in terms of biomass and ethrel oil content was obtained in black film.

According to Najafabadi *et al.* (2012) plastic mulch increased minimum temperature of soil. They tried different types of mulches in garlic both organic

and inorganic, and observed plastic mulch accelerated early growth, early yield, plant height and weed control.

According to Gunasekaran and Shakila (2014) black polythene mulch had effectively increased the tuber yield of medicinal coleus (*Coleus forskholli*). Among the different tuber characters examined black polythene mulch treatment had significant effect on the number of tubers per plant, tuber length, girth, volume and fresh weight.

Sarrou *et al.* (2016) investigated the influence of mulching material in herbage yield and essential oil content in sweet basil (*Ocimum basilicum* L.) and found that, in herbage yield significantly increased in plastic mulched field, but the essential oil content got higher value in un weeded plot because of the competition of crop with the weeds.

Lei *et al.* (2014) made a research on the influence of plastic film mulching in the yield of herbaceous annual *Chrysanthemum morifolium* with two kinds of treatments, black plastic mulch and open field cultivation. The results proved that plastic mulching effectively inhibited the weed growth and increased the plant fresh weight.

Sowinska and Turczuk (2016) studied the yield difference in Oriental garlic owing to different types of mulches. The mulches used in the experiment were black and white polyethylene foil, black polypropylene agrotextile, black biodegradable foil and miscanthus chaff during second and third year of plant growth. Significant increase in yield from garlic was obtained from the plots mulched with black polypropylene agrotextile, black polyethylene foil and black biodegradable foil. Mulching with white polyethylene foil favoured the accumulation of dry matter, carotenoids, phosphorus, potassium and nitrates by the crop.

Another field experiment was conducted by Giri *et al.* (2016) to evaluate weed dynamics, herbage and oil yield of sweet basil (*Ocimum basilicum)* under

various weed management practices. The different treatments used were, weed free, manual weeding, straw mulch, polythene mulch (100 and 160 gauge thickness) and chemical control using pendimethalin. Minimum weed population and dry matter was recorded under weed free treatment followed by polythene mulch 160 gauge thickness. The Weed free treatment recorded the highest fresh herbage and oil yield followed by polythene mulch at 160 gauge. Same result was observed in terms of benefit cost ratio.

A field experiment to find out the influence of different mulching materials in weed suppression of ginger resulted that white coloured polythene mulch treatment procured the highest yield (Thankamani *et al.,* 2016). Ricotta and Masiunas (1991) studied the primary and secondary advantages of plastic mulching. The immediate influences were soil heating and warming of air just above the soil surface due to convection. Further it had added advantages like controlling weeds, increased soil moisture, decreased leaching of fertilizers, improved crop quality and improved gas exchange to microclimate.

According to Aniekwe (2015) black polythene mulch had got 100% weed suppression than other mulching materials in okra. Black polythene mulch improved plant growth, yield and quality characters significantly over un mulched plots in watermelon and this resulted in high B: C ratio of crop. The highest B: C ratio using black polythene mulch over organic mulch was also reported by Sathiyamurthy *et al.* (2017).

In 2019, Ajibola and Amujoyegbeconduted a study to find the effect of different mulches in the growth and quality of cucumber, it was observed that black polythene mulch had significantly improved the morphology and fruit components like fruit length and fruit weight.

3. *Materials and Methods*

3. MATERIALS AND METHODS

A field experiment entitled "Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]" was conducted during May - Nov 2018 at the Agronomy Farm, Department of Agronomy, College of Horticulture, Vellanikkara. The details of the materials used and methods adopted for experimentation are presented in this chapter.

3.1. Geographical specification of the experimental site

Location

The experiment was conducted at the Agronomy Farm, Department of Agronomy, College of Horticulture, Vellanikkara, Thrissur, Kerala. The field is situated at 13^{o} 32'N latitude and 76^{o} 26'E longitude, at an altitude of 40 m above mean sea level.

Soil

The texture of the experimental site is sandy clay loam and is acidic in reaction with a pH of 4.45.

Season

The experiment was conducted during the period of May -Nov 2018.

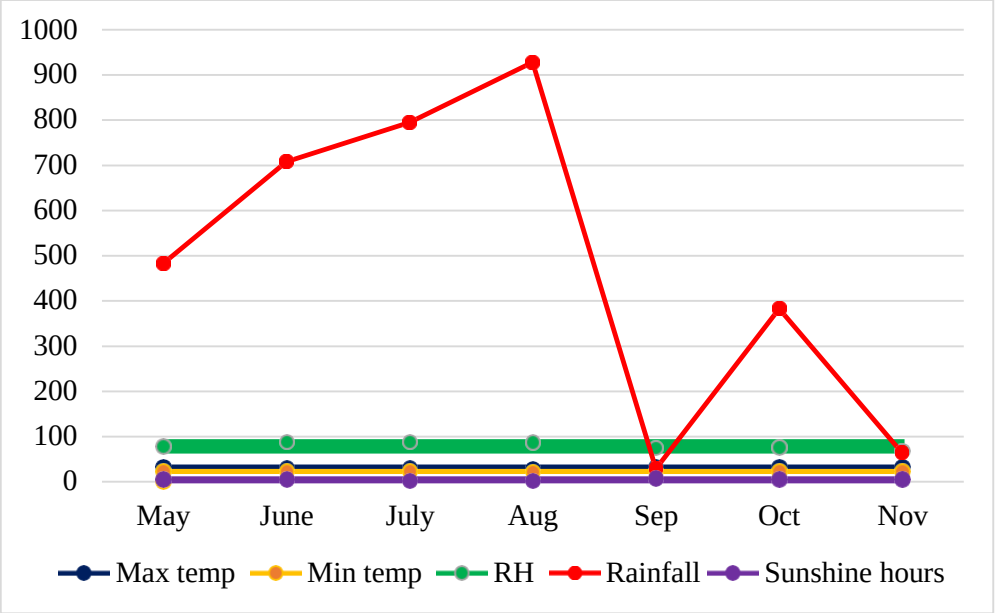


Fig. 1. Mean monthly weather data of atmospheric temperature, relative humidity, rainfall and sunshine hours during crop period

Table 1. 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	4.45	1: 2.5 soil water suspension (Jackson, 1958)
Organic carbon (%)	1.12	Walkley and Black method (Jackson, 1958)

Available N (kg/ha)	196.50	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg/ha)	22.56	Ascorbic acid reduced molybdo phosphoric blue colour method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965)
Available K (kg/ha)	194.83	Neutral normal ammonium acetate extraction and estimation using flame photometry (Jackson, 1958)

Crop

A local cultivar of *Iruveli* (*Plectranthus vettiveroides*) was used for the experiment.

Cropping history of the experimental site

The experimental area had been under cultivation with kiriyath (*Andrographis paniculata*) during the previous year.

3.2 Experimental details

The experiment was laid out in Randomized Block Design with factorial concept (FRBD) with 24 treatment combinations and three replications. The plot size was 3.0 m x 2.1 m with plant spacing of 30 cm x 30 cm. The treatment details are given in Table 2.

Treatments

Factor A: Growing condition

1. Open
2. 50% Shade

Factor B: Planting dates

1. May 15th
2. June 15th
3. July 15th
4. August 15th

Factor C: Mulching

1. No mulching
2. Organic mulch (Paddy straw) @ 5t/ha
3. Mulching with polythene sheet (30 micron silver top black bottom polythene)

Table 2. Details of treatments

Sl. No.	Treatment combinations	Treatment details
1	$A_1B_1C_1$	Open + May 15th + No mulch
2	$A_1B_1C_2$	Open + May 15th + Organic mulch @ 5t/ha
3	$A1B_1C_3$	Open + May 15th + Mulching with black polythene sheet
4	$A_1B_2C_1$	Open + June 15th + No mulch
5	$A_1B_2C_2$	Open + June 15th + Organic mulch @ 5t/ha
6	$A_1B_2C_3$	Open + June 15th + Mulching with black polythene sheet
7	$A_1B_3C_1$	Open + July 15th + No mulch
8	$A_1B_3C_2$	Open + July 15th + Organic mulch @ 5t/ha
9	$A_1B_3C_3$	Open + July 15th + Mulching with black polythene sheet
10	$A_1B_4C_1$	Open + August 15th + No mulch
11	$A_1B_4C_2$	Open + August 15th + Organic mulch @ 5t/ha
12	$A_1B_4C_3$	Open + August 15th + Mulching with black polythene sheet
13	$A_2B_1C_1$	50% Shade + May 15th + No mulch
14	$A_2B_1C_2$	50% Shade +May 15th + Organic mulch @ 5t/ha
15	$A_2B_1C_3$	50% Shade +May 15th + Mulching with black polythene sheet
16	$A_2B_2C_1$	50% Shade +June 15th + No mulch
17	$A_2B_2C_2$	50% Shade +June 15th + Organic mulch @ 5t/ha
18	$A_2B_2C_3$	50% Shade +June 15th + Mulching with black polythene sheet
19	$A_2B_3C_1$	50% Shade +July 15th + No mulch
20	$A_2B_3C_2$	50% Shade +July 15th + Organic mulch @ 5t/ha
21	$A_2B_3C_3$	50% Shade +July 15th + Mulching with black polythene sheet
22	$A_2B_4C_1$	50% Shade +August 15th + No mulch
23	$A_2B_4C_2$	50% Shade +August 15th + Organic mulch @ 5t/ha
24	$A_2B_4C_3$	50% Shade + August 15th + Mulching with black polythene sheet

Layout

The layout plan of the experimental field is given below.

N

	50 % SHADE				OPEN		
	R1	**R2**	**R3**		**R1**	**R2**	**R3**
B1	C1	C3	C2		C3	C2	C1
	C2	C1	C3		C1	C3	C2
	C3	C2	C1		C2	C1	C3
B2	C1	C3	C2		C3	C2	C1
	C2	C1	C3		C1	C3	C2
	C3	C2	C1		C2	C1	C3
B3	C1	C3	C2		C3	C2	C1
	C2	C1	C3		C1	C3	C2
	C3	C2	C1		C2	C1	C3
B4	C1	C3	C2		C3	C2	C1
	C2	C1	C3		C1	C3	C2
	C3	C2	C1		C2	C1	C3

2.1m

3 m

Fig. 2. Layout of the experiment

BI- May 15 C1- No mulch

B2- June 15 C2- organic mulch

B3- July 15 C3- Black polythene mulch

B4- August 15

Land preparation

The experimental field was initially ploughed with disc plough and then brought to a fine tilth by a cultivator. Weeds and stubbles of previous crop were removed and plots were laid out as per the layout plan. Beds were prepared and as per the treatments, mulch materials were spread uniformly on individual plots. Shade nets were erected to provide artificial light intensity. Green coloured shade nets were erected to regulate light intensity to 50%. Organic mulch (paddy straw) @ 5 t/ha and polythene mulch was applied uniformly in the respective plots.

Planting

The planting material used was rooted stem cuttings procured from AICRP on Medicinal and Aromatic plants. For this purpose, stem cuttings were grown in polythene bags one month before planting. Planting was done manually by digging small holes, at a spacing of 30 cm x 30 cm. Planting in polythene mulched plots was done by making circular holes of 5 cm diameter. The plots were irrigated immediately after planting.

Irrigation

Hose irrigation was done on the beds at 10 mm depth daily twice, in the morning and evening.

Weed management

Weed management was done as per the treatments. Hand weeding was done at 30 and 60 days after planting in the plots without any mulching.

Plant protection

No serious disease or pest attack was observed in the experimental area during the cropping period.

Harvesting

Harvesting of the crop was carried out after three months of planting by uprooting plants.

3.3 Observations recorded

3.3.1 Soil analysis

The pH, organic carbon and major nutrients were estimated before and after the experiment. Soil samples were collected, dried, powdered and passed through a 0.5 mm sieve and used for analyzing the organic carbon content, and samples passed through 2 mm sieve were used for analyzing major nutrients *viz.*, available N, available P and available K using standard procedures detailed in Table 1. The soil pH was analyzed in a soil: water suspension of 1: 2.5 using a pH meter.

3.3.2 Weather observations (on daily basis)

1. Maximum and minimum temperatures (ºC)
2. Rainfall (mm)
3. Relative humidity (%)
4. Bright sunshine hours

3.3.3 Micrometeorological observations (on weekly basis)

Soil temperature

Soil temperature at 10 cm depth was recorded daily with the help of a soil thermometer and the mean was worked out.

Soil moisture content

Soil moisture content at 0-15 cm depth was determined at weekly intervals by thermo gravimetric method using the formula

$$Pw = \frac{Wm - Wd}{Wd} \times 100$$

Pw = Percentage of soil moisture by weight

Wm = Weight of moist sample

Wd = Weight of oven dry sample

Light intensity

Light intensity inside and outside the shade net was measured in lux using a lux meter

3.3.4 Biometric observations

Five plants per treatment per replication were randomly selected and tagged and the following observations were recorded:

1. Plant height at 30 DAP, 60 DAP and at harvest
2. No. of branches at 30 DAP, 60 DAP and at harvest
3. Biomass production per plant at 30 DAP, 60 DAP and at harvest
4. Biomass production at harvest (kg/ha)
5. Root yield at harvest (kg/ha)
6. Incidence of pest and disease

Plant height

Plant height was measured from the ground level to the growing tip of plants at 30 DAP, 60 DAP and at harvest and average was expressed in cm.

Number of branches per plant

Branches arising from main stem of the tagged plants were counted at 30 DAP, 60 DAP and at harvest and the average number of branches per plant was worked out.

Fresh weight

Randomly selected plants in each treatment and replication were uprooted at 30 DAP, 60 DAP and at harvest and their fresh weight was recorded and average fresh weight per plant was calculated and expressed in grams.

Dry weight

Plants used for fresh weight determination at 30 DAP, 60 DAP and at harvest were first shade dried and then dried in hot air oven till they attained constant weight. Sample dry weights were recorded and expressed in grams.

3.3.5. Physiological, chemical and biochemical observations

1. Chlorophyll content at 30 DAP, 60 DAP and at harvest
2. Crop growth rate at 30 DAP, 60 DAP and at harvest
3. Relative growth rate at 30 DAP, 60 DAP and at harvest
4. N, P, K uptake at harvest
5. Essential oil content at harvest

Chlorophyll content

Chlorophyll content in the leaves was estimated at 30DAP, 60 DAP and at harvest using Dimethyl sulphoxide (DMSO) chlorophyll extraction technique of Hiscox and Israelstam (1979).

Crop growth rate (CGR)

Crop growth rate indicates at what rate the crop is growing *i.e.*, whether the crop was growing at a faster rate or slower rate than normal. It is expressed as gram of dry matter produced per day. Crop growth rate was calculated by the following formula and expressed as g/ day/m^2 (Watson, 1952).

$$\text{CGR (g/day/m}^2) = \frac{W_1 - W_2}{T_2 - T_1}$$

Where W_1 and W_2 are dry weights of plants at time T_1 and T_2 respectively.

Relative growth rate (RGR)

This parameter indicates rate of growth per unit dry matter. It is expressed as gram of dry matter produced by a gram of existing dry matter in a day. Relative growth rate was calculated by the following formula (Blackman, 1919) and expressed as g/g/day.

$$\text{RGR (g/g/day)} = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

Where W_1 and $W_2$are dry weights of plants at time T_1 and T_2, respectively

N, P* and *K uptake at harvest

N, P, K contents of the experimental plants was estimated by selecting five plants at random from each replication of each treatment. Whole plants were subjected to analysis. Plants were cleaned, dried in an oven dried till constant weight. Then the samples were powdered and used for analysis. The methods used for nutrient analysis are given in Table 3.

Table 3. Methods for nutrient analysis of plant samples

Sl.No.	Nutrients	Method
1.	Nitrogen	H_2SO_4 digestion, distillation and titration (Jackson, 1958)
2.	Phosphorus	9:4 HNO_3 –$HClO_4$ diacid digesion and Vanado Molybdate yellow colour method using spectrophotometer (Jackson, 1958)
3.	Potassium	9:4 HNO_3 –$HClO_4$ diacid digesion and direct reading using flame photometer (Jackson, 1958)

Essential oil content at harvest

Essential oil content was estimated by hydro distillation method, using Clevenger apparatus as per AOAC (1975) and expressed in percent. 25 g of powdered root sample was distilled for 4 hrs. and the oil yield obtained was expressed in percentage. Essential oil yield was computed by multiplying oil content with yield.

3.3.6. Observation on weeds

1. Species wise weed count at 30 DAP and 60 DAP
2. Species wise weed dry weight at 30 DAP and 60 DAP
3. Weed control efficiency
4. Weed index

Weed count

Weed count was recorded using a 50 cm x 50 cm (0.25 m^2) quadrat. The observations were recorded at 30 DAP, 60 DAP and at harvest by

placing the quadrat in each plot at random. The count was expressed in number per square meter.

Weed Dry Weight

Weeds collected from the quadrat were cleaned, air dried and oven dried at 80 ± 5ºC and dry weight was recorded in g/m^2.

Weed control efficiency

The weed control efficiency was worked out using the formula suggested by Mani *et al.* (1973).

$$WCE = \frac{(W_1 - W_2) \times 100}{W_1}$$

X = Weed dry weight in un weeded plot

Y = Weed dry weight in treated plot

Weed index

Weed index was calculated using the formula suggested by Gill and Vijaykumar (1969).

$$WI = \frac{(X-Y) \times 100}{X}$$

X = crop yield in the highest yielding plot

Y = crop yield in the treated plot

3.3.7 Economic analysis

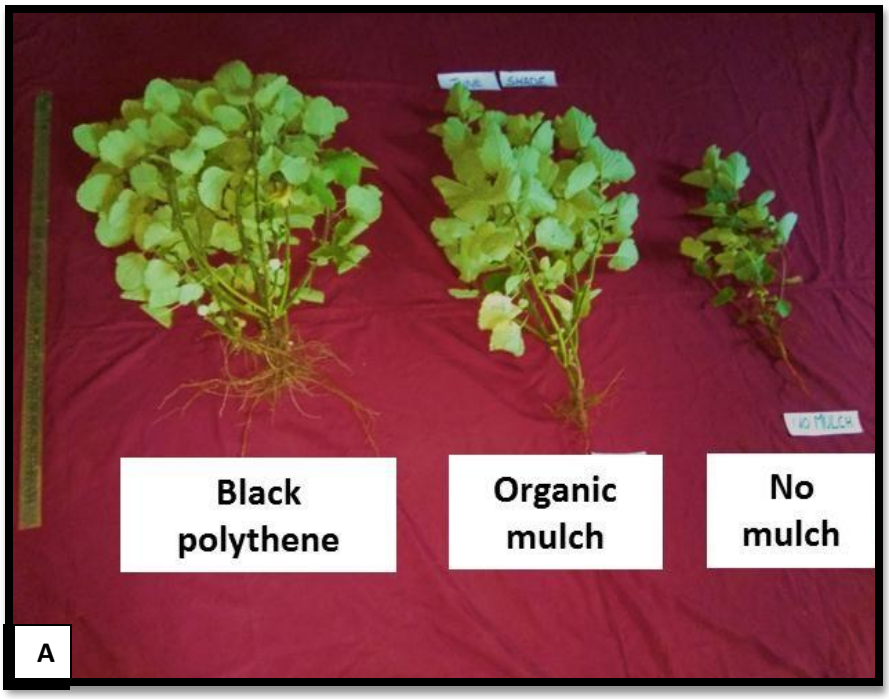
The Benefit : Cost ratio was worked out using the formula given below:

$$BCR = \frac{\text{Gross returns}}{\text{Cost of cultivation}}$$

3.3.8 Statistical analysis

The data collected were subjected to analysis of variance using the statistical package 'OP Stat' (Sheoran *et al*., 1998). The data on weed density and weed biomass which showed wide variation were subjected to square root transformation to make the analysis of variance valid (Gomez and Gomez, 1984).

Plate 1. General field view



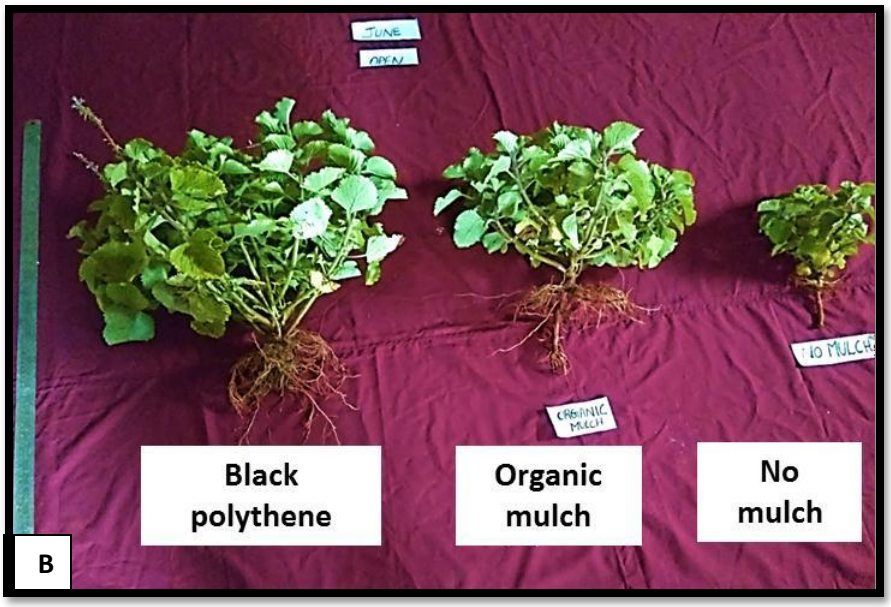


Plate 2. Effect of treatments on biomass yield: (A) shade, (B) open

4. Results

4. RESULT

4.1. Direct effect of treatments

4.1.1. Biometric observations

Plant height at 30 and 60 DAP and at harvest

The observed result showed that all the three factors such as growing condition, planting dates and mulching significantly influenced the plant height of *Plectranthus vettiveroides* at all growing stages (Table 4.). At one month after planting, the tallest plants were recorded under 50% shade (26.67 cm) whereas the height in open condition was only 18.28 cm. Among different dates of planting, June planted crop recorded taller plants (24.30 cm), and was on par with May (23.19 cm) and July (23.02cm). The smallest plants were observed in August planted crop (19.39). The plants mulched with black polythene showed the highest plant height (25.68 cm) and the shortest plants were observed in no mulch treatment (20.00 cm).

A similar trend was observed at 60 DAP. At 60 DAP, the greatest plant height (37.61 cm) was observed in shaded condition and the lowest was seen in open condition (28.26 cm). While considering the planting dates, plots planted in June recorded the tallest (36.57 cm) plants. Among different mulching conditions, black polythene recorded the taller plants (40.22 cm), followed by organic mulching (30.50 cm) and the shortest plants were noted in no weeding plots (28.10 cm).

At the time of harvest, the tallest plants were observed under shaded condition (71.12 cm). However, unlike the previous months observations, the May planted crop recorded the tallest plants (58.32 cm) and the other three planting dates were on par. The black polythene mulched plot recorded the highest plant height (63.66 cm) followed by organic mulch (49.28 cm) and no mulched treatments (45.55 cm).

Number of branches per plant at 30 and 60 DAP and at harvest

Comparing different conditions of growth, the open grown plants produced the highest number of branches (4.98) followed by shade (3.50) (Table 5.). Among different dates of planting, June planted crop had significantly higher number of branches (5.40). Among different mulch treatments, black polythene mulch got the highest number of branches (5.07) and the other two treatments were on par.

At 60 DAP, the open condition followed the similar trend of higher number of branches (7.16) than shaded condition (5.51). Also like the first month, June (7.24) planted crop had the highest number of branches and the May planted crop had the least number (5.59). The black polythene (8.02) mulch treatment had significantly higher number of branches in all the three months.

At the time of harvest, the open (13.19) planted crop recorded the highest number of branches. Regarding the date of planting, August (11.97) planted crop recorded higher number of branches and was on par with June (11.26) planted crop. Black polythene (16.48) mulching had the highest number of branches at harvest also. It was followed by organic (8.81) mulch and no mulch treatment (6.20).

Biomass yield per plant at 30 and 60 DAP and at harvest

During the first month of growth, plants grown in shaded condition showed significantly higher biomass yield per plant (17.20g) as compared to plants grown under open condition (15.58g). Among different dates of planting, June planted crop showed the highest biomass yield (24.27g). (Table 6.). Among different mulching methods tried, the highest biomass per plant was recorded in the treatment with black

polythene mulch (20.01g) which is followed by no mulch (15.70g) and organic mulch (13.45g).

At 60 DAP, shaded condition got highest biomass yield (112.09g). The highest biomass yield per plant was observed in May planted plots (120.27g) followed by June (94.87g), August (66.86g) and July (63.80g) which were on par. Mulching with black polythene sheet recorded the highest biomass yield per plant (111.70 g) and the lowest biomass yield per plant was observed in the plots without mulching (66.22 g).

At the time of harvest, the biomass yield at open and shaded condition was on par (253.09 g and 223.48 g respectively). Regarding the date of planting, the May planted crop had the highest biomass yield per plant (494.68g). Among mulching treatments, black polythene mulch (398.5g) recorded the highest biomass yield per plant followed by organic mulching (195.51g) and no mulching (120.84g).

Total biomass production at harvest

The direct effect of treatments on total biomass production of *Plectranthus vettiveroides* at harvest stage is given in Table 7. The open condition resulted in the highest biomass yield (10382 kg/ha) compared to shaded condition (7472 kg/ha). The May planted crop recorded the highest biomass yield of 15694 kg/ha. The lowest biomass yield was recorded from August planted crop (3315 kg/ha). The highest biomass yield was obtained when black polythene (16235 kg/ha) was used as mulch. Plants grown without mulch recorded the lowest biomass at harvest (4072 kg/ha).

Total root yield at harvest

Data on the influence of growing conditions, dates of planting and mulching on root yield at harvest are given in Table 7. Among the two growing conditions, open condition recorded the highest root yield (1216 kg/ha) and the lowest was under shaded

condition (985 kg/ha). Among four dates of plantings the May planted crop recorded the highest root yield (2508 kg/ha). Lower yield was in the July (414 kg/ha) planted crop which was on par with August (468 kg/ha) planted crop. Mulching treatments also recorded significant influence on root yield. Black polythene mulching resulted in the highest root yield (1786 kg/ha). Root yield in plots with organic mulch was 953 kg/ha. Plots without mulching recorded the lowest root yield of 565 kg/ha.

Table 4. Effect of treatments on plant height of *Plectranthus vettiveroides* at different growth stages

Treatments	Plant height (cm)		
	30 DAP	**60 DAP**	**Harvest**
Growing condition			
Open	18.28	28.26	34.54
50% Shade	26.67	37.61	71.12
CD (0.05)	1.47	1.39	3.45
Date of planting			
May 15	23.19	33.93	58.32
June 15	24.30	36.57	51.67
July 15	23.07	31.35	50.51
August 15	19.39	29.90	50.83
CD (0.05)	2.08	1.97	4.88
Mulching			
No mulch	20.00	28.10	45.55
Organic mulch	21.73	30.50	49.28
Black polythene mulch	25.68	40.22	63.67
CD (0.05)	1.80	1.70	4.23

Table 5. Effect of treatments on no. of branches of *Plectranthus vettiveroides* at different growth stages

Treatments	Number of branches		
	30 DAP	60 DAP	Harvest
Growing condition			
Open	4.98	7.16	13.19
50% Shade	3.50	5.51	7.81
CD (0.05)	0.44	0.50	1.02
Date of planting			
May 15	3.73	5.59	9.18
June 15	5.40	7.24	11.26
July 15	4.60	5.97	9.59
August 15	3.23	6.53	11.97
CD (0.05)	0.63	0.70	1.44
Mulching			
No mulch	3.68	5.12	6.20
Organic mulch	3.97	5.86	8.82
Black polythene mulch	5.07	8.07	16.48
CD (0.05)	0.54	0.61	1.25

Table 6. Effect of treatments on plant biomass yield of *Plectranthus vettiveroides* at different growth stages

Treatments	Plant biomass (g/plant)		
	30 DAP	**60 DAP**	**Harvest**
Growing condition			
Open	15.57	60.64	253.09
50% Shade	17.20	112.09	223.48
CD (0.05)	1.15	6.44	NS
Date of planting			
May 15	18.57	120.27	494.68
June 15	24.27	94.87	279.83
July 15	10.40	63.50	83.04
August 15	12.31	66.84	95.59
CD (0.05)	1.63	9.11	70.48
Mulching			
No mulch	15.70	66.22	120.84
Organic mulch	13.45	81.19	195.51
Black polythene mulch	20.01	111.69	398.50
CD (0.05)	1.41	7.89	61.04

Table 7. Effect of treatments total biomass and root yield of *Plectranthus vettiveroides*

Treatments	At harvest	
	Total biomass yield (kg/ha)	**Total root yield (kg/ha)**
Growing condition		
Open	10382	1216
50% Shade	7472	985
CD (0.05)	593	110
Date of planting		
May 15	15694	2508
June 15	10362	1012
July 15	6336	414
August 15	3315	468
CD (0.05)	1122	850
Mulching		
No mulch	4072	565
Organic mulch	6474	953
Black polythene mulch	16235	1786
CD (0.05)	972	380

4.1.2. Soil analysis

Soil pH

Data on the effect of different treatments on soil pH are depicted in Table 8. The pre experimental data showed that the soil is acidic in nature with a mean pH of 4.45. Compared to pre experiment soil, pH slightly increased in post experiment soil. However, there was no statistical difference among treatments.

Organic carbon

Data on the effect of growing condition, planting dates and mulching on organic carbon content of soil are depicted in (Table 8.). Compared to the pre experimental organic carbon content (1.12%), the content has increased after the experiment in all the treatments. However, between treatments no significant variation was observed with respect to organic carbon content.

Available nitrogen

The direct effect of growing condition, planting dates and mulching exhibited significant effect on soil nitrogen content after the harvest of the crop (Table 8.) Shaded condition recorded the highest available nitrogen content of 270.52 kg/ha, compared to open (229.08 kg/ha). July planted plots had significantly higher nitrogen content after harvest (282.75 kg/ha), and among mulching treatments, organic mulched plots had the highest amount of soil nitrogen content (283.38 kg/ha).

Available phosphorus

The data showing the effect of treatments on available soil phosphorus are given in Table 8. Growing condition and planting dates significantly influenced the available P content. P content was the highest under 50% shaded condition (27.14 kg/ha). August (25.56 kg/ha) and July (25.39 kg/ha) planting resulted in the higher P contents compared to other two planting dates. Mulching treatments did not exhibit any significant influence on soil P content after harvest.

Available potassium

Data on the influence of different treatments on available K are given in Table 8. No significant difference was observed with respect to available K content of soil due to growing conditions. Among planting dates, August planted plots had the highest K content (173.40 kg/ha). Among mulching treatments, organic mulch (168.57 kg/ha) treatment recorded the highest K content compared to black polythene (163.20 kg/ha) and non mulched (161.62 kg/ha) treatments.

Table 8. Effects of treatments on soil pH, organic carbon, available N, P and K after harvest of *Plectranthus vettiveroides*

Treatments	pH	Organic carbon (%)	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
Growing condition					
Open	4.76	1.32	229.08	20.64	165.39
50% Shade	4.77	1.30	270.52	27.14	163.54
CD (0.05)	NS	NS	11.46	0.26	NS
Date of planting					
May 15	4.79	1.33	256.95	21.90	164.67
June 15	4.78	1.29	244.71	22.72	160.80
July 15	4.85	1.33	282.75	25.39	158.98
August 15	4.61	1.28	214.79	25.56	173.40
CD (0.05)	NS	NS	16.21	0.27	2.72
Mulching					
No mulch	4.81	1.17	240.41	23.79	161.62
Organic mulch	4.83	1.48	283.38	24.08	168.57
Black polythene mulch	4.65	1.27	225.61	23.80	163.20
CD (0.05)	NS	NS	14.04	NS	2.35
Pre experimental	4.45	1.12	196.50	22.56	194.83

4.1.3. Micrometeorological observations

Soil temperature at 10 cm depth

Main effects of treatments on soil temperature are depicted in the Table 9. Throughout the growing period, higher soil temperature observed was in open condition compared to shaded condition. However, difference in soil temperature was not significant. Higher temperature was recorded in open condition on 1st week of planting (27.04ºC) and lower temperature was in shaded condition on 2nd week (25.24 ºC).

Regarding the different dates of planting, the effect on soil temperature was found significant in a few weeks only. Soil temperature was the highest in the first week of May planted crop (29.39 ºC). Again, a significantly higher temperature was observed in sixth week of August planted crop (27.16 ºC). The lower soil temperature recorded was in August planted crop in 2nd week (24.94 ºC).

Comparing different mulch treatments, under black polythene sheet mulch during most of the growing period higher soil temperature was observed, whereas organic mulch and no mulch condition showed almost similar soil temperatures. The highest temperature was noted in 13th week under black polythene cover (27.41 ºC) compared to organic (26.18 ºC) and no mulch treatments (25.79 ºC).

Soil moisture at 15 cm depth

Data pertaining to soil moisture content at different days after planting are given in Table 10. Growing condition influenced greatly on soil moisture content throughout the growing period. In general, higher soil moisture content was observed under shaded condition than open condition with the highest moisture content (26.89%) recorded at 2nd week under and the lowest (16.47%) observed at 11th week in open condition.

All the planting dates showed significant influence on soil moisture content. Highest soil moisture content was recorded at 6th week of June planted crop (30.32%). 1st week of May planted crop recorded lower soil moisture content (12.55%).

Regarding the effect of mulching, all the three treatments had significant effect on soil moisture. Mulched plots showed higher soil moisture content in all the observed weeks, and unmulched condition recorded the lowest. Between black polythene and organic mulch, under black polythene mulch higher soil moisture content was observed. Higher value (28.38 %) was found at 2nd week under black polythene mulch and lower soil moisture (15.12 %) in no mulch condition at 11th week.

Light intensity

Data on the influence of light intensity measured on weekly basis are given in the Table 11. Growing condition and planting dates had significant influence on light intensity. Among growing conditions, highest rate of light intensity (16470 lux) was observed during 11th week in open condition and the lowest was at 10th week in shaded condition (8652 lux). Considering the direct effect of dates of planting, 2nd week of May recorded the highest light intensity (17784 lux) and 4th week of July crop (9128 lux) recorded the lowest rate.

Table 9. Effect of treatments on soil temperature at 10 cm depth

Treatments	Soil temperature (^{0}C)												
	Weeks												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Growing condition													
Open	27.04	26.01	26.31	26.53	26.24	26.16	26.18	26.44	26.44	26.28	26.36	26.57	26.52
50% Shade	26.65	25.24	25.66	26.59	26.15	25.84	26.08	26.07	26.34	26.27	26.12	26.01	26.4
CD (0.05)	NS	0.65	NS	NS	NS	NS	NS	NS	NS	0.79	NS	NS	NS
Date of planting													
May 15	29.39	25.89	26.00	26.95	26.73	25.97	26.00	26.17	26.13	25.71	25.37	25.45	25.35
June 15	26.84	25.97	26.00	26.17	26.13	25.71	25.37	25.45	25.35	25.15	26.53	26.56	26.77
July 15	26.14	25.71	25.37	25.45	25.35	25.15	26.53	26.56	26.77	27.14	26.80	26.65	25.05
August 15	25.02	24.94	26.57	26.67	26.55	27.16	26.61	26.85	27.30	26.85	26.28	26.50	26.67
CD (0.05)	0.89	NS	NS	NS	NS	0.95	NS	NS	1.02	1.12	0.93	NS	1.02
Mulching													
No mulch	26.43	25.17	25.61	25.90	25.77	25.61	25.58	25.88	26.05	25.86	25.75	26.00	25.79
Organic mulch	26.50	25.28	25.72	26.00	25.76	25.61	25.71	25.95	25.89	26.04	26.01	25.87	26.18
Black polythene mulch	26.61	26.42	26.61	27.03	25.05	26.76	27.09	26.94	27.23	26.92	26.96	27.00	27.41
CD (0.05)	0.77	0.8	NS	NS	0.9	0.82	0.95	NS	0.88	NS	0.81	NS	0.89

Table 10. Effect of treatments on soil moisture at 15 cm depth

Treatments	Soil moisture (%)												
	Weeks												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Growing condition													
Open	25.60	23.96	19.61	19.77	21.00	22.31	19.04	19.14	20.07	21.10	16.47	17.16	17.71
50% Shade	26.26	26.89	22.71	22.85	24.35	24.56	19.70	20.19	21.41	21.93	17.63	17.22	17.09
CD (0.05)	0.40	0.65	0.97	0.77	0.74	1.11	NS	0.48	0.38	NS	0.45	NS	0.36
Date of planting													
May 15	12.55	14.29	15.36	14.61	25.44	26.84	26.92	26.62	28.11	29.25	26.50	29.05	28.65
June 15	25.86	26.83	27.32	26.97	28.47	30.32	26.16	26.86	28.31	27.75	13.82	13.92	14.31
July 15	29.65	29.31	26.74	29.27	28.34	27.19	13.82	13.92	14.31	15.96	13.75	13.53	12.76
August 15	29.65	28.26	13.23	13.38	13.43	14.40	13.19	12.67	12.65	14.10	14.14	14.25	13.88
CD (0.05)	0.56	0.92	1.37	1.07	1.04	1.57	1.47	0.68	0.54	1.31	0.63	0.52	0.51
Mulching													
No mulch	23.63	20.55	17.95	18.88	19 .55	19.97	16.43	16.92	17.48	18.80	15.12	15.20	14.79
Organic mulch	26.59	27.34	21.38	21.58	22.93	23.80	19.31	19.24	19.70	20.95	16.57	17.21	18.17
Black polythene mulch	27.57	28.38	24.15	23.47	25.54	26.54	22.38	22.84	22.05	24.79	19.47	19.14	19.23
CD (0.05)	0.49	0.80	1.18	0.95	0.90	1.36	1.27	0.59	0.47	1.14	0.56	0.45	0.45

Table 11. Effect of treatments on light intensity

Treatments	Light intensity (lux)												
	Weeks												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Growing condition													
Open	15435	15655	14908	14110	14286	14841	15128	14302	15293	15822	16469	15822	16147
50% Shade	8864	9376	9234	9199	8917	8919	8962	8885	8996	8652	9545	9291	9586
CD (0.05)	11.32	11.32	11.33	10.62	8.46	8.80	8.81	8.23	8.26	8.26	8.25	8.26	8.42
Date of planting													
May 15	16314	17784	16786	16889	12694	12772	11289	11011	12927	12199	10872	11122	11705
June 15	12718	12970	11947	11787	11099	11273	11556	10841	9709	10927	9795	11271	10098
July 15	10416	10168	9711	9128	9333	9658	10207	9553	10580	11146	11514	11176	11106
August 15	9152	9141	9841	1012	10281	10815	11129	10968	11362	11676	11848	11657	10555
CD (0.05)	15.583	16.01	16.03	15.02	11.96	12.45	12.46	11.65	11.62	11.69	11.67	11.69	11.91
Mulching													
No mulch	13181	13822	13239	12959	12626	12853	12856	12428	12820	12708	13704	13178	13805
Organic mulch	11875	12058	11465	11058	10903	11168	11459	10904	11653	11896	12590	12149	12493
Black polythene mulch	11394	11667	11509	10945	11276	11618	11821	11448	11960	12108	12728	12342	12300
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.4. Physiological, chemical and biochemical observations

Total chlorophyll content at 30 DAP, 60 DAP and at harvest

Data depicting the influence of different growing conditions, dates of planting and mulching on total chlorophyll content at 30 DAP, 60 DAP and at harvest are presented in Table 12. Comparing the two growing conditions, at 30 DAP, there was no significant difference in total chlorophyll content. But the total chlorophyll content was significantly higher in shaded condition during 60 and at harvest. The highest chlorophyll content was observed under 50% shaded condition during 60 DAP and at harvest (1.77 mg/g and 2.26 mg/g respectively).

Planting dates significantly influenced the total chlorophyll content at 30 DAP, 60 DAP and at harvest. At 30 DAP, total chlorophyll content was significantly higher in the crop planted in August (1.44 mg/g and minimum recorded in the crop planted in May (1.10 mg/g). At 60 DAP higher total chlorophyll content recorded was in June planting (1.98 mg/g). At harvest higher chlorophyll content was recorded in June planted crop (2.16 mg/g) and was on par with May planted crop (2.15 mg/g).

Mulching had significant effect on chlorophyll content of the crop. Black polythene sheet mulching recorded higher chlorophyll content (1.25 mg/g) and was on par with no mulch condition (1.14 mg/g) at 30 DAP. Crop planted with organic mulching recorded the lowest chlorophyll content (0.86 mg/g). At 60 DAP plants with black polythene mulch recorded higher total chlorophyll content (1.74 mg/g) and was on par with no mulch condition (1.66 mg/g). Chlorophyll content was lowest in plants grown with organic mulch (1.46 mg/g). Mulching treatments did not made any significant effect on total chlorophyll content at harvest.

Crop growth rate

Data on crop growth rate (CGR) at different growing condition during 30 and 60 DAP and at harvest are presented in Table 13. At 30 DAP CGR was not influenced by growing condition. However, during 60 DAP, plants grown under shade showed the highest CGR (1.636 g/m^2/day) than open condition (0.747 g/m^2/day). At harvest stage, the growth rate of plants grown under open condition (3.57 g/m^2/day) was significantly higher than the plants grown under shade (2.24 g/m^2/day).

Planting dates significantly influenced the CGR at 30, 60 DAP and at harvest with higher growth rates in June planting (0.421 g/m^2/day) during 30 DAP and in May planting during 60 DAP (1.733 g/m^2/day) and at harvest (7.02 g/m^2/day) respectively.

Considering the mulching effect, black polythene mulch recorded the highest CGR throughout the crop growth (0.349 g/m^2/day, 1.562 g/m^2/day and 5.34 g/m^2/day at 30, 60 DAP and at harvest respectively). At 30 DAP the lowest CGR was recorded by no mulch (0.273 g/m^2/day) treatment. At 60 DAP also no mulch recorded lowest CGR (0.859 g/m^2/day) and at harvest CGR in organic mulch treatment (2.17 g/m^2/day) was on par with no mulching treatment (1.21 g/m^2/day).

Relative growth rate

Growing condition not exhibit any significant influence on crop growth rate at 30 DAP. However, at 60 DAP and at harvest there was significant influence. At 60 DAP and at harvest, the highest RGR was recorded by plants under shade (0.028 g/g/day) and by open (0.015 g/g/day) condition respectively.

Considering the planting dates, RGR had significant influence at 30, 60 DAP and at harvest with highest RGR in June planting (0.36 g/g/day) at 30 DAP.

At 60 DAP and at harvest May planting resulted in higher RGR (0.026 g/g/day and 0.021 g/g/day respectively).

Mulching significantly influenced the relative growth rate. During 30 DAP (0.033 g/g/day) and at harvest (0.015 g/g/day) plants under black polythene mulch showed higher RGR. However at 60 DAP, RGR was higher in organic mulched (0.026 g/g/day) plot and was on par with black polythene (0.024 g/g/day).

N, P and K uptake at harvest

The direct effect of growing condition, dates of planting and mulching on plant uptake of nutrients are depicted in the Table 14. Nitrogen uptake was the highest in plants grown under open condition (252.62 kg/ha). Comparing date of planting nitrogen uptake was the highest in May planted crop (405.99 kg/ha). Among different mulching treatments the highest nitrogen uptake was observed in black polythene (440.24 kg/ha) mulched crop followed by organic (153.89 kg/ha) and no mulch (88.24 kg/ha).

Growing condition, date of planting and mulching had significant effect on P uptake. P uptake was the highest in plants grown under open condition (41.84 kg /ha). Regarding date of planting P uptake was the highest in May planted crop (86.18 kg/ha). Among different mulching treatments black polythene mulch resulted in the highest P uptake (86.39 kg/ha).

Potassium uptake was not significantly influenced by growing condition. Planting dates had influence on potassium uptake of crop. Among different dates of planting K uptake was the highest in May planted crop (188.62 kg/ha). Potassium uptake was found influenced by mulching treatments also. Black polythene mulching resulted in highest K uptake (204.26 kg/ha) and the lowest with no mulch treatment (55.12 kg/ha).

Essential content (%)

The results on essential oil content in Plectranthus indicated that growing condition, planting dates and mulching had significant effect on essential oil content (Table 14). Essential oil content found to be the highest (1.77%) under open condition. 50 % shaded condition recorded essential oil content of 1.31 %. Comparing different dates of planting, oil content was found maximum (1.73%) in May planting and minimum was in August (1.37%) planting. Among different mulches, the highest value (1.81%) was recorded in black polythene mulching and minimum was recorded in no mulch condition (1.32%).

Table 12. Effect of treatments on total chlorophyll at different growth stages

Treatments	Total chlorophyll (mg/g)		
	30 DAP	60 DAP	Harvest
Growing condition			
Open	1.04	1.46	1.58
50% Shade	1.13	1.77	2.26
CD (0.05)	NS	0.18	0.21
Date of planting			
May 15	1.10	1.64	2.16
June 15	0.97	1.98	2.15
July 15	0.83	1.41	1.67
August 15	1.44	1.45	1.70
CD (0.05)	0.18	0.25	0.29
Mulching			
No mulch	1.14	1.66	1.88
Organic mulch	0.86	1.46	1.92
Black polythene mulch	1.25	1.74	1.95
CD (0.05)	0.16	0.22	NS

Table 13. Effect of treatments on CGR (g/m^2/day) and RGR (g/g/day) in *Plectranthus vettiveroides* at different growth stages

Treatments	0 - 30 DAP		30 - 60 DAP		60 DAP - Harvest	
	CGR	RGR	CGR	RGR	CGR	RGR
Growing condition						
Open	0.290	0.030	0.747	0.018	3.570	0.015
50% Shade	0.281	0.029	1.636	0.028	2.240	0.008
CD (0.05)	NS	NS	0.109	0.002	0.910	0.002
Date of planting						
May 15	0.324	0.330	1.733	0.026	7.020	0.021
June 15	0.421	0.360	1.202	0.019	3.520	0.013
July 15	0.181	0.024	0.906	0.025	0.470	0.006
August 15	0.217	0.027	0.926	0.024	0.610	0.007
CD (0.05)	0.028	0.002	0.155	0.002	1.280	0.003
Mulching						
No mulch	0.273	0.029	0.859	0.020	1.210	0.009
Organic mulch	0.234	0.027	1.155	0.026	2.170	0.011
Black polythene mulch	0.349	0.033	1.562	0.024	5.340	0.015
CD (0.05)	0.025	0.001	0.134	0.002	1.110	0.002

Table 14. Effect of treatments on N, P and K uptake and essential oil content of *Plectranthus vettiveroides* at harvest

Treatments	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)	Essential oil (%)
Growing condition				
Open	252.62	59.50	108.82	1.77
50% Shade	202.29	41.84	118.60	1.31
CD (0.05)	30.51	9.00	NS	0.04
Date of planting				
May 15	405.99	86.18	188.62	1.73
June 15	279.74	57.99	128.89	1.60
July 15	150.57	38.08	91.60	1.46
August 15	73.53	20.44	45.24	1.37
CD (0.05)	43.14	12.43	34.26	0.06
Mulching				
No mulch	88.24	22.30	55.12	1.32
Organic mulch	153.89	43.33	81.39	1.49
Black polythene mulch	440.24	86.39	204.26	1.81
CD (0.05)	37.36	11.02	29.67	0.05

4.1.5. Observations on weeds

Weed count

Data on direct effect of treatments on weed count and weed dry weight, are given in Tables 15, 16, and 17.

Broad leaf weeds

At 30 DAP, growing condition, different dates of planting and mulching exhibited significant influence on count of broad leaved weed (Table 15). The higher weed count observed under open condition (45.33 no./m^2) while shaded condition recorded weed count of 27.3 no./m^2. Among different dates of planting, the lowest weed count was noticed in plots of August planting (21.06 no./m^2) and the highest was in May planted crop (43.28 no./m^2). Mulching had significant effect on weed count and black polythene sheet recorded lower weed count (0.83 no./m^2) followed by organic mulching (41.83 no./m^2). Higher weed count was observed in plots without any mulch (66.29 no./m^2).

At 60 DAP also, effect of growing condition on total weed count was significant and lower weed count was observed in shaded condition (17.58 no./m^2). Dates of planting and mulching also exhibited significant influence on weed count. August planted plots recorded the lower weed count (18.56 no./m^2) whereas May planting (30.94 no./m^2) resulted in higher broad leaf weed count. At 60 DAP also black polythene sheet mulch had similar effect in preventing weed establishment and recorded the lowest weed count of 1.25 no./m^2. Higher Weed count was noticed in plots without mulch (43.5 no./m^2).

During harvest, the shaded condition had much lower weed count than open condition. When comparing planting dates, lower weed count was in June (6.94 no./m^2). Black polythene mulch continued its superiority in preventing weed growth till harvest stage. At harvest stage the broad leaf weed count in plots with black polythene mulching was 0.25 no./m^2 as compared to 19.58 no./m^2 inorganic mulch and 28.37 no./m^2 in no mulch plots.

Grasses

The count of grass weeds did not showed any significant difference due to growing condition and dates of planting at any stage of observation (Table 16.) However, mulching significantly influenced the grass weed count with the lowest grass weed count in plots with black polythene mulching.

Sedges

The overall count of sedge weeds was very less in the experiment plots (Table 17). At 30 DAP higher sedge count was observed under open (0.83 no./m^2) condition compared to shade (0.25 no./m^2) At 60 DAP and at harvest, the influence of growing condition was non significant. The date of planting had no significant influence on sedge count. Among mulching treatments the lowest count of sedges were noticed in plots with polythene mulching.

Total weed count

At 30 DAP, the highest count of total weeds were observed under open condition (47.44 no./m^2) while shaded condition recorded weed count of 28.25 no./m^2. Among different dates of planting, the highest weed count was noticed in plots of May planting (45.44 no./m^2) and the lowest was in August month crop (22.28 no./m^2). Among different mulch treatments, black polythene sheet recorded

lower weed count (0.83 no./m^2) and higher weed count was observed in plots without any mulch (69.33 no./m^2).

At 60 DAP also, effect of shading on total weed count was significant and weed count observed in shaded condition was 18.19 no./m^2. At 60 DAP also August planted plots recorded the lower weed count (19.00 no./m^2) whereas May planting (31.61 no./m^2) resulted in higher broad leaf weed count. Black polythene sheet mulch had high efficiency in preventing weed establishment and recorded the lowest weed count of 1.25 no./m^2. Higher weed count was noticed in plots without mulch (44.88 no./m^2).

At harvest stage, the shaded condition observed lower weed count (10.75 no./m^2) than open condition (22.75 no./m^2). Among the four planting dates, lower weed count was on August (12.50 no./m^2). The total weed count in plots with black polythene mulching was 0.25 no./m^2 as compared to 29.92 no./m^2in plots without any mulch.

Weed dry weight

Broad leaf weeds

Growing condition, different dates of planting and mulching showed significant influence on weed dry weight. At 30 DAP weed dry weight was higher under open condition (16.18 g/m^2). The effect of date of planting on weed dry weight was not significant. Among mulches, black polythene mulch treatment showed the lowest weed dry weight (1.15 g/m^2).

At 60 DAP, weed dry weight was higher in open condition (12.01 g/m^2) than in shaded condition (7.67 g/m^2). Planting dates had significant influence on dry weight of broad leaf weeds at 60 DAP. The lower broad leaf weed weight was

observed in July planting followed by June planting. The highest dry weight of broad leaved weeds was in no mulch condition (71.26 g/m^2) and the lowest was under black polythene mulching (8.66 g/m^2). At harvest also, open condition recorded highest weed dry weight (8.50 g/m^2). Among different dates of planting, the lowest broad leaf weed dry weight was observed in July planting (4.50 g/m^2).

Grasses

The influence of growing condition on weed dry weight of grasses was significant at 30 DAP. Higher weed dry weight was observed in open condition (3.98 g/m^2) compared to shade (0.74 g/m^2). At 60 DAP and at harvest the effect of growing condition was found non significant. Planting dates had no significant influence on dry weight of grass weeds. However, mulches had significant influence. Highest weed growth was observed in no mulched plots at 30 DAP (4.98 g/m^2), 60 DAP (0.61 g/m^2) and at harvest (0.38 g/m^2).

Sedges

The influence of growing condition on the dry weight of sedge weeds was found significant at 30 DAP only. Among growing conditions open plots had significantly higher sedge weed dry weight (1.34 g/m^2). The date of planting was non significant with respect to sedge weed dry weight. Sedge weed dry weight was higher in non mulched plots compared to mulched plots.

Total weed dry weight

Similar to the species wise dry weight, at 30 DAP total weed dry weight was higher under open condition (21.50 g/m^2). The May planted plots exhibited higher weed dry weight at 30 DAP (21.7 g/m^2) and August had the lowest (11.81 g/m^2). Among mulches, black polythene mulch treatment showed the lowest weed dry weight (0.41 g/m^2).

Similarly at 60 DAP, weed dry weight was higher in open condition (12.42 g/m^2) than in shaded condition (7.97 g/m^2). The lower dry weed weight was observed in July planting (7.99 g/m^2). The lowest dry weight among mulches was under black polythene mulching (0.65 g/m^2) and the highest dry weight was in no mulch condition (16.98 g/m^2).

At harvest, open condition recorded highest weed dry weight recorded was under open (8.77 g/m^2), May planting (8.00 g/m^2), and no mulching condition (11.64 g/m^2) and the lowest being in shade (4.31 g/m^2), July planting (4.50 g/m^2) and polythene mulch (0.08 g/m^2),.

Table 15. Effects of treatments on count and dry weight of broad leaved weeds

Treatments	Count of broad leaf weeds (no./m^2)			Dry weight of broad leaf weeds (g/m^2)		
	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest
Growing condition						
Open	5.83 (45.33)	5.01 (31.28)	4.19 (21.78)	3.67 (16.18)	3.26 (12.01)	2.79 (8.50)
50% Shade	4.62 (27.31)	3.84 (17.58)	3.00 (10.36)	3.13 (11.04)	2.70 (7.67)	2.10 (4.14)
CD (0.05)	0.36	0.28	0.21	0.25	0.23	0.13
Date of planting						
May 15	5.71 (43.28)	4.92 (30.94)	4.15 (22.11)	3.58 (14.93)	3.14 (11.04)	2.64 (7.62)
June 15	5.53 (39.94)	4.57 (26.89)	3.66 (6.94)	3.52 (14.74)	2.91 (9.42)	2.48 (6.67)
July 15	5.50 (41.00)	4.25 (21.33)	3.36 (13.56)	3.38 (13.82)	2.73 (7.72)	2.16 (4.50)
August 15	4.16 (21.06)	3.95 (18.56)	3.20 (11.67)	3.11 (10.95)	3.16 (11.19)	2.50 (6.48)
CD (0.05)	0.52	0.39	0.29	NS	0.32	0.18
Mulching						
No mulch	8.01 (66.29)	6.54 (43.50)	5.27 (28.37)	4.89 (23.76)	4.05 (16.18)	3.39 (11.12)
Organic mulch	6.42 (41.83)	5.35 (28.54)	4.43 (19.58)	4.17 (16.66)	3.67 (12.69)	2.91 (7.75)
Black mulch	1.25 (0.83)	1.38 (1.25)	1.08 (0.25)	1.15 (0.41)	1.24 (0.65)	1.03 (0.08)
CD (0.05)	0.45	0.34	0.25	0.31	0.28	0.15

** $\sqrt{x+0.5}$ transformed values, original values are given in parenthesis

Table 16. Effects of treatments on count and dry weight of grasses

Treatments	Count of grasses (no./m^2)			Dry weight of grasses (g/m^2)		
	30 DAP	**60 DAP**	**Harvest**	**30 DAP**	**60 DAP**	**Harvest**
Growing condition						
Open	1.40 (1.28)	1.15 (0.44)	1.18 (0.50)	1.77 (3.98)	1.11 (0.30)	1.08 (0.20)
50% Shade	1.24 (0.69)	1.16 (0.44)	1.11 (0.31)	1.25 (0.74)	1.10 (0.25)	1.05 (0.13)
CD (0.05)	NS	NS	NS	0.406	NS	NS
Date of planting						
May 15	1.40 (1.33)	1.21 (0.61)	1.23 (0.67)	1.81 (4.56)	1.16 (0.43)	1.12 (0.34)
June 15	1.30 (0.94)	1.19 (0.50)	1.10 (0.28)	1.68 (3.19)	1.15 (0.40)	1.04 (0.09)
July 15	1.30 (0.89)	1.11 (0.33)	1.11 (0.28)	1.34 (1.06)	1.07 (0.19)	1.03 (0.07)
August 15	1.26 (0.78)	1.10 (0.33)	1.15 (0.39)	1.22 (0.62)	1.04 (0.09)	1.07 (0.17)
CD (0.05)	NS	NS	NS	NS	NS	NS
Mulching						
No mulch	1.60 (1.92)	1.32 (0.96)	1.29 (0.83)	2.06 (4.98)	1.22 (0.61)	1.15 (0.38)
Organic mulch	1.34 (1.04)	1.14 (0.37)	1.14 (0.37)	1.48 (2.11)	1.09 (0.23)	1.05 (0.12)
Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
CD (0.05)	0.24	0.20	0.17	0.50	0.13	0.09

** $\sqrt{x+0.5}$ transformed values, original values are given in parenthesis

Table 17. Effects of treatments on count and dry weight of sedges

Treatments	Count of sedges (no./m^2)			Dry weight of sedges(g/m^2)		
	30 DAP	**60 DAP**	**Harvest**	**30 DAP**	**60 DAP**	**Harvest**
Growing condition						
Open	1.28 (0.83)	1.09 (0.22)	1.17 (0.47)	1.31 (1.34)	1.04 (0.10)	1.03 (0.07)
50% Shade	1.10 (0.25)	1.07 (0.17)	1.03 (0.08)	1.09 (0.24	1.02 (0.04)	1.01 (0.03)
CD (0.05)	0.14	NS	0.11	0.41	NS	NS
Date of planting						
May 15	1.26 (0.83)	1.02 (0.06)	1.08 (0.22)	1.46 (2.27)	1.01 (0.02)	1.02 (0.04)
June 15	1.09 (0.22)	1.09 (0.22)	1.06 (0.17)	1.03 (0.06)	1.04 (0.10)	1.01 (0.03)
July 15	1.24 (0.67)	1.16 (0.39)	1.10 (0.28)	1.21 (0.59)	1.04 (0.09)	1.02 0.03)
August 15	1.17 (0.44)	1.05 (0.17)	1.16 (0.47)	1.10 (0.23)	1.03 (0.08)	1.05 (0.10)
CD (0.05)	NS	NS	NS	NS	NS	NS
Mulching						
No mulch	1.39 (1.12)	1.16 (0.42)	1.26 (0.71)	1.35 (1.13)	1.08 (0.18)	1.07 (0.14)
Organic mulch	1.17 (0.50)	1.07 (0.17)	1.05 (0.12)	1.25 (1.24)	1.01 (0.03)	1.01 (0.02)
Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
CD (0.05)	0.17	0.09	0.14	0.50	0.05	0.04

** $\sqrt{x+0.5}$ transformed values, original values are given in parenthesis

Table 18. Effects of treatments on total weed count and dry weight

Treatments	Total weed count (no./m^2)			Total weed dry weight (g/m^2)		
	30 DAP	60 DAP	Harvest	30 DAP	60 DAP	Harvest
Growing condition						
Open	5.95 (47.44)	5.06 (31.94)	4.27 (22.75)	4.09 (21.50)	3.31 (12.42)	2.82 (8.77)
50% Shade	4.69 (28.25)	3.89 (18.19)	3.04 (10.75)	3.25 (12.02)	2.74 (7.97)	2.13 (4.31)
CD (0.05)	0.37	0.28	0.21	0.38	0.23	0.13
Date of planting						
May 15	5.83 (45.44)	4.97 (31.61)	4.23 (23.00	4.09 (21.77)	3.19 (11.49)	2.69 (8.00)
June 15	5.60 (41.11)	4.62 (27.61)	3.69 (17.39	3.82 (17.99)	2.97 (9.92)	2.50 (6.79)
July 15	5.60 (42.56)	4.32 (22.06)	3.41 (14.11)	3.56 (15.48)	2.77 (7.99)	2.18 (4.61)
August 15	4.27 (22.28)	3.99 (19.00)	3.29 (12.50)	3.21 (11.81)	3.18 (11.36)	2.54 (6.75)
CD (0.05)	0.52	0.40	0.29	0.53	0.33	0.19
Mulching						
No mulch	8.18 (69.33)	6.64 (44.88)	5.41 (29.92)	29.86 (29.86)	4.14 (16.98)	3.47 (11.64)
Organic mulch	6.54 (43.38)	5.40 (29.08)	4.48 (20.08)	4.47 (20.01)	3.70 (12.95)	2.93 (7.89)
Black polythene mulch	1.25 (0.83)	1.39 (1.25)	1.08 (0.25)	1.15 (0.41)	1.24 (0.65)	1.03 (0.08)
CD (0.05)	0.45	0.34	0.25	0.46	0.28	0.16

4.1.6. Weather observations

Various weather parameters experienced in the field from planting to harvest are presented in Table 19. The weather parameters like maximum and minimum temperature, relative humidity, rainfall and bright sunshine hours were recorded on daily basis and converted to weekly basis and presented.

Maximum and minimum temperature

The average maximum temperature ranged from 27.10 ºC to 33.66 ºC in open condition and 25.90ºc to 32.46ºc in shaded condition. The highest maximum temperature was recorded on 26th week in open and lowest on 14th week in the shaded condition. The minimum temperature ranged from 21.67 ºC to 23.79 ºC in open condition and 21.47 ºC to 23.87 ºC in shaded condition.

Relative Humidity

The forenoon relative humidity ranged from 79.14 % to 100 % in open condition and in shade it ranged from 81.14 % to 100 %. In open condition, higher forenoon relative humidity of 100 % was observed in 7th, 9th, 10th, 11th, 13th, and 14th weeks and the lowest in 24th week.

The lowest afternoon relative humidity under open condition and shaded condition was at 24th week (44.86 % and 47.56 % respectively). The higher afternoon relative humidity was observed during 9th and 10th weeks in both open and shade which was 100%.

Rainfall

The year 2018 was a year which received copious rainfall. The highest cumulative rainfall observed was 629 mm in the 14th week. During weeks of 17, 18, 19

and 26 no rain was received. The total rainfall received during the cropping period was 3226.2 mm.

Bright sunshine hours

The 17th week received maximum bright sunshine hours (9.57) and 10th week received minimum sunshine hours (0.09).

Table 19. Weekly weather data during cropping period

Weeks	Maximum temperature (°C)		Minimum temperature(°C)		Forenoon Relative humidity (%)		Afternoon Relative humidity (%)		Rainfall (mm)	Bright sunshine hours
	open	shade	open	shade	open	shade	open	shade		
1	33.22	32.02	22.57	22.37	91.43	93.43	63.71	66.41	74.90	4.93
2	32.44	31.24	22.26	22.06	90.00	92.00	71.57	74.27	113.40	3.47
3	30.43	29.23	24.07	23.87	92.71	94.71	81.00	83.70	194.50	2.10
4	30.29	29.09	23.56	23.36	96.00	98.00	81.57	84.27	230.70	1.71
5	29.36	28.16	23.54	23.34	97.00	99.00	82.29	84.99	236.00	1.27
6	28.34	27.14	22.53	22.33	96.00	98.00	86.86	89.56	142.70	1.64
7	30.19	28.99	22.69	22.49	100.00	100.00	76.43	79.13	98.00	2.99
8	31.46	30.26	22.81	22.61	93.71	95.71	93.71	100.00	65.50	3.49
9	28.01	26.81	21.70	21.50	100.00	100.00	100.00	100.00	304.20	0.33
10	28.80	27.60	22.09	21.89	100.00	100.00	100.00	100.00	256.10	0.09
11	29.54	28.34	23.11	22.91	100.00	100.00	76.71	79.41	110.50	0.99
12	29.93	28.73	23.09	22.89	96.50	100.00	75.71	78.41	103.60	1.51
13	28.70	27.50	22.04	21.84	100.00	100.00	84.00	86.70	208.60	0.41
14	27.10	25.90	21.67	21.47	100.00	100.00	89.43	97.20	629.00	0.44
15	30.60	29.40	22.17	21.97	94.86	96.86	69.71	72.41	12.90	6.07
16	30.21	29.01	22.73	22.53	94.29	96.29	67.86	70.56	32.60	2.87
17	31.56	30.36	21.99	21.79	91.71	93.71	59.14	61.84	0.50	9.57
18	31.91	30.71	22.33	22.13	90.29	92.29	60.57	63.27	0.00	7.61
19	32.50	31.30	22.40	22.20	91.71	93.71	57.29	59.99	0.90	7.63
20	33.57	32.37	22.46	22.26	91.43	93.43	62.71	65.41	27.60	4.96
21	33.23	32.03	22.63	22.43	88.14	90.14	67.14	69.84	131.00	4.86
22	32.49	31.29	24.00	23.80	95.43	100.00	70.43	73.13	65.70	5.01
23	31.96	30.76	23.17	22.97	95.71	100.00	69.71	72.41	146.50	4.81
24	33.33	32.13	22.33	22.13	79.14	81.14	44.86	47.56	39.80	7.81
25	32.76	31.56	23.79	23.59	84.57	86.57	54.43	57.13	1.00	6.13
26	33.66	32.46	22.83	22.63	81.14	83.14	49.14	51.84	0.00	7.17

4.1.7. Crop weather correlations

Simple linear correlation between important morphological, yield and quality parameters and mean weekly weather parameters like surface air temperature, relative humidity (forenoon and afternoon), rainfall and sunshine hours were carried out and the coefficients are presented in Tables 20, 21, 22, 23, 24, 25, 26 and 27

Plant height

A negative correlation was observed between plant height and maximum temperature during all crop stages. Minimum temperature also had a negative correlation with the height which was significant at 2^{nd} and 8^{th} week. Forenoon relative humidity had negative correlation during the first week, but later on it had positive correlation. Afternoon relative humidity also followed the same trend. Rainfall did not exhibit any effect on plant height. Light intensity has got significant negative correlation with plant height. Correlation of soil temperature and soil moisture with plant height was non significant.

Number of branches per plant

Number of branches had significant positive correlation with maximum temperature during the initial stages. However, towards later stages correlation was non significant. In general, minimum temperature had non significant correlation on number of branches. Fore noon and afternoon relative humidity was negatively correlated with number of branches. Rainfall had a negative correlation, but was not significant. Light intensity, soil temperature and soil moisture exhibited positive correlation with number of branches of *Plectranthus*.

Biomass yield

Correlation between total biomass yield ad maximum temperature was not significant during initial period, but later at harvest stage, correlation became positive. Minimum temperature has got positive correlation with biomass yield at initial stage, but later on it was negatively correlated. Forenoon and afternoon relative humidity was initially negatively correlated with biomass yield, but later at active growth stage and at harvest stage, it was positively correlated. Rainfall had positive correlation with biomass yield. The correlation of light intensity was non significant on total biomass yield. Soil temperature was positively correlated with total biomass yield during initial growth stages, but later on it becomes non significant. Soil moisture correlated negatively initially, but later it was a significant positive correlation.

Root yield

At initial stages of plant growth, maximum temperature was correlated positively correlated with root yield but later on the correlation was negative. Minimum temperature related positively at vegetative stage. But at harvesting stage, the relation was negative. Forenoon and afternoon relative humidity was initially negatively correlated with root yield but later on the relation was positive excepting the initial two weeks, rainfall had positive correlation with total root yield. Bright sun shine hours had negative correlation with total root yield except for first weeks. Light intensity initially had positive correlation with root yield. But later stages it become non significant. Soil temperature also positively correlated with total root yield. But later on it becomes non significant. Soil moisture correlated negatively at first two weeks, but later it had significant positive correlation.

Essential oil content

Maximum temperature positively influenced essential oil content during the vegetative stages and negatively during final stages. The effect of minimum temperature was not significant. Generally forenoon and afternoon relative

humidity influenced positively with essential oil content except. The correlation of oil content with rainfall was positive. The light intensity did not significantly influenced significantly the essential oil content. The soil temperature and soil moisture has got a positive correlation with essential oil content.

Table 20. Correlation between T max and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	-0.08	-0.19	-0.72**	-0.60**	-0.35	-0.29	-0.37	-0.36	-0.38	-0.31	-0.44*	-0.41*	-0.40
Number of branches	0.01	0.10	0.42**	0.44**	0.26*	0.29	0.27	0.27*	0.22*	0.14	0.27	0.19	0.25
Total Biomass yield	0.55**	0.29	0.17	0.15	-0.24	-0.27	-0.35	0.15	0.49*	0.36	0.50*	0.421*	0.52**
Total root yield	0.76**	0.56**	0.29	0.15	0.13	0.19	0.31	0.00	0.61**	0.41*	0.64**	0.58**	0.73**
Essential oil content	0.44*	0.33	0.27	0.05	0.16	0.19	0.27	0.07	0.23	0.30	0.417*	0.36	0.46*

Table 21. Correlation between T min and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	-0.07	-0.44*	-0.02	-0.05	0.01	-0.16	-0.21	-0.43*	-0.17	-0.21	-0.10	-0.16	-0.32
Number of branches	0.07	0.29	0.08	0.10	0.05	0.17	0.18	0.24	0.21	0.16	0.02	0.20	0.19
Total Biomass yield	0.31	0.19	0.46*	0.48*	0.39	0.23	0.25	0.22	-0.42*	-0.36	0.43*	-0.14	-0.45*
Total root yield	0.32	0.19	0.68**	0.56**	0.66**	0.49*	0.30	0.18	0.42*	-0.33	0.68**	0.02	0.54**
Essential oil content	0.30	0.23	0.46*	0.45*	0.40	0.27	0.27	0.26	-0.36	-0.30	0.45*	-0.08	-0.39

Table 22. Correlation between forenoon relative humidity and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	-0.01	0.06	0.05	0.47*	0.15	0.14	0.23	0.31	0.31	0.26	0.18	0.32	0.23
Number of branches	0.02	-0.07	-0.07	-0.37	-0.19	-0.18	-0.15	-0.23	-0.05	-0.02	-0.19	-0.26	-0.19
Total Biomass yield	-0.55**	-0.42*	-0.22	0.23	0.26	0.16	0.50*	0.26	0.30	0.28	0.50*	0.49*	0.56**
Total root yield	-0.78**	-0.69**	-0.49*	0.19	0.16	0.02	0.54**	0.16	0.46*	0.45*	0.55**	0.58**	0.69**
Essential oil content	-0.55**	-0.44*	-0.26	0.14	0.20	0.10	0.44*	0.18	0.28	0.27	0.45*	0.41*	0.50*

Table 23. Correlation between afternoon relative humidity and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	-0.04	0.00	0.34	0.15	0.09	0.12	0.29	0.29	0.19	0.20	0.21	0.28	0.22
Number of branches	0.02	-0.10	-0.29	-0.12	-0.10	-0.15	-0.21	-0.20	-0.08	-0.08	-0.17	-0.22	-0.23
Total Biomass yield	-0.52**	-0.12	0.47*	0.33	0.28	0.30	0.46*	0.53**	0.49*	0.47*	0.53**	0.54**	0.50*
Total root yield	-0.76**	-0.38	0.54**	0.28	0.18	0.20	0.51*	0.77**	0.72**	0.65**	0.64**	0.68**	0.65**
Essential oil content	-0.51*	-0.16	0.40	0.28	0.23	0.25	0.39	0.48*	0.46*	0.44*	0.48*	0.48*	0.45*

Table 24. Correlation between Rainfall and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Wee 10	Week 11	Week 12	Week 13
Plant height	-0.11	-0.02	0.13	0.14	0.05	-0.05	0.09	-0.03	0.13	0.02	0.14	0.15	0.11
Number of branches	0.16	-0.13	-0.18	-0.18	-0.10	-0.10	-0.02	0.18	-0.05	0.07	-0.08	-0.15	-0.19
Total Biomass yield	-0.52**	0.08	0.53**	0.52**	0.37	-0.05	0.43*	-0.20	0.50*	0.19	0.41*	0.55**	0.40
Total root yield	-0.60**	-0.10	0.68**	0.69**	0.33	0.25	0.55**	-0.14	0.72**	0.20	0.710**	0.76**	0.54**
Essential oil content	-0.47*	0.04	0.49*	0.48*	0.33	-0.07	0.40	-0.17	0.48*	0.18	0.405*	0.52**	0.37

Table 25. Correlation between light intensity and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	-0.75**	-0.79**	-0.85**	-0.82**	-0.85**	-0.86**	-0.87**	-0.85**	-0.88**	-0.88**	-0.89**	-0.88**	-0.88*
Number of branches	0.39	0.432*	0.455*	0.453*	0.448*	0.443*	0.453*	0.438*	0.452*	0.437*	0.452*	0.454*	0.468*
Total Biomass yield	0.37	0.28	0.16	0.17	0.07	0.07	0.05	0.00	0.04	0.10	0.12	0.06	0.16
Total root yield	0.408*	0.31*	0.14	0.17	0.00	-0.01	-0.06	-0.10	-0.09	-0.04	0.01	-0.07	0.09
Essential oil content	0.35**	0.28*	0.15*	0.17	0.05	0.04	0.01	0.03	0.01	0.04	0.07	0.01	0.13

Table 26. Correlation between soil temperature and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	0.14	-0.06	-0.14	0.05	0.23	0.02	0.13	-0.06	0.09	0.04	0.03	-0.11	0.09
Number of branches	0.14	0.58**	0.73**	0.59**	0.54**	0.52**	0.59**	0.60**	0.48*	0.33	0.49*	0.62**	0.56**
Total Biomass yield	0.74**	0.79**	0.31	0.594**	0.53**	0.23	0.26	0.14	0.05	-0.11	0.12	0.14	0.08
Total root yield	0.85**	0.61**	0.29	0.64**	0.55**	0.27	0.14	0.06	-0.03	-0.26	-0.17	-0.17	-0.23
Essential oil content	0.69**	0.77**	0.38	0.64**	0.55**	0.30	0.31	0.22	0.16	-0.04	0.15	0.13	0.06

Table 27. Correlation between soil moisture and plant characters

Characters	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13
Plant height	-0.02	0.15	0.23	0.18	0.28	0.25	0.27	0.32	0.18	0.32	0.31	0.23	0.22
Number of branches	0.20*	0.28*	0.13	0.07	0.06	0.17	0.22	0.17	0.15	0.18	0.04	0.04	-0.02
Total Biomass yield	-0.42*	-0.31	0.12	0.04	0.28	0.40	0.75**	0.69**	0.68**	0.74**	0.72**	0.69**	0.59**
Total root yield	-0.66**	-0.55**	-0.16	-0.24	0.05	0.17	0.74**	0.71**	0.72**	0.76**	0.90**	0.91**	0.82**
Essential oil content	-0.40*	-0.31	0.09	0.01	0.23	0.34	0.68**	0.61**	0.58**	0.68**	0.72**	0.69**	0.57**

Correlation between biometric observations, root yield and oil content

A correlation matrix between plant characters (Table 28) showed that plant height had significant negative relation with number of branches (-0.32) and positive correlation with biomass yield (0.42). Correlation between plant height and total root yield (0.27) and essential oil content (0.20) was non significant. Number of branches had significant positive correlation with biomass yield (0.50), and total root yield (0.55) and the correlation with essential oil content (0.29) was non significant. The biomass yield had significant positive correlation with the total root yield (0.89) and oil content (0.99). A significant correlation was observed between total root yield and oil content (0.87).

Table 28. Correlation between biometric observations, root yield and oil content

	Plant height	Number of branches	Biomass yield	Total root yield	Essential oil content
Plant height	1				
Number of branches	-0.32*	1			
Biomass yield	0.42*	0.50*	1		
Total root yield	0.27	0.55**	0.89**	1	
Essential oil content	0.20	0.29	0.99**	0.87**	1

4.2. Two factor interactions

4.2.1. Interaction between growing condition and date of planting

4.2.1. a Biometric observations

Plant height at 30, 60 DAP and at harvest

Interaction between growing condition and planting dates on plant height, and number of branches are depicted in Table 29. At 30 and 60 DAP interaction was found to be significant. At 30 DAP, planting in July under 50 per cent shaded condition or in June under shade was found to be better with respect to plant height (28.97 cm and 28.94 cm respectively). Planting in August under open condition recorded the lower plant height (16.56 cm). At 60 DAP planting in June under shaded condition recorded the taller plants (42.98 cm) and those planted in August month in open condition observed to be as shorter (26.54 cm) and was on par with planting in July or May under open condition (27.60 cm and 28.75 cm respectively) . Significant interaction was not found at harvest stage.

Number of branches per plant at 30, 60 DAP and at harvest

At 30 DAP and 60 DAP, the interaction was non significant. At harvest, higher number of branches was noticed in the treatment combination August planting under open condition (14.40) and was on par with planting in June in open condition (14.14). Lowest number of branches was recorded in May grown crops under 50 per cent shade (5.40).

Fresh biomass yield at 30, 60 DAP and at harvest

Data on interaction effect of growing condition and planting dates on biomass yield, total biomass yield and total root yield of *Plectranthus* are presented in Table 30. At 30 DAP the highest plant biomass was observed in June planted crop under shaded condition (27.09 g/plant). Lower biomass was observed in July planting under shade (11.30 g/plant), which was on par with shade planting in August (11.12 g/plant).

At 60 DAP planting in May under 50 per cent shade recorded the highest biomass (154.64 g/plant). With same date of planting, significantly higher biomass yield was obtained under shaded condition. Lower biomass yield was obtained in August (46.26 g/plant) grown crop in open condition which was on par with July planting (46.71 g/plant) under open condition. At harvest the interaction was not significant.

Total biomass yield

The highest biomass yield was observed in May planting under open condition (17863 kg/ha) (Table 30). May planting under shade (13526 kg/ha) was the next best treatment. Planting in August under shaded condition recorded lower yield of 3178 kg/ha and was on par with planting in open condition during the same month (3452 kg/ha).

Total root yield

The yield recorded in May planted crop in open condition (2710.48 kg/ha) marked the highest root yield (Table 30). Yield in July planting under shade (357.45 kg/ha) marked the least value which was on par with August planting under shade condition (427.48 kg/ha), July planting under open condition (470.63 kg/ha) and August planting under open condition (509.37 kg/ha).

Table 29. Interaction effect of growing condition and date of planting on plant height and number of branches of *Plectranthus vettiveroides* at different growth stages

Treatments	Plant height (cm)						Number of branches					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	0pen	50% shade	0pen	50% shade
May 15	19.84	26.53	28.75	39.12	38.40	78.25	4.31	3.16	6.56	4.62	12.96	5.40
June 15	19.65	28.94	30.16	42.98	35.78	67.56	5.81	4.99	8.39	6.08	14.14	8.38
July 15	17.07	28.97	27.60	35.10	31.14	69.87	5.33	3.88	6.64	5.31	11.25	7.93
August 15	16.56	22.22	26.54	33.26	32.83	68.82	4.47	1.99	7.03	6.02	14.40	9.54
CD (0.05)	2.94		2.78		NS		NS		NS		1.37	

Table 30. Interaction effect of growing condition and date of planting on biomass yield and total yield of *Plectranthus vettiveroides*

Treatments	Biomass yield (g/plant)						Total biomass yield (kg/ha)		Total root yield (kg/ha)	
	30 DAP		60 DAP		Harvest		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	17.84	19.29	85.89	154.64	550.44	438.91	17863	13526	2710.48	2305.56
June 15	21.46	27.09	63.73	126.01	300.33	259.33	12389	8336	1174.74	849.89
July 15	9.49	11.30	46.71	80.30	71.08	95.00	7826	4847	470.63	357.45
August 15	13.50	11.12	46.26	87.43	90.50	100.69	3452	3178	509.37	427.48
CD (0.05)	2.30		12.88		NS		1587		218.86	

4.2.1. b Soil analysis

Soil pH

Interaction effect between growing condition and planting date on soil pH was non significant (Table 31).

Organic carbon

Interaction effect of growing condition and planting date had no significant effect on organic carbon content of soil after the harvest of crop (Table 31).

Available nitrogen

Interaction effect between growing condition and planting date was significant on soil available nitrogen content after harvest with the highest available N content in July planting under shade (317.89 kg/ha) (Table 31).. The lowest content was in August planting under open condition (175.14 kg/ha**)**. All other treatment combinations were on par.

Available phosphorus

Significant interaction between growing condition and different dates of planting on available soil phosphorus content (Table 31) was observed. The highest percentage of phosphorus was found in shaded condition compared to open in all planting dates. The highest level was in July planting under shaded condition (29.15 kg/ha) and the lowest level was in May planting under open condition (18.80 kg/ha).

Available potassium

The interaction between growing condition and planting dates had no significant effect on available soil K (Table 31).

Table 31. Interaction effect of growing condition and date of planting on soil pH, organic carbon and available N, P and K after the experiment

Treatments	pH		Organic Carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	4.79	4.81	1.327	1.334	251.39	262.51	18.80	25.00	154.81	174.53
June 15	4.83	4.72	1.3	1.289	242.19	247.23	19.17	26.27	157.87	163.74
July 15	4.83	4.88	1.327	1.338	247.61	317.89	21.64	29.15	162.61	155.35
August 15	4.59	4.65	1.326	1.25	175.14	254.46	22.98	28.16	186.27	160.54
CD (0.05)	NS		NS		22.93		0.52		NS	

4.2.1.c Micrometeorological observations

Soil temperature

Table 32. depicts the interaction between growing condition and planting dates on soil temperature. Temperature in the growing period ranged from 24.72 ºC to 29.42ºC. The interaction effect was non significant.

Soil moisture

The data showing interaction effect of growing condition and planting date on weekly soil moisture content are presented in Table 33. Interaction had significant influence on soil moisture during all the weeks under observation. Moisture content varied from highest (33.89%) at shaded condition in 1st week of July planting to lowest (12.24%) at 11th week of August planting at open condition.

Light intensity

The effect of growing condition and planting dates on the light intensity in the experimental plots is given in table 34. Almost double of the light intensity in the shaded condition was observed in the open condition. Maximum light intensity was observed in 1st week of May planted in open condition (19477 lux) and the lowest was in week 5 of August planting in shaded condition (4504 lux).

Table 32. Interaction effect of growing condition and date of planting on soil temperature

Treatments	Soil temperature (°C)													
	Week1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	29.42	29.36	26.68	25.08	26.90	25.08	27.37	26.53	26.88	26.59	26.52	25.41	26.18	25.81
June 15	26.99	26.69	26.52	25.41	26.18	25.81	26.60	25.74	26.44	25.83	25.86	25.56	25.35	25.38
July 15	26.44	25.82	25.86	25.56	25.35	25.38	25.41	25.50	25.32	25.38	24.97	25.33	26.79	26.27
August 15	25.32	24.72	24.97	24.91	26.79	26.35	26.75	26.59	26.31	26.80	27.28	27.04	26.38	26.85
CD (0.05)	NS		NS		NS		NS		NS		NS		NS	

Table 32 contd.

Treatments	Soil temperature (ºC)											
	Week8		Week 9		Week 110		Week 11		Week 12		Week 13	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	26.60	25.74	26.44	25.83	25.86	25.57	25.35	25.38	25.41	25.50	25.32	25.38
June 15	25.41	25.50	25.32	25.38	24.97	25.33	26.79	26.27	26.75	26.37	26.31	27.22
July 15	26.75	26.37	26.31	27.22	27.28	27.48	26.38	27.20	27.02	26.29	27.69	26.40
August 15	27.01	26.69	27.69	26.97	27.02	26.69	26.90	25.65	27.12	25.88	26.75	26.59
CD (0.05)	NS		NS		NS		NS		NS		NS	

Table 33. Interaction effect of growing condition and date of planting on soil moisture at 15 cm depth

Treatments	Soil moisture (%)													
	Week1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	12.32	12.79	13.31	15.27	15.06	15.66	14.91	14.31	20.31	20.57	22.73	20.96	22.63	26.01
June 15	22.67	29.06	22.94	30.73	23.02	31.61	23.33	32.61	23.54	33.40	26.49	34.15	26.41	25.90
July 15	33.71	33.89	29.53	29.09	26.37	31.10	26.95	31.59	27.15	29.52	27.50	26.88	13.77	13.87
August 15	30.84	31.59	30.05	32.46	13.98	12.48	13.88	12.87	12.97	13.89	12.54	16.26	13.37	13.00
C D(0.05)	0.80		1.30		1.93		1.54		1.47		2.22		2.08	

Treatments	Soil moisture (%)											
	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	23.22	27.21	23.43	28.78	26.72	29.78	26.43	26.56	27.22	26.88	29.26	28.04
June 15	27.21	26.50	28.78	23.43	28.78	26.72	13.77	13.87	13.76	14.07	14.80	13.82
July 15	13.76	14.07	14.80	13.82	14.43	17.48	13.44	14.06	12.89	14.16	13.25	12.26
August 15	12.36	12.97	13.27	13.62	14.48	13.72	12.24	16.04	14.76	13.75	13.53	14.22
C D(0.05)	0.97		0.77		1.86		0.91		0.74		0.73	

Table 34. Interaction effect of growing condition and date of planting on light intensity

Treatments	Light intensity(lux)													
	Week1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	19477	13151	19477	16091	16477	17094	16578	17199	14171	17216	14287	17257	13287	13287
June 15	15922	9513	16002	9938	14335	9559	13957	9618	13153	9045	13552	8993	14391	14391
July 15	13731	7101	13982	6354	13902	5521	12786	5471	13761	4904	14462	4855	15669	15669
August 15	12611	5692	13160	5121	14918	4764	13118	4507	16058	4504	17061	4570	17166	17166
CD (0.05)	22.04		22.64		22.66		21.24		16.92		17.60		17.62	

Treatments	Light intensity (lux)											
	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	12651	17370	12644	17210	13193	15204	14951	16793	13151	17093	16091	17318
June 15	12899	8783	14857	8561	15708	8146	16364	9226	15776	8766	16783	9412
July 15	14474	4633	16448	4713	17128	5165	17224	5803	17182	5169	16540	5672
August 15	17183	4753	17224	5499	17258	6093	17337	6358	17177	6137	15171	5940
CD (0.05)	16.47		16.52		16.53		16.50		16.53		16.84	

4.2.1.d Physiological, chemical and biochemical observations

Total chlorophyll content 30 DAP, 60 DAP and at harvest

Data on interaction between growing condition and planting dates on total chlorophyll content is presented in Table 35. Interaction effect showed significant influence on total chlorophyll content at 30 DAP. Higher chlorophyll content was recorded in August planting under shaded and open condition (1.60 and 1.27 mg/g) and crop planted in July under shade (0.969 mg/g) had minimum total chlorophyll content. At 60 DAP, and at harvest no significant difference was observed in total chlorophyll content.

Essential oil content (%)

Essential content at harvest was significantly influenced by the interaction between growing condition and planting date (Table 35). Higher essential oil content was obtained from May planting in open condition (1.99 %). The next best oil yield was in crops planted on June under open condition (1.83%). The lowest yield was obtained in August planted crop in 50 percent shaded condition (1.07%). With the same dates of planting higher essential oil content was observed under open condition (Table 35).

Crop growth rate

Data on interaction effect of growing condition and planting date on crop growth rate and relative growth rate are given in Table 36. Crop growth rate was significant at 30 DAP and 60 DAP. At 30 DAP the highest CGR was observed in June planted crop in 50 percent shaded condition (0.441 g/m^2/day). July planting in open condition recorded lower CGR (0.177 g/m^2/day) and was on par with July planting in shaded condition (0.182 g/m^2/day) and July planting in shaded condition (0.184 g/m^2/day).

At 60 DAP to harvest significantly higher crop growth rate was recorded in May planting under shaded condition (2.33 g/m^2/day). Lower CGR was recorded in August under open condition (0.540 g/m^2/day) and was on par with July (0.622 g/m^2/day) and June (0.690 g/m^2/day) planting in open condition.

Relative growth rate

Significant difference in RGR was observed during all the stages of observation. Higher RGR during 0-30 DAP was recorded in June planting in shaded condition (0.037 g/g/day) and was on par with June planting in open condition (0.036 g/g/day). Lower RGR was recorded in July planting under both open and shaded condition and also at shaded condition of August planting (0.024 g/g/day).

At 30-60 DAP, August planting in shaded condition recorded higher RGR (0.031 g/g/day) which was on par with May planting in shaded condition (0.030 g/g/day) and July planting in shaded condition (0.029 g/g/day). Minimum RGR was observed in June planting under open condition (0.015 g/g/day) which was on par with August planting in open condition (0.016 g/g/day).

At harvest, May planting in open condition recorded higher RGR (0.027 g/g/day). Minimum RGR was observed in August planting under shaded condition (0.003 g/g/day) which was on par with July planting in shaded condition (0.004 g/g/day).

N, P and K uptake

Data on interaction effect of growing condition and planting dates on major uptake of plant nutrients N, P and K uptake at harvest is presented in the Table 37. Highest N uptake was noticed in May planted crop under open situation (444.55 kg/ha) and minimum in the August planted crop under in open condition (68.40 kg/ha). Similarly phosphorus uptake was found higher in May planted crop at open condition (101.08 kg/ha) and lowest uptake by August planted crops at the shaded condition (18.83 kg/ha).

The K uptake was found to be the highest in shaded plots planted in the month of May (202.35 kg/ha) and the lowest uptake was in August planted crop under open condition (38.34 kg/ha).

Table 35. Interaction effect of growing condition and date of planting on total chlorophyll content at different growth stages and essential oil content

Treatments	Total chlorophyll (mg/g)						Essential oil (%)	
	30 DAP		60 DAP		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	1.225	0.971	1.474	1.799	1.835	2.494	1.988	1.470
June 15	1.102	0.830	1.818	2.147	1.843	2.458	1.826	1.380
July 15	0.969	0.700	1.316	1.495	1.307	2.034	1.601	1.310
August 15	1.269	1.604	1.242	1.649	1.348	2.053	1.671	1.066
CD (0.05)	0.259		NS		NS		0.085	

Table 36. Interaction effect of growing condition and date of planting on crop growth rate, relative growth rate at different growth stages

Treatments	CGR (g/m^2/day)						RGR (g/g/day)					
	0 - 30 DAP		30 – 60 DAP		60 DAP - Harvest		0 - 30 DAP		30 – 60 DAP		60 DAP - Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	0.332	0.316	1.137	2.330	8.543	5.491	0.033	0.032	0.021	0.030	0.027	0.014
June 15	0.400	0.442	0.690	1.713	4.372	2.677	0.036	0.037	0.015	0.023	0.017	0.010
July 15	0.177	0.184	0.622	1.190	0.496	0.441	0.024	0.024	0.022	0.029	0.007	0.004
August 15	0.251	0.182	0.540	1.312	0.854	0.368	0.029	0.024	0.016	0.031	0.010	0.003
CD (0.05)	0.040		0.219		NS		0.002		0.003		0.004	

Table 37. Interaction effect of growing condition and date of planting on nutrient uptake at harvest (kg/ha)

Treatments	Nitrogen uptake (kg/ha)		Phosphorus uptake (kg/ha)		Potassium uptake (kg/ha)	
	Open	50% shade	Open	50% shade	Open	50% shade
May 15	444.55	367.42	101.08	71.28	174.89	202.35
June 15	315.53	243.95	68.02	47.96	118.76	139.03
July 15	182.01	119.13	46.87	29.29	103.30	79.91
August 15	68.40	78.65	22.05	18.83	38.34	52.15
CD (0.05)	60.61		16.41		29.12	

4.2.1.e Observations on weeds

Weed count

Broad leaf weeds

Table 38. depicts interaction effect of growing condition and planting date on weed count, dry weight of broad leaved weeds. At 30 DAP and at harvest stage, the effect was found to be non significant. At 60 DAP, May planting in open condition (41.89 no./m^2) recorded maximum weed count and minimum was in August planting in shaded condition (14.89 no./m^2)

Grasses

Data on the weed count of grasses are presented in table 39. The effect was significant only at 30 DAP. The highest grass count was observed in May planted crop in open condition (2.22 no./m^2). Lower weed count was noted in shaded condition of June planted crop (0.22 no./m^2) which was on par with July crop in open condition (0.33 no./m^2) and August crop in 50% shaded condition (0.67 no./m^2).

Sedges

The interaction effect of growing condition and planting dates on weed count of sedges were found to be non significant (Table 40.)

Weed dry weight

Broadleaf weeds

At 30 DAP, weed dry weight was found to be non significant. At 60 DAP, higher weed dry weight was noticed in May planted plots (13.84 g/m^2) which was on par with August planting under open condition (13.62 g/m^2) and lower weed dry weight was observed in July planting in shaded condition (6.72 g/m^2) and was on

par with June planting in shaded condition (6.98 g/m^2). At the time of harvest, higher weed dry weight was observed in June planting under open condition (9.92 g/m^2). Lower weed dry weight was observed in July planting in shaded condition (3.21 g/m^2) and was on par with June planting in shaded condition (3.41 g/m^2)

Grasses

Interaction effect was non significant on dry weight of grass weeds at 30 DAP and at harvest. At 60 DAP weed dry weight ranged from nil to 0.460 g/m^2.

Sedges

At 30 DAP, the highest sedge weed dry weight was noted in May planted plots under open condition (4.55 g/m^2) and the lowest count was in May planted crop under shade.

Table 38. Interaction effect of growing condition and date of planting on weed count and dry weight of broad leaf weeds at different growth stages

Treatments	Count of broad leaf weeds (no./m^2)						Dry weight of broad leaf weeds (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% Shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	**6.69 (58.44)	4.74 (28.11)	5.75 (41.89)	4.10 (20.00)	4.72 (28.56)	3.59 (15.67)	3.93 (18.47)	3.23 (11.39)	3.47 (13.84)	2.81 (8.24)	2.90 (9.53)	2.38 (5.71)
June 15	6.22 (50.67)	4.83 (29.22)	5.31 (35.89)	3.82 (17.89)	4.50 (25.11)	2.81 (8.78)	3.53 (15.32)	3.511 (14.16)	3.24 (11.86)	2.57 (6.98)	3.00 (9.92)	1.96 (3.41)
July 15	5.93 (48.00)	5.07 (34.00)	4.65 (25.11)	3.86 (17.56)	3.84 (18.00)	2.87 (9.11)	3.691 (16.93)	3.08 (10.72)	2.90 (8.72)	2.56 (6.72)	2.392 (5.80)	1.93 (3.21)
August 15	4.48 (24.22)	3.84 (17.89)	4.33 (22.22)	3.58 (14.89)	3.70 (15.44)	2.71 (7.89)	3.51 (14.01)	2.72 (7.89)	3.45 (13.62)	2.87 (8.76)	2.87 (8.73)	2.13 (4.24)
CD (0.05)	NS		0.554		NS		NS		0.34		0.25	

** √x+0.5 transformed values, original values are given in parenthesis

Table 39. Interaction effect of growing condition and date of planting on weed count and dry weight of grasses at different growth stages

Treatments	Count of grasses (no./m^2)						Dry weight of grasses (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% Shade	Open	50% shade	Open	50% shade	Open	50% shade
May 15	**1.64 (2.22)	1.16 (0.44)	1.22 (0.67)	1.21 (0.56)	1.22 (0.67)	1.23 (0.667)	2.44 (8.64)	1.17 (0.48)	1.16 (0.46)	1.16 (0.40)	1.12 (0.3)	1.13 (0.38)
June 15	1.51 (1.67)	1.09 (0.22)	1.16 (0.44)	1.21 (0.56)	1.19 (0.56)	1.00 (0.00)	2.17 (5.82)	1.19 (0.57)	1.15 (0.389)	1.16 (0.41)	1.07 (0.19)	1.00 (0.0)
July 15	1.13 (0.33)	1.47 (1.44)	1.23 (0.67)	1.00 (0.00)	1.14 (0.33)	1.08 (0.22)	1.19 (0.59)	1.49 (1.54)	1.15 (0.37)	1.00 (0.0)	1.04 (.08)	1.02 (.06)
August 15	1.30 (0.89)	1.22 (0.67)	1.00 (0.00)	1.21 (0.67)	1.17 (0.44)	1.21 (0.33)	1.30 (0.86)	1.15 (0.39)	1.00 (0.00)	1.07 (0.19)	1.10 (0..23)	1.05 (0.30)
CD (0.05)	0.395		NS		NS		NS		0.34		NS	

** √x+0.5 transformed values, original values are given in parenthesis

Table 40. Interaction effect of growing condition and date of planting on weed count and dry weight of sedge at different growth stages

Treatments	Count of sedges (no./m^2)						Dry weight of sedges (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% Shade
May 15	**1.51 (1.67)	1.00 (0.00)	1.00 (0.00)	1.05 (0.11)	1.11 (0.33)	1.05 (0.11)	1.92 (4.55)	1.00 (0.00)	1.00 (41.89)	1.02 (0.04)	1.02 (0.04)	1.02 (0.04)
June 15	1.13 (0.33)	1.05 (0.11)	1.13 (0.33)	1.05 (0.11)	1.13 (0.33)	1.00 (0.00)	1.04 (0.08)	1.02 (0.03)	1.07 (0.17)	1.02 (0.04)	1.03 (0.06)	1.00 (0.00)
July 15	1.26 (0.78)	1.21 (.56)	1.13 (0.33)	1.18 (0.44)	1.209 (0.56)	1.00 (0.00)	1.17 (0.43)	1.26 (0.76)	1.04 (0.08)	1.04 (0.09)	1.03 (0.07)	1.00 (0.00)
August 15	1.21 (0.56)	1.13 (0.33)	1.09 (0.22)	1.00 (0.00)	1.24 (0.67)	1.08 (0.22)	1.13 (0.30)	1.07 (0.17)	1.07 (0.16)	1.00 (0.00)	1.06 (0.13)	1.03 (0.08)
CD (0.05)	NS		NS		NS		0.514		NS		NS	

** $\sqrt{x+0.5}$ transformed values, original values are given in parenthesis

4.2.2. Interaction between growing condition and mulching

4.2.2.a Biometric observations

Plant height at 30, 60 DAP and at harvest

Interaction effect between growing condition and mulching on plant height, and number of branches are given in Table 41. At 30 DAP, the taller plants were noticed in treatment combination black polythene mulching and 50 % shade (30.46 cm) and the shorter plants were observed under open without mulch and with organic mulch (16.55 cm and 17.38 cm respectively). At 60 DAP and at harvest, black polythene mulching under shaded condition resulted in better plant height (45.53 cm and 82.21 cm respectively) and lower plant height was in no mulch condition under open (23.33 cm and 28.02 cm).

Number of branches per plant at 30 DAP, 60 DAP and at harvest

At 30 DAP, it was observed that the data was non-significant (Table 41). At 60 DAP more number of branches was observed in black polythene mulched plants under open condition (9.34) and lower branching was noticed in no mulch condition under 50 percent shade (4.78) and it was on par with 50 percent shade condition with organic mulch (5.06). At harvest, the highest number of branches was seen in black polythene mulch in open condition (21.82) and the least branching was observed under shade without mulch (4.39).

Biomass yield per plant at 30 DAP, 60 DAP and at harvest

Interaction effect between growing condition and mulching on biomass yield per plant, total biomass yield and total root yield are shown in Table 42. The interaction effect was significant at all stages of observation. At 30 DAP, black polythene mulching under shaded condition resulted in higher biomass yield per plant (20.68

g/plant) and was on par with black polythene mulching under open (19.34 g/plant) During 60 DAP, the highest biomass yield was obtained from black polythene mulched plot under shaded condition and (143.80 g/plant) and the lowest was obtained from no mulch treatment under open condition (42.97 g/plant). At harvest stage the highest biomass yield per plant was in black polythene mulching under open condition (443.33 g/plant) and shaded condition without any mulch resulted in lowest per plant biomass yield (112.70 g/plant).

Total biomass yield at harvest

The highest biomass yield at harvest was obtained from open condition when black polythene mulch was used (18988kg/ha). The next best treatment was black polythene mulching under 50 percent shade (13481 kg/ha). The lowest yield was obtained from planting without mulch under shade (3246 kg/ha).

Total root yield at harvest

The interaction effect of growing condition and mulching on total root yield was significant (Table 42). The highest root yield was obtained from open condition when black polythene was used (1968.81 kg/ha) and the lowest root yield was obtained from unmulched plots of shaded condition (476.11 kg/ha).

Table 41. Interaction effect of growing condition and mulching on plant height and number of branches of *Plectranthus Vettiveroides at different growth stages*

Treatments	Plant height (cm)						Number of branches					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	16.55	23.45	23.33	32.87	28.02	63.09	4.41	2.94	5.46	4.78	8.01	4.39
Organic mulch	17.3	26.08	26.55	34.44	30.47	68.08	4.79	3.15	6.66	5.06	9.73	7.90
Black polythene mulch	20.90	30.46	34.91	45.53	45.12	82.21	5.73	4.41	9.34	6.69	21.82	11.13
CD (0.05)	2.18		4.94		7.44		NS		0.76		1.76	

Table 42. Interaction effect of growing condition and mulching on biomass yield and total yield of *Plectranthus*

Treatments	Biomass yield (g/plant)				Total biomass yield (kg/ha)				Total root yield (kg/ha)	
	30 DAP		60 DAP		Harvest		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	14.83	16.57	42.97	89.48	128.99	112.70	4898	3246	653.00	476.11
Organic mulch	12.55	14.34	59.37	103.01	186.94	204.08	7261	5687	1027.11	876.56
Black polythene mulch	19.34	20.68	79.58	143.80	443.33	353.67	18988	13481	1968.81	1602.61
CD (0.05)	3.28		11.16		37.66		1374.40		188.14	

4.2.2.b Soil analysis

Soil pH

Data on interaction effect of growing condition and mulching on soil pH was found non-significant (Table 43.).

Organic carbon

A non significant interaction between growing condition and mulching could be observed with respect to organic carbon (Table 43.).

Available nitrogen

The interaction effect of growing condition and mulching had significant influence on the available nitrogen content (Table 43.). The highest nitrogen content was found in organic mulched plot under 50 percent shade (313.402 kg/ha) and the lowest was found in no mulch treatment under open condition (206.687 kg/ha).

Available phosphorus

Interaction effect of growing condition and mulching recorded significant influence on available soil phosphorus content of soil (Table 43.). Higher available phosphorus content was found in organic mulched plot under 50 percent shade (27.65kg/ha) and it was on par with co no mulch treatment under 50 percent shade (27.16 kg/ha). The lowest phosphorus content was found in no mulch treatment under open condition (20.43 kg/ha).

Available potassium

The treatment combination of growing condition and mulching was found to be non-significant with respect to available potassium content of the soil after harvest of the crop.

Table 43. Interaction effect of growing condition and mulching on pH, organic carbon and available N, P and K.

Treatments	pH		Organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	4.61	5.00	1.18	1.16	206.69	274.14	20.43	27.16	154.62	168.62
Organic mulch	4.88	4.78	1.49	1.48	253.36	313.40	20.51	27.65	170.50	166.65
Black Polythene mulch	4.79	4.52	1.29	1.27	227.20	224.03	21.00	26.62	171.06	155.35
CD (0.05)	NS		NS		19.86		0.45		NS	

4.2.2.c Micrometeorological observations

Soil temperature

The interaction between growing condition and mulching significantly influenced soil during the weeks 2, 3, 4 and 5 (Table 44). Higher soil temperature was observed in treatment combinations with black polythene mulching. The soil temperature ranged between 24.8 ºC to 27.9ºC with higher temperature recorded on under black polythene sheet mulch in open condition (27.9 ºC). Lower soil temperature was noticed under shade without mulch and with organic mulch (24.8 ºC).

Soil moisture

The interaction effect was significant in most of the stages (Table 45). The highest soil moisture content was observed in 2nd week in black polythene mulched plot under shaded situation (29.85 %).The lower soil moisture content was recorded in the 13th week in no mulch treatment under open condition (13.48 %).

Light intensity

Effect of growing condition and mulching on light intensity was significant in all the weeks Table 46. Higher light intensity was observed in open condition than in shade during all weeks. Highest value of intensity was observed in no mulch treatment in open condition (16469 lux) and the lowest rate was at 10th week in organic mulched plot in shaded condition (7661 lux).

Table 44. Interaction effect of growing condition and mulching on soil temperature at 10 cm depth

Treatments	Soil temperature (ºC)													
	Week1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	26.4	26.5	25.5	24.8	25.9	25.4	26.0	25.8	25.7	25.8	25.6	25.6	25.6	25.6
Organic mulch	26.8	26.2	25.8	24.8	26.0	25.5	26.1	25.8	25.8	25.7	25.9	25.3	25.6	25.8
Black Polythene mulch	27.9	27.3	26.7	26.1	27.1	26.1	27.4	26.6	27.1	26.9	26.9	26.6	27.4	26.8
CD (0.05)	NS		0.02		0.03		0.03		0.03		NS		NS	

Treatments	Soil temperature (ºC)											
	Week8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	26.2	25.6	26.0	26.1	25.9	25.8	25.9	25.6	26.2	25.8	26.0	25.6
Organic mulch	25.9	26.0	25.8	25.9	25.8	26.3	25.9	26.1	26.0	25.7	26.0	26.4
Black Polythene mulch	27.3	26.6	27.5	27.0	27.1	26.7	27.3	26.6	27.5	26.5	27.6	27.2
CD (0.05)	NS		NS		NS		NS		NS		NS	

Table 45. Interaction effect of growing condition and mulching on soil moisture at 15 cm depth

Treatments	Soil moisture (%)													
	Week1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	24.65	22.60	18.94	22.15	17.26	18.63	17.64	20.12	18.72	20.38	18.46	21.48	16.51	16.34
Organic mulch	25.75	27.43	26.02	28.66	18.60	24.17	19.32	23.83	20.39	25.47	22.33	25.27	17.92	20.70
Black Polythene mulch	26.40	28.75	26.91	29.85	22.97	25.34	22.35	24.58	23.88	27.19	26.15	26.93	22.70	22.06
CD (0.05)	0.69		NS		1.67		1.34		1.28		NS		1.80	

Treatments	Soil moisture (%)											
	Week8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	16.77	17.06	17.94	17.02	18.39	19.22	14.46	15.77	15.25	15.16	13.48	14.10
Organic mulch	18.92	19.55	20.12	19.28	20.68	21.23	16.00	17.13	17.21	17.21	18.45	17.89
Black Polythene mulch	21.72	23.95	22.16	21.93	24.24	25.33	18.95	20.00	19.01	19.28	19.19	19.27
CD (0.05)	0.84		NS		NS		NS		NS		0.63	

Table 46. Interaction effect of growing condition and mulching on light intensity

Treatments	Light intensity (lux)													
	Week1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	16469	9892	16633	11012	15322	11157	14755	11163	14291	10961	14734	10971	14700	11012
Organic Mulch	15147	8601	15339	8776	14529	8402	13730	8387	13844	7962	14399	7938	15054	7863
Black Polythene mulch	14689	8098	14994	8340	14873	8145	13845	8046	14723	7829	15389	7847	15631	8011
CD (0.05)	19.09		19.60		19.63		18.39		14.65		15.24		15.26	

Treatments	Light intensity (lux)											
	Week8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	13880	10977	14622	11019	15155	10260	16080	11328	15145	11212	16123	11486
Organic mulch	14005	7803	15483	7824	16131	7661	16642	8537	16161	8137	16415	8572
Black Polythene mulch	15021	7874	15775	8150	16180	8035	16685	8770	16159	8526	15902	8699
CD (0.05)	14.26		14.31		14.31		14.29		14.31		14.58	

4.2.2.d Physiological, chemical and biochemical

Total chlorophyll content 30 DAP, 60 DAP and at harvest

Interaction between growing condition and mulching had influenced total chlorophyll content and essential oil content (Table 47). At 30 DAP total chlorophyll content was found higher under open condition compared to shaded condition.

Plants grown without any mulch in open condition recorded higher chlorophyll content (1.27 mg/g) at 30 DAP and was on par with no mulch in shaded condition (1.23 mg/g) and black polythene mulched plants in open condition (1.20 mg/g). The lowest chlorophyll content was in plants with organic mulch under shaded condition (0.78 mg/g).

At 60 DAP, plants grown without mulch under shade recorded the highest chlorophyll content (2.12 mg/g). At harvest stage, higher chlorophyll content was observed in black polythene (2.46 mg/g) mulch under shaded condition and was on par with organic mulch(2.22 mg/g) and no mulch (2.11 mg/g) under shade.

Essential oil content (%)

Plants grown in black polythene mulch under open condition recorded the highest essential oil content of 2.01 % and the lowest of 1.03 % was noticed from plants grown without mulch in open condition (Table 47).

Crop growth rate

Table 48. represents the interaction effect of growing condition and mulching on crop growth rate and relative growth rate. At 30 DAP and at harvest, interaction was not significant. At 60 DAP significantly higher CGR was observed in plants with black

polythene mulch under shaded condition (2.12 g/m^2/day) and the lowest CGR was recorded from no mulch condition under open condition (0. g/m^2/day).

Relative growth rate

Interaction effect of growing condition and mulching was not significant at 30 DAP, 60 DAP and at harvest stages (Table 48).

Plant N, P and K uptake

Data on effect of date of planting and mulching on plant N, P and K uptake at harvest is depicted in the Tables 49. Higher nitrogen uptake was in plants with black polythene mulching under open situation (492.57 kg/ha) and it was on par with polythene mulched plot under shade (387.91 kg/ha). The lower rate of N uptake occurred in no mulched plot under shaded condition (74.39 kg/ha). Same trend was observed in case of P uptake also. Higher phosphorus uptake was in black polythene mulched plants under open situation (99.37 kg/ha) and it was on par with black polythene mulched plot under shade (73.41 kg/ha). The lower rate of N uptake occurred in no mulched plot in shaded condition (15.38 kg/ha).

The interaction effect of growing condition and mulching was not significant with respect to potassium uptake by the crop.

Table 47. Interaction effect of growing condition and mulching on total chlorophyll content (mg/g) at different growth stages and essential oil (%)

Treatments	Total chlorophyll (mg/g)						Essential oil (%)	
	30 DAP		60 DAP		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	1.27	1.23	1.3	2.12	1.65	2.11	1.62	1.03
Organic mulch	0.95	0.78	1.33	1.58	1.46	2.22	1.69	1.29
Black Polythene mulch	1.20	1.07	1.69	1.62	1.64	2.46	2.01	1.60
CD (0.05)	0.16		0.31		0.43		0.07	

Table 48. Interaction effect of growing condition and mulching on crop growth rate, relative growth rate at different growth stages

Treatments	CGR (g/m^2/day)						RGR (g/g/day)					
	0 - 30 DAP		30 - 60 DAP		60 DAP- Harvest		0 - 30 DAP		30 - 60DAP		60 DAP - Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	0.277	0.270	0.458	1.260	1.612	0.804	0.030	0.029	0.015	0.019	0.011	0.006
Organic mulch	0.234	0.234	0.782	1.528	2.385	1.955	0.028	0.027	0.021	0.030	0.014	0.008
Black polythene mulch	0.360	0.338	1.002	2.122	6.703	3.973	0.034	0.033	0.019	0.029	0.021	0.010
CD (0.05)	NS		0.189		NS		NS		NS		NS	

Table 49. Interaction effect of growing condition and mulching on plant N, P, K uptake at different growth stages

Treatments	N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	102.09	74.39	29.21	15.38	59.90	50.34
Organic mulch	163.22	144.57	49.93	36.73	75.97	86.81
Black polythene mulch	492.57	387.91	99.37	73.41	190.59	217.93
CD (0.05)	52.84		13.21		NS	

4.2.2.e Observations on weeds

Weed count

Broad leaf weeds

Interaction effect of growing condition and mulching on weed count and dry weight of broad leaved weeds, grasses and sedges are given in Tables 50, 51, and 52. Interaction effect of mulching with growing condition was significant with respect to count and dry weight of broad leaf weeds at all stages of observation. Black polythene mulching under shaded condition resulted in lower broad leaf weed count throughout crop growth period (0.50, 0.75 and nil counts during 30, 60 DAP and at harvest). Open condition without any mulch recorded the highest broad leaf weed count of 82.50, 55.75 and 38.42 no./m^2 respectively during 30, 60 DAP and at harvest.

Grasses

In the case of grass weeds, interaction effect of mulching with growing condition was significant with respect to count and dry weight at all stages of observation. Black polythene mulching both under open and shaded condition resulted in lower grass weed count throughout crop growth period (zero count) and at harvest it was on par with organic mulched plot under shade (0.17 no./m^2). Open condition without any mulch recorded the highest count of grass weeds (2.58, 0.92 and 0.92 no./m^2) respectively during 30, 60 DAP and at harvest.

Sedges

Significant interaction between growing condition and mulches at all stages of observation was observed for sedge count too. No sedges were noticed when black polythene mulch was used as mulch under shaded condition. Open condition without any mulch recorded the highest sedge count of 1.67, 0.58 and 1.17 no./m^2 respectively during 30, 60 DAP and at harvest.

Weed dry weight

Broad leaf weeds

Interaction between mulching and growing condition was significant with respect to dry weight of broad leaf weeds (Table 50, 51, and 52.). The lower dry weight of broad leaf weeds at 30 DAP was observed in combination of black polythene mulching under open (0.41 g/m^2) and was on par with black polythene under shade (0.42 g/m^2). The highest dry weight of broad leaf weeds at this stage was in unmulched plots under open condition (29.39 g/m^2). At 60 DAP and harvest stage also, black polythene mulching continued its superiority in controlling broad leaf weed dry weight (0.48 g/m^2 at 60 DAP and no counts at harvest). No mulch under open condition resulted in the highest dry weight of broad leaf weeds at 60 DAP and at harvest (21.03 g/m^2 and 15.37 g/m^2 respectively).

Grasses

The grass weeds showed the lowest dry weight throughout the growth period when black polythene was used as mulch. The highest dry weight of grasses at 30 DAP was in unmulched plots under open condition (8.21 g/m^2). No mulch under open condition resulted in the highest dry weight of grasses at 60 DAP (0.67 g/m^2) and it was on par with no mulch at 50 percent shade (0.54 g/m^2). At harvest stage also unmulched plots under open condition resulted in the highest grass weed dry weight (0.40 g/m^2).

Sedges

Dry weight of sedges at 30 DAP was zero by the application of both with black polythene mulch and organic mulch under shade at all stages of observation. The highest dry weight of sedges at 30 DAP was in organic mulched plots under open condition (2.26 g/m^2). At 60 DAP no mulch under open condition resulted in the highest dry weight of sedges (0.28 g/m^2). At harvest stage, the interaction was non significant.

Table 50. Interaction effect of growing condition and mulching on weed count and dry weight of broad leaved weeds

Treatments	Count of broad leaf weeds (no./m^2)						Dry weight of broad leaf weeds (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	8.95 (82.50)	7.05 (50.08)	7.43 (55.75)	5.64 (31.25)	6.21 (38.42)	4.33 (18.31)	5.44 (29.39)	4.32 (18.12)	4.63 (21.03)	3.46 (11.34)	4.02 (15.37)	2.77 (6.87)
Organic mulch	7.20 (52.33)	5.64 (31.33)	6.07 (36.33)	4.632 (20.75)	5.199 (26.42)	3.66 (12.75)	4.41 (18.75)	3.934 (14.57)	3.86 (14.19)	3.47 (11.20)	3.28 (9.95)	2.54 (5.55)
Black polythene mulch	1.34 (1.17)	1.16 (0.50)	1.53 (1.75)	1.24 (0.75)	1.16 (0.50)	1.00 (0.00)	1.15 (0.41)	1.15 (0.42)	1.30 (0.82)	1.18 (0.48)	1.07 (0.17)	1.00 (0.00)
CD (0.05)	0.63		0.48		0.36		0.43		0.39		0.22	

Table 51. Interaction effect of growing condition and mulching on weed count and dry weight of grasses

Treatments	Count of grasses (no./m^2)						Dry weight of grasses (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	1.79 (2.58)	1.42 (1.25)	1.30 (0.92)	1.34 (1.00)	1.33 (0.92)	1.26 (0.75)	2.55 (8.21)	1.57 (1.75)	1.24 (0.67)	1.21 (0.54)	1.16 (0.40)	1.13 (0.36)
Organic mulch	1.40 (1.25)	1.29 (0.83)	1.16 (0.42)	1.13 (0.33)	1.21 (0.58)	1.07 (0.17)	1.77 (3.73)	1.19 (0.48)	1.10 (0.24)	1.09 (0.21)	1.08 (0.20)	1.02 (0.04)
Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
CD (0.05)	0.32		0.28		0.24		0.68		0.18		0.12	

Table 52. Interaction effect of growing condition and mulching on weed count and weed dry weight of sedges

Treatments	Count of sedges (no./m^2)						Dry weight of sedges (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No mulch	1.56 (1.67)	1.23 (0.58)	1.23 (0.58)	1.10 (0.25)	1.42 (1.17)	1.10 (0.25)	1.52 (1.75)	1.19 (0.50)	1.12 (0.28)	1.04 (0.08)	1.09 (0.19)	1.04 (0.09)
Organic mulch	1.28 (0.83)	1.061 (0.17)	1.03 (0.08)	1.10 (0.25)	1.10 (0.25)	1.00 (0.00)	1.62 (2.26)	1.07 (0.21)	1.01 (0.02)	1.02 (0.04)	1.02 (0.03)	1.00 (0.00)
Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
CD (0.05)	0.24		0.12		0.26		0.44		0.07		NS	

4.2.3. Interaction between date of planting and mulching

4.2.3.a Biometric observations

Plant height at 30, 60 DAP and at harvest

Data on interaction between planting dates and mulching on plant height, number of branches are depicted in Table 53. At 30 DAP, interaction was found to be non-significant. However at 60 DAP and at harvest significant variations were observed. At 60 DAP, the tallest plants were observed in July planting with black polythene mulch (46.57 cm) and shorter plants (8.29 cm) were observed in August planted crop with organic mulch (26.58 cm) and it was on par with August planted crop without mulch (26.95 cm), July planted crop without mulch (27.00 cm).At harvest, higher plant height of 72.67 cm was recorded in June planting with black polythene mulching (58.45 cm) and lower plant height was in June planting without mulch (36.00 cm).

No. of branches per plant at 30 DAP, 60 DAP and at harvest

Interaction between planting dates and mulching was not significant on number of branches at 30 and 60 DAP (Table 54). At harvest significant interaction was observed with more number of branches in June planting with black polythene mulch (19.50) and it was on par with August planting with black polythene mulch (18.33). Minimum number of branches was noticed in June planting without any mulch (5.01) and was on par with July planted crop without mulch (6.34), August planting without mulch (6.57), May planting with organic mulch (6.83) and May planting without mulch (6.89).

Fresh biomass yield at 30, 60 DAP and at harvest

Data on interaction between planting dates and mulching on fresh biomass yield and total yield are depicted in Table 55. The data was significant at 30 DAP, 60 DAP and harvest. At 30 DAP, higher biomass yield was recorded in June planting with black

polythene mulch (29.57 g/plant). Crop planted in July with organic mulch recorded lower biomass yield (8.09 g/plant) and was on par with July planting without mulch (9.01 g/plant) and August planting with organic mulch (10.19 g/plant) and August planting without mulch (10.59 g/plant).

At 60 DAP higher biomass yield was obtained in May planting with black polythene mulch (162.433 g/plant) and lower yield was obtained in August planting without any mulch (56.65 g/plant) and was on par with August planting with organic mulch (64.82 g/plant). At harvest, maximum biomass yield (819.67 g/plant) was obtained from May planted crops in black polythene mulch and a minimum of 57.19 g/plant recorded in July and August planting without any mulching.

Total yield

The combined effect of planting dates and mulching on total yield was found significant with maximum yield (30352 kg/ha) from May planting in black polythene mulch. The next best treatment combination was June planting and black polythene mulching (16950 kg/ha). Lower yield was recorded in August planting without mulch (1804 kg/ha) and was on par with August planting with organic mulch (2207 kg/ha), July planting without mulch (3531 kg/ha) and July planting with organic mulch (3774 kg/ha).

Total root yield

The interaction effect of date of planting and mulching was found to be significant on total root yield (Table 55). The maximum root yield (4053 kg/ha) obtained from May planting in black polythene mulch. May planting with organic mulch gave the next best yield (2080 kg/ha). Lower root yield was recorded in July planting without mulch (224 kg/ha) and was on par with August planting without mulching (269 kg/ha), July planting with organic mulch (404 kg/ha) and August planting with organic mulch (433 kg/ha).

Table 53. Interaction effect of date of planting and mulching on plant height of *Plectranthus vettiveroides* at different growth stages

Treatments	Plant height (cm)								
	30 DAP			60 DAP			Harvest		
	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene
May 15	20.40	23.73	25.42	28.35	31.65	41.80	52.12	56.09	66.77
June 15	21.57	23.68	27.64	30.10	33.03	46.57	36.00	46.33	72.67
July 15	20.82	21.28	26.95	27.00	30.72	36.34	47.53	47.22	56.77
August 15	17.23	18.23	22.70	26.95	26.58	36.17	46.57	47.47	58.45
CD(0.05)	NS			3.41			8.46		

Table 54. Interaction effect of date of planting and mulching on number of branches of *Plectranthus vettiveroides* at different growth stages

Treatments	No. of branches								
	30 DAP			60 DAP			Harvest		
	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene
May 15	3.63	3.67	3.90	4.50	5.17	7.10	6.89	6.83	13.81
June 15	4.64	4.89	6.66	5.23	6.99	9.49	5.01	9.27	19.50
July 15	3.86	3.99	5.95	4.77	5.37	7.79	6.34	8.07	14.37
August 15	2.58	3.33	3.78	5.99	5.91	7.68	6.57	11.10	18.23
CD(0.05)	NS			NS			2.50		

Table 55. Interaction effect of date of planting and mulching on biomass yield and total yield of *Plectranthus vettiveroides* at different growth stages

Treatments	Biomass yield (g/ plant)									Total yield (kg/ha)			Total root yield (kg/ha)		
	30 DAP			60 DAP			Harvest			30 DAP			60 DAP		
	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene
May 15	19.47	15.98	20.24	90.27	108.09	162.43	268.83	395.53	819.67	7487	9244	30352	1392	2080	4053
June 15	23.74	19.52	29.57	70.32	95.43	118.85	85.50	223.00	531.00	3467	10670	16950	374	891	1773
July 15	9.01	8.09	14.09	70.32	95.43	118.85	57.19	77.28	114.64	3531	3774	11704	224	404	615
August 15	10.59	10.19	16.14	56.65	64.82	79.05	57.19	77.28	114.64	1804	2207	5933	269	433	701
CD(0.05)	2.82			13.78			122.08			1943			219.85		

4.2.3.b Soil analysis

Soil pH

The interaction between different dates of planting and mulching on soil pH was non significant (Table 56).

Organic carbon

A non significant interaction was observed between different dates of planting and mulching on soil organic carbon content (Table 56)

Available nitrogen

Significantly higher available N (307.05 kg/ha) was obtained in the interaction between July planting and organic mulch (Table 57) and it was on par with black polythene much planting in May (295.45 kg/ha) and organic mulch with planting in June (291.33 kg/ha).

Available phosphorus

The interaction effect of dates of planting and mulching and not have any significant influence on the available phosphorus content (Table 57).

Available potassium

Significantly higher available K content (200.09 kg/ha) was recorded in the interaction between August planting and organic mulch (Table 57). Planting in July with black polythene mulch recorded the lowest soil potassium content after the experiment (145.97 kg/ha).

Table 56. Interaction effect of date of planting and mulching on pH, and organic carbon

Treatments	pH			Organic carbon (%)		
	No mulch	Organic mulching	Black polythene	No mulch	Organic mulching	Black polythene
May 15	4.85	4.72	4.82	1.17	1.47	1.35
June 15	4.90	4.868	4.56	1.04	1.57	1.27
July 15	4.93	4.79	4.84	1.19	1.44	1.36
August 15	4.53	4.9	4.38	1.29	1.46	1.12
CD (0.05)	NS			NS		

Table 57. Interaction effect of date of planting and mulching on available N, P and K

Treatments	Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene	No mulching	Organic mulch	Black polythene
May 15	246.88	228.53	295.45	21.30	21.97	22.42	162.35	171.66	160.00
June 15	237.12	291.33	205.68	22.53	22.31	23.31	152.21	153.23	176.97
July 15	258.24	307.05	282.96	24.55	25.33	26.29	181.67	149.30	145.97
August 15	219.41	239.70	185.28	26.79	26.71	23.20	150.24	200.09	169.88
CD (0.05)	28.08			NS			4.70		

4.2.3.c Micrometeorological observations

Soil temperature at 10 cm depth

Table 58. shows the interaction effect of planting dates and mulching on soil temperature. The soil temperature in this combination ranged from 24.40 ºC to 30.17 ºC. Higher soil temperature was recorded in May planting with black polythene mulch during the 1st week of May planting. 1st week of August planting recorded lower soil temperature under no mulch condition (24.40ºC).

Soil moisture at 15 cm depth

Interaction effect of planting dates and mulching on soil moisture (Table 59) was significant in all weeks except 13th week. Maximum soil moisture observed was 34.06% in the 2nd week of July planting with black polythene mulch. Lower soil moisture content (11.20 %) was observed at 8th week of August planted plots without mulch.

Light intensity

The effect of planting dates and mulching on the light intensity in the experimental plots is given in table 60. Maximum light intensity was observed in 1st week of May planted crop with black polythene mulch (17889 lux) and the lowest was in week 5 of June planting without mulching (8810 lux).

Treatments	Soil temperature (˚C)											
	Week 6			Week 7			Week 8			Week 9		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	25.17	25.69	27.05	25.56	25.53	26.88	26.18	25.71	26.61	25.96	25.63	26.81
June 15	25.50	25.48	26.15	25.25	24.97	25.87	25.45	24.94	25.96	25.31	24.85	25.87
July 15	24.86	25.26	25.33	25.91	26.34	27.34	25.78	26.38	27.51	25.93	26.44	27.91
August 15	26.95	26.00	28.54	25.61	25.98	28.26	26.12	26.77	27.67	26.98	26.61	28.31
CD (0.05)	0.10			0.11			NS			0.11		

Table 58. Interaction effect of date of planting and mulching on soil temperature

Treatments	Soil temperature (˚C)														
	Week1			Week 2			Week 3			Week 4			Week 5		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	28.99	29.01	30.18	25.23	25.27	27.16	25.94	25.69	26.35	26.62	26.21	28.02	26.72	25.90	27.59
June 15	26.72	26.22	27.59	25.17	25.69	27.05	25.57	25.54	26.88	26.18	25.72	26.62	25.96	25.63	26.81
July 15	25.61	25.98	26.81	25.51	25.47	26.15	24.79	25.44	25.88	24.97	25.42	25.97	24.82	25.36	25.88
August 15	24.40	24.79	25.88	24.79	24.70	25.33	26.17	26.20	27.35	25.83	26.65	27.53	25.60	26.14	27.93
CD (0.05)	0.11			0.09			0.22			0.11			0.10		

Table 58 contd.

Treatments	Soil temperature (˚C)											
	Week 10			Week 11			Week 12			Week13		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	25.50	25.48	26.17	25.32	24.94	25.87	25.45	24.94	25.97	25.31	24.85	25.61
June 15	25.29	24.24	25.29	26.16	26.08	27.34	26.06	26.09	27.52	26.13	26.19	27.92
July 15	26.52	27.08	28.51	25.38	26.80	28.29	25.91	26.43	27.66	25.88	26.98	28.31
August 15	26.12	26.84	27.67	26.35	26.19	26.36	26.57	26.13	26.92	25.83	26.67	27.53
CD (0.05)	0.07			NS			0.03			0.04		

Table 59. Interaction effect of date of planting and mulching on soil moisture at 15 cm depth

Treatments	Soil moisture (%)														
	Week1			Week 2			Week 3			Week 4			Week 5		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	11.83	12.32	13.51	13.49	13.94	15.46	14.57	14.89	16.62	13.85	14.68	15.31	19.23	19.50	22.60
June 15	19.80	28.56	29.24	21.51	29.06	29.94	22.22	27.59	32.14	23.66	29.09	31.17	24.45	29.44	31.52
July 15	31.44	32.74	33.77	21.02	32.85	34.06	22.84	29.63	33.74	25.74	28.90	33.17	22.05	29.35	33.62
August 15	31.44	32.74	33.77	26.17	33.53	34.02	12.16	13.42	14.11	12.27	13.65	14.21	12.47	13.42	14.41
CD (0.05)	0.98			2.60			2.37			1.89			1.81		

Treatments	Soil moisture (%)											
	Week 6			Week 7			Week 8			Week 9		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	19.40	19.19	22.90	19.19	22.90	30.87	21.53	24.32	29.80	23.30	25.18	29.83
June 15	24.60	21.54	26.84	21.54	26.84	30.09	22.18	25.18	33.20	23.30	25.18	29.83
July 15	22.24	12.77	14.04	12.77	14.04	14.65	12.76	14.19	14.80	12.48	15.60	14.85
August 15	13.65	12.20	13.46	12.20	13.46	13.91	11.20	13.26	13.54	10.85	12.83	13.67
CD (0.05)	2.72			2.55			1.19			0.94		

Table 59 contd.

Treatments	Soil moisture (%)											
	Week 10			Week 11			Week 12			Week 13		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	24.47	27.15	33.14	22.06	24.10	33.34	21.81	26.27	33.07	24.37	27.84	33.73
June 15	23.53	26.87	32.85	12.77	14.04	14.65	12.76	14.19	14.80	12.48	15.60	14.85
July 15	14.86	15.14	17.88	13.14	13.80	14.31	12.99	13.83	13.75	10.82	14.37	13.08
Aug 15	12.36	14.66	15.27	12.50	14.33	15.59	13.26	14.56	14.95	11.51	14.86	15.26
CD(0.05)	2.28			1.11			0.91			0.89		

Table 60. Interaction effect of planting dates and mulching on light intensity

Treatments	Light intensity(lux)														
	Week1			Week 2			Week 3			Week 4			Week 5		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	16245	16278	16419	17715	17748	17889	16717	16750	16890	16820	16853	16993	15633	15626	15823
June 15	10987	10928	10937	10557	10573	10581	9558	9538	9545	9261	9245	9256	8810	8815	8817
July 15	11078	11053	9117	10711	10683	9111	9675	9647	9811	9358	9228	8800	8933	8796	10269
Aug 15	9113	9240	9102	9107	9226	9088	9808	9927	9789	8798	8907	8732	10267	10376	10201
CD (0.05)	26.99			27.72			27.76			26.01			20.72		

Table 60 contd.

Treatments	Light intensity(lux)														
	Week6			Week7			Week 8			Week 9			Week 10		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	15714	15707	15896	15231	15224	15413	14960	14956	15117	14876	14873	15033	14148	14144	14305
June 15	9041	9040	9037	9658	9706	9703	8817	8833	8830	14776	10176	10174	10848	10868	10866
July 15	9155	9017	10803	9820	9683	11117	8940	8765	10956	10282	10110	11350	10975	10801	11664
August 15	10801	10909	10736	11115	11222	11050	10954	11063	10888	11348	11455	11283	11661	11770	11596
C D(0.05)	21.56			21.58			20.17			20.24			20.24		

Treatments	Light intensity (lux)								
	Week 11			Week 12			Week 13		
	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene	No mulch	Organic mulch	Black polythene
May 15	15821	15818	15978	15071	15068	15228	16645	16655	16815
June 15	15721	11333	11331	14971	10922	10920	16558	11369	11366
July 15	11441	11265	11835	11029	10854	11645	11474	11302	10543
August 15	11833	11943	11767	11643	11752	11577	10541	10649	10476
C D (0.05)	20.21			20.24			20.63		

4.2.3.d Physiological, chemical and biochemical observations

Total chlorophyll content 30 DAP, 60 DAP and at harvest

Data on interaction effect of planting dates and mulching on total chlorophyll and essential oil content are given in Table 61. At 30 DAP, the highest total chlorophyll content (1.806 mg/g) was observed in the crop planted in August with black polythene mulch whereas minimum was recorded in July planting with organic mulch (0.563 mg/g) and was on par with July planting with black polythene mulch (0.57 mg/g) and June planting with organic mulch (0.80 mg/g).

At 60 DAP, June planted crop without any mulch showed the highest chlorophyll content (2.53 mg/g) whereas minimum (1.25 mg/g) was recorded by the crop planted in August with organic mulch (1.174 mg/g) and it was on par with July planting with organic mulch (1.305 mg/g), August planting without mulch (1.402 mg/g), July planting without any mulch (1.412 mg/g) and July planting with black polythene mulch (1.499 mg/g). At harvest, chlorophyll content recorded was non significant.

Essential oil content (%)

Interaction between dates of planting and mulching had significant influence on essential oil content at harvest. Essential oil content was found maximum with May planting with black polythene mulching (2.08 %) and minimum essential oil content was recorded in August planting without mulching (1.15 %).

Crop growth rate

Interaction effect of planting date and mulching on crop growth rate and relative growth rate are depicted in Table 62. At 30 DAP, the highest CGR was recorded in June planting with black polythene mulch (0.513 $g/m^2/day$) whereas lower CGR was found with July planting with organic mulch (0.140 $g/m^2/day$), July planting without any mulch (0.158 $g/m^2/day$), August planting with organic mulch

(0.180 g/m^2/day) and August planting without any mulch (0.185 g/m^2/day). At 60 DAP , May planting with black polythene mulching recorded higher CGR value (12.84 g/m^2/day) and lower CGR was observed in July planting without any mulching (0.658 g/m^2/day), August planting without any mulching (0.783 g/m^2/day), June planting without any mulching(0.790 g/m^2/day), July planting with organic mulching(0.825 g/m^2/day).

Relative growth rate

At 30 DAP 60 DAP, higher RGR was recorded with June planting and black polythene mulching (0.040 g/g/day). At 60 DAP, significantly higher RGR of 0.029 g/g/day was recorded in May planting under black polythene mulch and was on par with May and June planting with organic mulching (0.027 g/g/day), July planting with black polythene mulching and August planting with organic mulching (0.026 g/g/day). At harvest higher RGR was recorded from May planting with black polythene mulch (0.026 g/g/day) and June planting with black polythene condition (0.023 g/g/day).

Plant N, P and K uptake

Interaction effect of planting dates and mulching on plant nutrient uptake is given in the Table 64. The highest uptake of nitrogen was in May planted crop grown with black polythene mulch (838.48 kg/ha). The lower rate of N uptake was in August planted crop without mulch (34.07 kg/ha) and it was on par with N uptake of August planted crop with organic mulch (49.12 kg/ha), July planted crop without mulch (69.20 kg/ha), June planted crop without mulch (84.95 kg/ha) and July planted crop with organic mulch (90.31 kg/ha).

Effect of date of planting and mulching on plant phosphorus uptake at harvest was found significant. The highest P uptake was in black polythene mulched plot of May planting (150.64 kg/ha). The lower rate of P uptake was in August planted crop without mulching (9.69 kg/ha) and it was on par with no mulched plot

planted in June (15.92 kg/ha), August planted crop with organic mulching (17.28 kg/ha), July planted crop without mulching (20.84 kg/ha), and July planted crop with organic mulching (24.50 kg/ha).

Similar trend was observed in the case of K uptake also. The highest potassium uptake was in black polythene mulched plot of May planting (99.37 kg/ha). The lower rate of K uptake was in August planted plot without mulching (25.03 kg/ha) and it was on par with August planting and organic mulched plot (26.27 kg/ha), June planted plot without mulching (45.77 kg/ha), July planted plot without mulching (53.30 kg/ha) , and July planted plot with organic mulching (57.07 kg/ha).

Table 61. Interaction effect of date of planting and mulching on total chlorophyll content and essential oil (%) at different growth stages

Treatments	Total chlorophyll content (mg/g)									Essential oil (%)		
	30 DAP			60 DAP			Harvest			Harvest		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	1.158	0.935	1.202	1.598	1.667	1.644	2.213	2.202	2.078	1.507	1.602	2.078
June 15	1.132	0.800	0.965	2.531	1.694	1.722	2.167	2.223	2.062	1.350	1.575	1.883
July 15	1.367	0.563	0.573	1.412	1.306	1.499	1.533	1.676	1.803	1.280	1.413	1.673
August 15	1.340	1.164	1.806	1.402	1.174	1.761	1.605	1.654	1.844	1.149	1.368	1.588
CD (0.05)	0.317			0.440			NS			0.104		

Table 62. Interaction effect of date of planting and mulching on crop growth rate at different growth stages

Treatments	CGR (g/m^2/day)								
	60 DAP			60 DAP			Harvest		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	0.338	0.278	0.355	1.205	1.572	2.423	3.575	5.347	12.130
June 15	0.412	0.338	0.513	0.790	1.295	1.520	0.527	2.423	7.623
July 15	0.158	0.140	0.243	0.658	0.825	1.235	0.353	0.442	0.610
August 15	0.185	0.180	0.285	0.783	0.927	1.068	0.377	0.468	0.988
CD (0.05)	0.049			0.268			2.226		

Table 63. Interaction effect of date of planting and mulching on relative growth rate at different growth stages

Treatments	RGR (g/g/day)								
	60 DAP			60 DAP			Harvest		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	0.034	0.031	0.034	0.021	0.027	0.029	0.018	0.020	0.025
June 15	0.036	0.033	0.040	0.015	0.022	0.019	0.005	0.012	0.023
July 15	0.022	0.021	0.029	0.023	0.027	0.026	0.006	0.006	0.005
August 15	0.025	0.024	0.031	0.023	0.026	0.022	0.006	0.006	0.009
CD (0.05)	0.003			0.004			0.005		

Table 64. Interaction effect of date of planting and mulching on plant nutrient content

Treatments	Plant nutrient uptake								
	Nitrogen (kg/ha)			Phosphorus (kg/ha)			Potassium (kg/ha)		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	164.74	214.73	838.48	42.74	65.16	150.64	96.40	102.10	367.37
June 15	84.95	261.40	492.87	15.92	66.38	91.68	45.77	146.12	194.79
July 15	69.20	90.31	292.20	20.84	24.50	68.89	53.30	57.07	170.45
August 15	34.07	49.12	137.39	9.69	17.28	34.35	25.03	26.27	84.43
CD (0.05)	74.73			22.04			39.34		

4.2.3.e Observations on weeds

Weed count

Broad leaf weeds

Interaction effect of date of planting and mulching on count of broad leaf weeds grasses and sedges and are given in Tables 65, 66, 67 respectively. At 30 DAP the count of broad leaved weeds at 30 DAP was found significant and highest weed count was noticed in no mulch condition planted in May 15 (79.83 no./m^2) and black polythene mulch planted in the month of July recorded lower Weed count (Zero count) which was on par with August planting with black polythene mulch(0.67 no./m^2). At 60 DAP higher weed count was obtained at no mulch treatment combined with May planting. (57.67 no./m^2) and lower count was found in the black polythene mulch at month of June (0.67 no./m^2). Same trend of weed count was observed during harvest also. No mulch treatment in May month showed highest weed count of 40.0 no./$m^2$and the lower weed count was observed at black polythene during May and July months (nil count) and it was significantly on par during June (0.33 no./m^2) and August(0.67 no./m^2).

Grasses

The weed count of grasses at 30 DAP was highest at May crop without mulch (2.83 no./m^2) and black polythene mulch at all months gave lowest zero weed count. At 60 DAP, also May planted plot without mulch gave highest weed count(1.33 no./m^2) and again black polythene mulched plots did not have any weeds. The same trend observed during harvest also. Black polythene mulched plots do not had any grass weeds and May planted plots had highest weed count of 1.33 no./m^2**.**

Sedges

Taking the weed count of sedges, at 30 DAP, it was highest at May crop without mulch (1.67 no./m^2) and black polythene mulch at all months gave zero

weed count. At 60 DAP the interaction was non significant. At harvest August planted plot without mulch gave highest weed count (1.17 no./m^2) and black polythene mulched plots did not have any weeds.

Weed dry weight

Broad leaf weeds

The data pertaining to the interaction effect on weed dry weight of grasses, sedges and broad leaf weeds are shown in the Tables 68, 69, 70. Significant effect was found in the weed dry weight of broad leaf weeds due to the interaction of planting dates and mulching. At 30 DAP the weed dry weight was found highest by June planting without mulching (28.30 g/m^2). Zero weed dry weight was observed in July planted crop with black polythene mulch which was on par with August (0.37 g/m^2) and June (0.39 g/m^2) planted crop under black polythene mulch. At 60 DAP highest weed dry weight was observed by no mulch treatment at May (20.50 g/m^2) and lower weight was recorded at black polythene mulch condition at June (0.30 g/m^2) which was on par with black polythene at August(0.68 g/m^2) and May (0.750 g/m^2) respectively. Same pattern was observed at harvest also. Higher dry weight was observed at no mulch treatment in May (14.25 g/m^2). Lower rate of weed dry weight was observed at May and July crops under black polythene (nil dry weight) which was on par with June (0.12 g/m^2) and August (0.22 g/m^2) planted plots under black polythene.

Grasses

The weed dry weight of grasses at 30 DAP was highest at May crop without mulch (9.19 g/m^2) and black polythene mulch at all months gave zero value. At 60 DAP, also May planted plot without mulch gave highest weed dry weight (0.95 g/m^2) and black polythene mulched plots in all the four seasons did not have any weeds. The same trend observed during harvest also. Black polythene mulched plots do not had any weeds and May planted plots without mulch had highest weed dry weight (0.77 g/m^2)

Sedges

Taking the dry weight of sedges, at 30 DAP, it was highest in May planted crop without mulch (2.66 g/m^2) and black polythene mulch at all months gave zero weight of sedge weeds. At 60 DAP the interaction was non significant. At harvest August planted plot without mulch gave highest weed dry weight (0.27 g/m^2) and black polythene mulched plots did not have any weeds in all the four month treatments.

Table 65. Interaction effect of date of planting and mulching on count of broad leaved weeds at different growth stages

Treatments	Count of broad leaf weeds (no./m^2)								
	30 DAP			60 DAP			Harvest		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	**8.74 (79.83)	6.88 (48.17)	1.51 (1.83)	7.55 (57.67)	5.73 (33.50)	1.48 (1.67)	6.30 (40.00)	5.17 (26.33)	1.00 (0.00)
June 15	8.50 (73.00)	6.80 (46.00)	1.29 (0.83)	6.96 (50.00)	5.53 (30.00)	1.21 (0.67)	5.46 (30.83)	4.40 (19.67)	1.12 (0.33)
July 15	8.78 (77.17)	6.73 (45.83)	1.00 (0.00)	5.85 (33.50)	5.43 (29.00)	1.49 (1.50)	4.87 (23.50)	4.20 (17.17)	1.00 (0.00)
August 15	5.99 (35.17)	5.29 (27.33)	1.21 (0.67)	5.79 (32.83)	4.70 (21.67)	1.36 (1.17)	4.45 (19.17)	3.95 (15.17)	1.21 (0.67)
CD (0.05)	0.89			0.68			0.51		

** √x+0.5 transformed values, original values are given in parenthesis

Table 66. Interaction effect of date of planting and mulching on count of grasses at different growth stages

Treatments	Count of grasses (no./m^2)								
	30 DAP			60 DAP			30 DAP		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	**1.84 (2.83)	1.36 (1.17)	1.00 (0.00)	1.45 (1.33)	1.19 (0.50)	1.00 (0.00)	1.44 (1.33)	1.24 (0.67)	1.00 (0.00)
June 15	1.58 (1.83)	1.33 (1.00)	1.00 (0.00)	1.31 (0.83)	1.24 (0.67)	1.00 (0.00)	1.17 (0.50)	1.12 (0.33)	1.00 (0.00)
July 15	1.59 (1.83)	1.31 (0.83)	1.00 (0.00)	1.28 (0.83)	1.07 (0.17)	1.00 (0.00)	1.26 (0.67)	1.07 (0.17)	1.00 (0.00)
Aug 15	1.41 (1.17)	1.37 (1.17)	1.00 (0.00)	1.24 (0.83)	1.07 (0.17)	1.00 (0.00)	1.31 (0.83)	1.14 (0.33)	1.00 (0.00)
CD (0.05)	0.38			0.24			0.20		

** √x+0.5 transformed values, original values are given in parenthesis

Table 67. Interaction effect of date of planting and mulching on count of sedges at different growth stages

Treatments	Count of sedges (no./m^2)								
	30 DAP			60 DAP			Harvest		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May-15	1.53 (1.67)	1.24 (0.83)	1.00 (0.00)	1.07 (0.17)	1.00 (0.00)	1.00 (0.00)	1.24 (0.67)	1.00 (0.00)	1.00 (0.00)
Jun-15	1.13 (0.33)	1.12 (0.33)	1.00 (0.00)	1.19 (0.50)	1.07 (0.17)	1.00 (0.00)	1.19 (0.50)	1.00 (0.00)	1.00 (0.00)
Jul-15	1.40 (1.17)	1.31 (0.83)	1.00 (0.00)	1.26 (0.67)	1.21 (0.50)	1.00 (0.00)	1.19 (0.50)	1.12 (0.33)	1.00 (0.00)
Aug-15	1.50 (1.33)	1.00 (0.00)	1.00 (0.00)	1.14 (0.33)	1.00 (0.00)	1.00 (0.00)	1.41 (1.17)	1.07 (0.17)	1.00 (0.00)
CD (0.05)	0.34			NS			0.26		

** $\sqrt{x+0.5}$ transformed values, original values are given in parenthesis

Table 68. Interaction effect of date of planting and mulching on dry weight of broad leaved weeds at different growth stages

Treatments	Dry weight of broad leaf weeds (g/m^2)								
	30 DAP			60 DAP			30 DAP		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	**5.07 (25.56)	4.37 (18.33)	1.31 (0.90)	4.59 (20.50)	3.56 (11.88)	1.27 (0.75)	3.82 (14.25)	3.09 (8.61)	1.00 (0.00)
June 15	5.36 (28.30)	4.06 (15.53)	1.15 (0.39)	3.92 (15.28)	3.68 (12.68)	1.11 (0.30)	3.45 (11.74)	2.95 (8.14)	1.05 (0.12)
July 15	4.76 (22.91)	4.39 (18.56)	1.00 (0.00)	3.41 (11.06)	3.46 (11.23)	1.32 (0.87)	2.99 (8.21)	2.50 (5.30)	1.00 (0.00)
August 15	4.33 (18.26)	3.88 (14.21)	1.13 (0.37)	4.26 (17.90)	3.97 (14.98)	1.24 (0.68)	3.31 (10.29)	3.10 (8.95)	1.09 (0.22)
CD (0.05)	0.61			0.556			0.310		

** $\sqrt{x+0.5}$ transformed values, original values are given in parenthesis

Table 69. Interaction effect of date of planting and mulching on dry weight of grasses at different growth stages

Treatments	Dry weight of grasses (g/m^2)								
	30 DAP			60 DAP			30 DAP		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	**2.62 (9.19)	1.81 (4.49)	1.00 (0.00)	1.34 (0.95)	1.14 (0.34)	1.00 (0.00)	1.27 (0.77)	1.10 (0.25)	1.00 (0.00)
June 15	2.39 (6.83)	1.66 (2.75)	1.00 (0.00)	1.28 (0.75)	1.18 (0.45)	1.00 (0.00)	1.07 (0.17)	1.05 (0.11)	1.00 (0.00)
July 15	1.79 (2.59)	1.24 (0.60)	1.00 (0.00)	1.18 (0.48)	1.04 (0.08)	1.00 (0.00)	1.08 (0.17)	1.02 (0.03)	1.00 (0.00)
August 15	1.44 (1.29)	1.22 (0.59)	1.00 (0.00)	1.10 (0.25)	1.02 (0.03)	1.00 (0.00)	1.18 (0.42)	1.04 (0.08)	1.00 (0.00)
CD (0.05)	0.98			0.27			0.18		

** √x+0.5 transformed values, original values are given in parenthesis

Table 70. Interaction effect of date of planting and mulching on dry weight of sedges at different growth stages

Treatments	Dry weight of sedges (g/m^2)								
	30 DAP			60 DAP			30 DAP		
	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch	No mulch	Organic mulch	Black Polythene mulch
May 15	**1.70 (2.66)	1.68 (4.16)	1.00 (0.00)	1.03 (0.07)	1.00 (0.00)	1.00 (0.00)	1.06 (0.13)	1.00 (0.00)	1.00 (0.00)
Jun 15	1.05 (0.10)	1.03 (0.07)	1.00 (0.00)	1.10 (0.25)	1.03 (0.05)	1.00 (0.00)	1.04 (0.09)	1.00 (0.00)	1.00 (0.00)
Jul 15	1.37 (1.04)	1.28 (0.74)	1.00 (0.00)	1.09 (0.19)	1.04 (0.07)	1.00 (0.00)	1.03 (0.07)	1.02 (0.03)	1.00 (0.00)
Aug 15	1.29 (0.70)	1.00 (0.00)	1.00 (0.00)	1.10 (0.23)	1.00 (0.00)	1.00 (0.00)	1.12 (0.27)	1.02 (0.03)	1.00 (0.00)
CD (0.05)	0.6			NS			0.06		

** √x+0.5 transformed values, original values are given in parenthesis

4.3. Three factor interactions

Interaction between growing condition, date of planting and mulching

4.3.1. Biometric observations

Plant height at 30, 60 DAP and at harvest

Combined effect of growing condition, planting dates and mulching on plant height and number of branches are depicted in Table 71. Significant interaction between growing condition, planting dates and mulching was observed for plant height at 30, 60 DAP and at harvest. At 30 DAP higher plant height of 34.33 cm was recorded in treatment combination June planting with black polythene mulching under shade. It was on par with July and planting with black polythene mulching under shaded condition (31.77 cm and 29.90 cm respectively). The lower plant height was noticed under open condition in July planting with organic mulch (13.90 cm), August planting without mulch (14.63 cm), July planting without mulch (15.17 cm), August planting with organic mulch (15.47 cm) and May planting without mulch (18.41 cm).

At 60 DAP, interaction had significant influence on plant height with maximum plant height in June planting under shade with black polythene mulch (55.67 cm). Crop planted in July without any mulch under open condition recorded lower plant height (21.07 cm) which was on par with July planted crops in organic mulch under open condition (22.90 cm), August planted crops without mulch under open condition (22.97 cm).

At harvest, the tallest plants were noticed in June planting with black polythene mulching under shaded condition (93.07 cm). The lower plant height was observed under open condition in June planting without mulch (26.13 cm).

No. of branches per plant at 30 DAP, 60 DAP and at harvest

At 30 DAP, interaction effect on number of branches was non significant. At 60 DAP combined effect of growing condition, planting dates and mulching was found to be significant with the highest number of branches (12.30) in June planting with black polythene mulching under open condition. The lower number of branches (3.53) was recorded in May planted crops under shade without any mulching and was on par with the May planting with organic mulch under open condition (3.72), and July planting with organic mulch in open condition (4.24). At harvest, combined effect of growing condition, planting dates and mulching was non significant.

Fresh biomass yield at 30, 60 DAP and at harvest

Combined effect of growing condition, planting dates and mulching on fresh biomass yield, total yield and total root yield are depicted in Table 72. Significant interaction between growing condition, planting dates and mulching was observed for biomass at 30, 60 DAP and at harvest. At 30 DAP highest yield of 31.62 g/plant was recorded in treatment combination June planting with black polythene mulching under shade. It was on par with June planting with black polythene mulching under open condition (27.52 g/plant). The lower plant biomass was noticed under open condition in July planting with organic mulch (6.87 g/plant) and was on par with August planting with organic mulch under open condition (8.50 g/plant), July planting without mulch under shade (8.68 g/plant), July planting with organic mulching under shade (9.32 g/plant), July planting without mulch in open (9.33 g/plant), and August planting without mulch in open (9.73 g/plant).

At 60 DAP, interaction had significant influence on biomass yield with maximum plant yield in May planting under shade with black polythene mulch (205.87 g/plant). At harvest, the highest plant biomass was noticed in May planting with black polythene mulching under open condition (872.00 g/plant).

Total yield

The effect of growing condition, planting dates and mulching on total yield is presented in Table 72. Significant interaction between growing condition, planting dates and mulching was observed for total yield at harvest. Total biomass yield of 34715 kg/ha was recorded in treatment combination June planting with black polythene mulching under open situation. The lower rate of total biomass was noticed under shade in August planting without mulch (1785 kg/ha) and was on par with August planting without mulch under open condition (1822 kg/ha), July planting without mulch under shade (1830 kg/ha), August planting with organic mulch under shade (2007 kg/ha).

Total root yield

Effect of the combination of three factors, growing condition, mulching and date of planting on total root yield was seen to have significant effect on total root yield with the highest root yield of 4221.11 kg/ha in May planted crop with black polythene mulch under open condition. The same date of planting with black polythene mulching under shaded condition was the next best treatment with respect to root yield (3884 kg/ha).

Table 71. Interaction effect of growing condition, date of planting and mulching on plant height and number of branches of *Plectranthus*at different growth stages

Treatment	Plant height (cm)						Number of branches					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	18.41	22.39	24.35	32.35	30.35	73.88	4.67	2.60	5.47	3.53	10.06	3.73
May x Organic mulch	20.16	27.31	28.90	34.40	35.83	76.34	4.27	3.07	6.61	3.723	8.87	4.80
May x Black Polythene mulch	20.95	29.90	33.00	50.60	49.01	84.54	4.00	3.80	7.60	6.60	19.95	7.67
June x No mulch	18.00	25.13	24.93	35.28	26.13	45.87	4.46	4.82	5.51	4.95	5.95	4.07
June x Organic mulch	20.00	27.37	28.07	38.00	28.93	63.73	5.35	4.43	7.36	6.62	10.20	8.333
June x Black Polythene mulch	20.95	34.33	37.467	55.67	52.27	93.07	7.60	5.72	12.30	6.68	26.27	12.73
July x No mulch	15.17	26.47	21.07	32.93	27.67	67.40	4.83	2.89	4.56	4.97	7.34	5.33
July x Organic mulch	13.90	28.67	26.33	35.10	29.00	65.43	5.19	2.80	6.50	4.24	9.02	7.12
July x Black Polythene mulch	22.13	31.77	35.40	37.28	36.77	76.77	5.96	5.93	8.85	6.73	17.40	11.33
Aug x No mulch	14.63	19.83	22.97	30.94	27.93	65.20	3.69	1.47	6.31	5.67	8.70	4.44
Aug x Organic mulch	15.47	21.00	22.90	30.27	28.13	66.80	4.35	2.31	6.17	5.65	10.83	11.37
Aug x Black Polythene mulch	19.57	25.83	33.77	38.57	42.43	74.47	5.37	2.20	8.62	6.74	23.67	12.80
CD (0.05)	4.63		4.82		6.57		NS		1.22		NS	

Table 72. Interaction effect of growing condition, date of planting and mulching on, biomass production and total biomass yield and total root yield

Treatments	Biomass production (g/plant)						Total biomass yield (kg/ha)		Total root yield (kg/ha)	
	30 DAP		30 DAP		Harvest		Harvest		Harvest	
	Open	50 % Shade	Open	50 % Shade	Open	50 % Shade	Open	50 % Shade	Open	50 % Shade
May x No mulch	17.69	21.26	53.83	126.72	342.00	195.67	8459	6515	1666.67	1116.67
May x Organic mulch	15.43	16.53	84.93	131.25	437.33	353.73	10415	8074	2243.67	1915.55
May x Black polythene mulch	20.41	20.07	118.90	205.97	872.00	767.33	34715	25989	4221.11	3884.45
June x No mulch	20.84	26.63	47.53	93.10	68.67	102.33	4078	2856	394.89	352.22
June x Organic mulch	16.02	23.02	65.24	125.62	171.33	274.67	11815	9526	923.67	857.89
June x Black polythene mulch	27.52	31.62	78.41	159.30	661.00	401.00	21275	12626	2205.67	1339.56
July x No mulch	9.33	8.68	35.70	59.61	46.83	67.55	5233	1830	240.22	207.22
July x Organic mulch	6.87	9.32	40.36	72.49	65.13	89.43	4407	3141	459.78	347.56
July x Black polythene mulch	12.277	15.91	64.06	108.80	101.27	128.02	13837	9570	711.89	517.55
Aug x No mulch	11.460	9.73	34.83	78.48	58.47	85.24	1822	1785	310.22	228.33
Aug x Organic mulch	11.890	8.50	46.97	82.67	73.97	98.49	2407	2007	481.33	385.22
Aug x Black polythene mulch	17.160	15.12	56.97	101.14	139.07	118.33	6126	5741	736.55	668.89
CD (0.05)	4.56		12.87		66.87		250.45		320.45	

4.3.2. Soil analysis

Combined effect of growing condition, planting dates and mulching on soil pH, organic carbon, available N, P and K are depicted in Table 73.

Soil pH

Combined effect of growing condition, planting dates and mulching on soil pH was found non significant (Table 73.)

Organic carbon

Data on combined effect of growing condition, planting dates and mulching on organic carbon was found non significant (Table 73.)

Available nitrogen

Interaction between growing condition, planting dates and mulching on soil available nitrogen was significant (Table 73). The highest value was found (348.63 kg/ha) in July planting in organic mulch under shaded condition and lower nitrogen content was recorded in August planting with black polythene mulch under open condition (162.16 kg/ha) and it was on par with August planting with organic mulch under open condition (174.71 kg/ha), June planting in black polythene mulch under shade (179.04 kg/ha) and August planting in no mulch plot under open condition (188.54 kg/ha).

Available phosphorus

Interaction effect of growing condition and planting dates had significant effect on available phosphorus content of soil after the harvest of the crop. Available P content in soil after experiment was found significantly higher (30.71 kg/ha) in August

planting with no mulch under shaded condition and it was on par with July planting in black polythene mulch under shaded condition (30.49 kg/ha), and August planting in organic mulch under shaded condition (30.46 kg/ha).

Available potassium

Available K content in soil after experiment was found non significant (Table 73).

Table73. Interaction effect of growing condition, date of planting and mulching pH, organic carbon and available N, P, K of soil

Treatment	pH		Organic carbon (%)		Available N (kg/ha)		Available P (kg/ha)		Available K (kg/ha)	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	4.45	5.26	1.16	1.18	206.16	287.60	18.62	23.99	136.48	188.22
May x Organic mulch	4.85	4.59	1.50	1.44	303.30	287.60	18.94	25.00	163.13	180.19
May x Black polythene mulch	5.07	4.58	1.32	1.39	244.72	212.34	18.84	26.01	164.81	155.18
June x No mulch	4.84	4.98	1.05	1.02	224.28	249.97	18.95	26.12	136.81	167.61
June x Organic mulch	5.05	4.68	1.59	1.56	269.97	312.69	18.61	26.01	163.47	142.99
June x Black polythene mulch	4.61	4.51	1.26	1.29	232.31	179.04	19.95	26.68	173.33	180.60
July x No mulch	4.73	5.13	1.17	1.22	207.76	308.72	21.30	27.81	179.60	183.74
July x Organic mulch	4.55	5.04	1.43	1.45	265.48	348.63	21.52	29.14	150.25	148.35
July x Black polythene mulch	5.21	4.46	1.38	1.35	269.59	296.33	22.09	30.49	157.98	133.96
Aug x No mulch	4.44	4.63	1.33	1.23	188.54	250.28	22.87	30.71	165.58	134.91
Aug x Organic mulch	5.08	4.80	1.44	1.48	174.71	304.69	22.97	30.46	205.13	195.05
Aug x Black polythene mulch	4.26	4.51	1.19	1.05	162.16	208.40	23.09	23.32	188.11	151.65
CD (0.05)	NS		0.219		20.76		0.25		NS	

4.3.3. Micrometeorological observations

Soil temperature at 10 cm depth

The influence of soil temperature by the combined effect of all the treatments was found non significant (Table74.)

Soil moisture at 15 cm depth

Combined effect of growing condition, planting dates and mulching showed significant influence on soil moisture content in most of the weeks except 3rd, 6th, 8th, 10th, 11th and 12th week. Maximum soil moisture (37.61%) observed was at 6th week on June planted plot with black polythene mulch under shaded condition. The Lowest soil moisture content was recorded at 13thweek in July planted plots under no mulch situation under open condition (10.18%) (Table 75).

Light intensity

The three factor interaction was found significant on light intensity during all the weeks observed (Table 76). The highest light intensity was observed under open condition at 1st and 2nd week of May, mulched with black polythene (19580 lux) and the lowest light intensity was observed in July planting with organic mulch under 50 percent shade (42781 lux).

Table 74. Interaction effect of growing condition, date of planting and mulching on soil temperature (ºC)

Treatments	Soil temperature (ºC)													
	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	28.97	29.00	26.10	24.35	27.07	24.80	26.66	26.58	26.55	26.89	25.980	24.35	25.890	25.24
May x organic mulch	28.97	29.05	26.05	24.49	26.63	24.75	26.83	25.57	26.31	25.49	26.30	25.07	25.34	25.74
May x Black Polythene mulch	30.30	30.05	27.92	26.41	27.01	25.69	28.62	27.42	27.78	27.40	27.29	26.80	27.31	26.46
June x No mulch	26.55	26.89	25.98	24.35	25.89	25.24	26.96	25.40	26.37	25.55	25.48	25.523	25.250	25.25
June x organic mulch	26.64	25.79	26.30	25.07	25.34	25.74	25.75	25.68	25.67	25.59	25.50	25.47	24.32	25.63
June x Black Polythene mulch	27.78	27.40	27.29	26.80	27.31	26.46	27.10	26.13	27.29	26.34	26.597	25.703	26.49	25.26
July x No mulch	25.67	25.55	25.50	25.52	24.317	25.25	24.45	25.50	24.35	25.28	24.42	25.30	26.17	25.65
July x organic mulch	26.37	25.59	25.48	25.47	25.25	25.63	25.40	25.43	25.350	25.36	25.26	25.27	26.67	26.01
July x Black Polythene mulch	27.29	26.34	26.60	25.70	26.49	25.26	26.37	25.57	26.26	25.49	25.22	25.43	27.55	27.14
Aug x No mulch	24.35	24.44	24.4	25.15	26.17	26.17	26.00	25.65	25.67	25.530	26.59	27.03	25.09	26.13
Aug x organic mulch	25.35	24.23	25.26	24.14	26.67	25.73	26.57	26.73	26.05	26.23	26.57	25.43	25.95	25.99
Aug x Black Polythene mulch	26.26	25.49	25.22	25.43	27.55	27.14	27.68	27.38	27.22	28.633	28.69	28.39	28.10	28.42
CD (0.05)	NS		NS		NS		NS		NS		NS		NS	

Treatments	Week 8		Week 9		Week 10		Week11		Week 12		Week 13	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	26.96	25.40	26.37	25.55	25.48	25.52	25.25	25.25	25.40	25.50	25.35	25.28
May x Organic mulch	25.75	25.68	25.67	25.59	25.50	25.47	24.32	25.63	24.45	25.43	24.35	25.36
May x Black polythene mulch	27.10	26.13	27.29	26.34	26.60	25.70	26.49	25.26	26.37	25.57	26.26	25.49
June x No mulch	25.40	25.50	25.35	25.28	25.26	25.30	26.67	25.65	26.57	25.55	26.05	26.20
June x Organic mulch	24.45	25.43	24.35	25.36	24.42	25.27	26.17	26.01	26.00	26.19	25.67	26.83
June x Black Polythene mulch	26.37	25.57	26.26	25.49	25.22	25.43	27.55	27.14	27.68	27.38	27.22	28.63
July x No mulch	26.00	25.55	25.67	26.20	26.59	26.47	25.09	25.52	26.34	25.45	26.55	25.21
July x Organic mulch	26.57	26.19	26.05	26.83	26.57	27.60	25.95	27.66	26.80	26.01	27.35	26.58
July x Black Polythene mulch	27.68	27.38	27.22	28.63	28.69	28.39	28.10	28.42	27.91	27.41	29.18	27.43
Aug x No mulch	26.34	25.91	26.55	27.42	26.34	25.91	26.63	25.95	26.54	26.63	26.00	25.65
Aug x Organic mulch	26.80	26.73	27.35	25.90	26.80	26.73	27.07	25.30	26.91	25.19	26.57	26.73
Aug x Black Polythene mulch	27.91	27.41	29.18	27.43	27.91	27.41	27.01	25.69	27.93	25.82	27.68	27.38
CD (0.05)	NS		NS		NS		NS		NS		NS	

Table 75. Interaction effect of growing condition, date of planting and mulching on soil moisture at 15 cm depth

Treatments	Soil moisture (%)													
	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	11.36	12.30	12.24	14.73	14.32	14.82	14.17	13.52	18.83	19.62	19.03	19.77	18.65	19.74
May x Organic mulch	12.19	12.46	12.97	14.90	14.70	15.07	14.83	14.52	19.50	19.50	23.70	20.00	20.07	25.73
May x Black Polythene mulch	13.40	13.62	14.73	16.18	16.15	17.08	15.74	14.88	22.60	22.60	25.47	23.10	29.17	32.57
June x No mulch	19.83	19.77	19.66	23.36	19.83	24.61	21.10	26.22	21.72	27.18	21.16	28.03	21.78	21.30
June x Organic mulch	23.40	33.71	23.70	34.41	20.07	35.11	22.37	35.81	22.37	36.51	25.73	34.21	24.10	29.57
June x Black Polythene mulch	24.77	33.71	25.47	34.41	29.17	35.11	26.53	35.81	26.53	36.51	32.57	37.61	33.34	26.83
July x No mulch	33.71	29.17	21.16	20.88	21.78	23.90	22.31	29.17	22.12	21.97	22.15	22.33	12.82	12.72
July x Organic mulch	33.71	31.77	33.71	31.99	25.44	33.82	26.04	31.77	26.44	32.27	26.94	25.73	13.76	14.32
July x Black Polythene mulch	33.71	33.83	33.71	34.41	31.90	35.58	32.50	33.83	32.90	34.33	33.40	32.57	14.72	14.57
Aug x No mulch	33.71	29.17	22.72	29.62	13.11	11.21	12.96	11.57	12.19	12.75	11.51	15.80	12.80	11.59
Aug x Organic mulch	33.45	31.77	33.71	33.36	14.18	12.67	14.06	13.24	13.24	13.60	12.93	18.15	13.76	13.17
Aug x Black Polythene mulch	33.71	33.83	33.71	34.41	14.64	13.57	14.63	13.80	13.49	15.33	13.17	14.84	13.56	14.26
C D(0.05)	1.38		2.26		NS		2.67		2.55		NS		3.60	

Treatments	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	20.75	22.31	21.40	25.20	21.86	27.07	21.86	22.25	22.31	21.30	26.63	22.11
May x Organic mulch	22.37	26.27	22.37	28.00	25.73	28.57	24.10	24.10	26.27	26.27	28.00	27.69
May x Black Polythene mulch	26.53	33.07	26.53	33.13	32.57	33.71	33.34	33.34	33.07	33.07	33.13	34.32
June x No mulch	22.31	22.06	25.20	21.40	25.20	21.86	12.82	12.72	12.81	12.71	12.63	12.33
June x Organic mulch	26.27	24.10	28.00	22.37	28.00	25.73	13.76	14.32	13.85	14.53	16.59	14.61
June x Black Polythene mulch	33.07	33.34	33.13	26.53	33.13	32.57	14.72	14.57	14.63	14.97	15.17	14.52
July x No mulch	12.81	12.71	12.63	12.33	13.28	16.43	12.84	13.43	12.45	13.53	10.18	10.45
July x Organic mulch	13.85	14.53	16.59	14.61	14.39	15.88	13.24	14.36	13.27	14.40	14.89	13.86
July x Black Polythene mulch	14.63	14.97	15.17	14.52	15.61	20.14	14.23	14.39	12.95	14.55	13.68	12.48
Aug x No mulching	11.23	11.17	12.52	9.17	13.19	11.52	10.33	14.67	13.42	13.10	11.49	11.53
Aug x Organic mulch	13.21	13.31	13.51	12.14	14.60	14.73	12.91	15.74	15.47	13.64	14.34	15.38
Aug x Black Polythene mulch	12.66	14.41	13.79	13.55	15.65	14.90	13.48	17.70	15.37	14.52	14.77	15.75
CD (0.05)	NS		1.33		NS		NS		NS		1.26	

Table 76 . Interaction effect of growing condition, date of planting and mulching on light intensity

Treatments	Light intensity (lux)													
	Week 1		Week 2		Week 3		Week 4		Week 5		Week 6		Week 7	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	19390	13100	19390	16040	16390	17043	16491	17148	14101	17165	14221	17206	13221	17240
May x Organic mulch	19460	13097	19460	16037	16460	17040	16561	17145	14091	17162	14211	17203	13211	17237
May x Black Polythene mulch	19580	13257	19580	16197	16580	17200	16681	17305	14323	17322	14429	17363	13429	17397
June x No mulch	19573	13000	19573	15940	16573	16943	16674	17048	14276	17065	14376	17106	13376	17140
June x Organic mulch	14101	7756	14221	6925	13221	5854	12600	5890	12593	5036	13142	4938	14900	4512
June x Black Polythene mulch	14091	7784	14211	6950	13211	5879	12597	5915	12590	5032	13139	4935	14897	4509
July x No mulch	14323	7832	14429	6993	13429	5921	12757	5958	12750	5115	13299	5010	15057	4583
July x Organic mulch	14276	7829	14376	6990	13376	5919	12500	5955	12493	5098	13042	4992	14800	4565
July x Black Polythene mulch	12593	5640	13142	5079	14900	4722	13100	4500	16040	4498	17043	4563	17148	5085
Aug x No mulch	12590	5636	13139	5075	14897	4718	13097	4499	16037	4496	17040	4562	17145	5084
Aug x Organic mulch	12750	5729	13299	5153	15057	4796	13257	4556	16197	4554	17200	4618	17305	5139
Aug x Black Polythene mulch	12493	5710	13042	5134	14800	4777	13000	4464	15940	4462	16943	4529	17048	5051
CD (0.05)	38.17		39.21		39.25		36.78		29.31		39.49		30.52	

Treatments	Week 8		Week 9		Week 10		Week 11		Week 12		Week 13	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	12600	17319	12593	17159	13142	15153	14900	16742	13100	17042	16040	17249
May x Organic mulch	12597	17316	12590	17156	13139	15150	14897	16739	13097	17039	16037	17273
May x Black polythene mulch	12757	17476	12750	17316	13299	15310	15057	16899	13257	17199	16197	17433
June x No mulch	12500	17219	12493	17059	13042	15053	14800	16642	13000	16942	15940	17176
June x Organic mulch	13100	4565	16040	4313	17043	4694	17148	5519	17165	4679	17206	5531
June x Black polythene mulch	13097	4564	16037	4311	17040	4692	17145	5517	17162	4677	17203	5530
July x No mulch	13257	4622	16197	4367	17200	4750	17305	5577	17322	4735	17363	5585
July x Organic mulch	13000	4529	15940	4279	16943	4658	17048	5481	17065	4643	17106	5497
July x Black polythene mulch	17165	4746	17206	5493	17240	6087	17319	6351	17159	6130	15153	5933
Aug x No mulch	17162	4745	17203	5492	17237	6085	17316	6350	17156	6129	15150	5932
Aug x Organic mulch	17322	4803	17363	5547	17397	6143	17476	6409	17316	6187	15310	5988
Aug x Black polythene mulch	17065	4710	17106	5459	17140	6051	17219	6314	17059	6095	15053	5899
CD (0.05)	28.52		28.62		28.63		28.58		28.62		29.17	

4.3.4. Physiological, chemical and biochemical observations

Combined effect of growing condition, date of planting and mulching on total chlorophyll content and essential oil (%) are depicted in Table 77.

Total chlorophyll content 30 DAP, 60 DAP and at harvest

Interaction between growing condition, date of planting and mulching significantly influenced total chlorophyll content at 30 DAP and at 60 DAP and it was non significant at harvest. At 30 DAP the highest chlorophyll content of 1.94 mg $g^{-1}$was recorded from combination of August planting with black polythene mulching under shade. The lower chlorophyll content of 0.37 mg/g was in July planting with organic mulch under shade. At 60 DAP, significantly higher chlorophyll content (3.46 mg/g) was recorded in June planting without mulch under shaded condition. Minimum chlorophyll content (1.024 mg/g) was recorded with August planting with organic mulch in open condition which was on par with July planting with organic in open condition (1.084 mg/g) and August planting without mulch in open condition (1.113 mg/g).

Essential oil content (%)

The interaction effect of three factors on total essential oil content of the crop at harvest was found significant with higher essential oil content of 2.35% in May planted crop with black polythene mulch under open condition and was on par with June planted crop with black polythene under open situation (2.09 %). The lowest content of essential oil was obtained from August planted crop without mulch under shaded condition (0.75%), which was on par with June planted crop without mulch under shaded condition (1.03%), August planted crop with organic mulch in shaded condition (1.06%), July planted crop without mulch in shaded condition (1.09%).

Crop growth rate

Data on interaction effect of growing condition, planting dates and mulching on crop growth rate was given in Table 78. At 30 DAP higher CGR was noticed in June planted crop with black polythene mulch under shade (0.514 g/m^2/day) which was on par with June planted crop with black polythene mulch under open situation(0.513 g/m^2/day). Lower CGR was observed in July planting under open condition with organic mulch (0.130 g/m^2/day) which was on par with no mulch and organic mulched treatments of July and August planting. At 60 DAP highest CGR was obtained during May planted crop with black polythene mulch under shade (3.19 g/m^2/day). At harvest the highest CGR was in open condition in May planted crop with black polythene mulch (13.827 g/m^2/day)

Relative growth rate

Relative growth rate was not influenced significantly by the combined effects of growing condition, planting dates and mulching treatments at different growth stages (Table 78).

Plant N, P and K uptake

A significant effect was found with respect to total nutrient uptake of plants at harvest due to the three factor interaction (Table 79). The highest nitrogen uptake was in May planted crop with black polythene mulch under open condition. The lower uptake occurred in August planted crop without mulching under open condition (2.74 kg/ha), and this was on par with July planting without mulch under shade (38.51 kg/ha), August planting without mulch under shade (40.39 kg/ha), August planting with organic mulch under open (47.60 kg/ha) and August planting with organic mulch under shade (50.64 kg/ha).

The interaction effect of three factors on the phosphorus uptake was non significant. Regarding K uptake, May planting with black polythene mulch under shade recorded highest K uptake. Both un mulched and organic mulched plots in August recorded significantly lower uptake of potassium.

Table 77. Interaction effect of growing condition, date of planting and mulching on total chlorophyll content and essential oil content at different growth stages

Treatments	Total chlorophyll (mg/g)						Essential oil (%)	
	30 DAP		60 DAP		Harvest		Harvest	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	1.21	1.10	1.30	1.90	1.94	2.49	1.78	1.23
May x Organic mulch	1.00	0.87	1.55	1.78	1.67	2.74	1.83	1.37
May x Black polythene mulch	1.46	0.94	1.57	1.71	1.90	2.25	2.35	1.80
June x No mulch	1.11	1.16	1.60	3.46	2.03	2.30	1.67	1.03
June x Organic mulch	1.04	0.56	1.68	1.71	1.65	2.80	1.73	1.42
June x Black polythene mulch	1.15	0.78	2.17	1.27	1.85	2.28	2.08	1.69
July x No mulch	1.62	1.11	1.39	1.43	1.35	1.72	1.47	1.09
July x Organic mulch	0.76	0.37	1.08	1.53	1.26	2.09	1.51	1.31
July x Black polythene mulch	0.53	0.62	1.47	1.53	1.31	2.29	1.82	1.52
Aug x No mulch	1.12	1.56	1.13	1.67	1.29	1.92	1.55	0.75
Aug x Organic mulch	1.01	1.31	1.02	1.32	1.26	2.05	1.68	1.06
Aug x Black polythene mulch	1.67	1.94	1.57	1.95	1.49	2.20	1.79	1.39
CD (0.05)	0.24		0.222		NS		0.37	

Table 78. Interaction effect of growing condition, date of planting and mulching crop growth rate, relative growth rate at different growth stages

Treatments	CGR (g/m^2/day)						RGR (g/g/day)					
	30 DAP		30 DAP		Harvest		30 DAP		30 DAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
May x No mulch	0.330	0.347	0.590	0.657	5.300	1.850	0.033	0.034	0.015	0.026	0.026	0.009
May x Organic mulch	0.287	0.270	1.167	1.977	6.503	4.190	0.031	0.030	0.024	0.030	0.025	0.015
May x Black polythene mulch	0.380	0.330	1.653	3.193	13.827	10.43	0.035	0.033	0.024	0.034	0.030	0.019
June x No mulch	0.390	0.433	0.423	1.157	0.437	0.617	0.036	0.037	0.011	0.019	0.006	0.005
June x Organic mulch	0.300	0.377	0.817	1.773	2.000	2.847	0.032	0.035	0.019	0.025	0.015	0.010
June x Black polythene mulch	0.513	0.514	0.830	2.210	10.680	4.567	0.040	0.039	0.014	0.024	0.032	0.014
July x No mulch	0.173	0.143	0.437	0.880	0.243	0.463	0.024	0.021	0.018	0.028	0.005	0.006
July x Organic mulch	0.130	0.150	0.563	1.087	0.493	0.390	0.020	0.022	0.024	0.030	0.008	0.004
July x Black polythene mulch	0.227	0.260	0.867	1.603	0.750	0.470	0.028	0.030	0.023	0.029	0.007	0.003
Aug x No mulch	0.213	0.157	0.383	1.183	0.467	0.287	0.027	0.022	0.015	0.031	0.009	0.003
Aug x Organic mulch	0.220	0.140	0.580	1.273	0.543	0.393	0.027	0.021	0.019	0.034	0.008	0.004
Aug x Black polythene mulch	0.320	0.250	0.657	1.480	1.553	0.423	0.033	0.029	0.016	0.028	0.014	0.003
CD (0.05)	0.06		0.39		0.45		NS		NS		NS	

Table 79. Interaction effect of growing condition, date of planting and mulching of plant nutrient uptake at different growth stages

Treatments	Nutrient content (kg/ha)					
	Nitrogen		Phosphorus		Potassium	
	Open	50% shade	Open	50% shade	Open	50% shade
May x No mulch	182.28	147.20	53.12	32.36	107.59	85.21
May x Organic mulch	238.46	191.01	74.08	56.23	92.85	111.35
May x Black polythene mulch	912.91	764.06	176.04	125.24	324.24	410.51
June x No mulch	98.45	71.45	19.98	11.85	35.45	56.10
June x Organic mulch	264.34	258.46	75.51	57.26	132.74	159.49
June x Black polythene mulch	583.80	401.94	108.57	74.79	188.08	201.49
July x No mulch	99.90	38.51	33.09	8.59	74.44	32.15
July x Organic mulch	102.46	78.16	30.28	18.72	51.14	51.00
July x Black polythene mulch	343.69	240.71	77.23	60.55	184.30	156.59
Aug x No mulch	27.74	40.39	10.64	8.74	22.14	27.92
Aug x Organic mulch	47.60	50.64	19.85	14.72	27.13	25.40
Aug x Black polythene mulch	129.86	144.92	35.64	33.05	65.74	103.13
CD (0.05)	52.49		NS		21.14	

4.3.5 Observations on weeds

Weed count

Broad leaf weeds

The weed observations on count of grasses, sedges and broad leaved weeds are given (Tables 80, 81 and 82). At 30 DAP, higher counts of broad leaved weeds were observed under open situation in May planted crop without mulching (110.33 no./m^2). At 60 DAP the highest weed count was observed in May planted crop under open situation without mulch (76.00 no./m^2). Same treatment recorded higher weed count at harvest also (52.33 no./m^2). The lowest broad leaf weed count observed when black polythene mulch was used. At 30 DAP the lowest count was in July planting with black polythene mulch both under shade and open and in August planting under shaded condition. At 60 DAP, lower values were in June planting under shaded condition with black polythene mulch, and in harvest stage, May panting with black polythene mulch both under open and shade, June planting under shade, July planting under open and shade and August planting under shade showed no counts of broad leaf weeds.

Grasses

Taking weed count of grasses, at 30 DAP, the highest grass count was observed under open condition in May planted crop without mulching (3.33 no./m^2). The lower weed count was found to be zero which were observed in the combinations of black polythene mulches at all the four months plots in both open and shaded conditions. At 60 DAP, the interaction was non significant. At harvest stage, the highest count was observed in open condition in May without any mulch (1.67 no./m^2). The lowest weed count value zero was observed in all the black polythene mulched plots in all four months plots in both open and shaded condition, the organic mulched plots in shaded

condition in all the four months planting and non mulched plots in shaded condition during the month of May .

Sedges

Taking weed count of sedges, at 30 DAP, the highest count was observed in open condition in May planted crop without mulching (3.33 no./m^2). The lowest weed count in sedges was zero which was found in all the treatment combinations including black polythene mulch, organic mulched plot under shade during the month of May, June and August and also organic mulched plot under open condition in the month of August. At 60 DAP, the interaction was non significant. At harvest stage, the highest count was observed in open condition in August planted crop without mulch (1.67 no./m^2). The lowest weed count of Zero was found in all the treatment combinations including black polythene, organic mulched plots under open and shade planted in May and June and under shade planted in July and August and Non mulched plots planted under shade planted in June and July months.

Weed dry weight

Broad leaf weeds

The observations on dry weight of grasses, sedges and broad leaf weeds are given in (Tables 80, 81 and 82) . At 30 DAP, the highest weed dry weight of broad leaf weeds were observed in open condition in May planted crop without mulching (33.88 g/m^2). At 60 DAP the highest weed dry weight was observed in may planted crop under open situation without mulch (26.03 g/m^2). Same treatment recorded higher dry weight at harvest also (19.26 g/m^2). At 30 DAP, lower dry weight was obtained with black polythene mulch in July planting both under shade and open and in August planting at shaded situation. At 60 DAP, it was in June planting under shaded condition with black polythene mulch. At harvest stage, black polythene mulched plots of May planting both

under open and shade, June planting under shade, July planting under open and shade and August planting under shade recorded lower dry weight of broad leaf weeds.

Grasses

Comparing dry weight of grasses, at 30 DAP, the highest weight was observed under open condition in May planting without mulch (1.61 g/m^2). Zero weed count were observed with the plots of black polythene mulch applied, and organic mulched plot under shade planted in June. At 60 DAP, the interaction was non significant. At harvest stage, the highest dry weight was observed in open condition in August planting without mulch (0.59 g/m^2). Zero weed count were observed in all the polythene mulched plots, organic mulched plots under shade planted in June and July, and non mulched plots under shade planted in July.

Sedges

Regarding interaction effect of growing condition, planting dates and mulching on dry weight of sedges, at 30 DAP, the highest dry weight was observed under open condition in May planting with organic mulch (8.32 g/m^2). The lowest weed dry weight observed was zero value found in the treatment combinations of all of the black polythene mulched plots, organic mulched plots under shade planted in the months of May, June, August, organic mulched plots planted under open condition in August, and non mulched plot planted under shade in the month of May. At 60 DAP, the interaction was non significant. At harvest stage, the highest dry weight was observed under open condition in June planting without any mulch (1.67 g/m^2). Zero dry weight of sedges were observed in all the black polythene mulched plots, organic mulched plots planted under both open and shade in May and June, organic mulched plots planted in shade during July and August and non mulched plots under shade planted during June and July.

Weed control efficiency (WCE)

Weed control efficiency ranged from 8.64 % to 100 % (Table 83). Black polythene mulch under shade in all the four month planted plots, black polythene mulched plots planted under open in the months of May and July gave 100 % WCE. Lower weed control efficiency was recorded in June planting without mulch in open condition (8.64%).

Weed Index (%)

Maximum weed index was recorded in June planting without mulch under open condition (89.63%) and minimum weed index was recorded in June planting with organic mulch under 50 percent shaded condition (35.02 %).

Table 80. Interaction effect of growing condition, date of planting and mulching on count and dry weight of broad leaved weeds

Treatments	Count of broad leaf weeds (no./m^2)						Dry weight of broad leaf weeds (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	10.49 (110.33)	7.00 (49.33)	8.76 (76.00)	6.34 (39.33)	7.30 (52.33)	5.30 (27.67)	5.896 (33.88)	4.253 (17.24)	5.20 (26.03)	3.99 (14.96)	4.48 (19.26)	3.17 (9.24)
May x Organic mulch	7.96 (62.67)	5.80 (33.67)	7.00 (48.00)	4.47 (19.00)	5.85 (33.33)	4.49 (19.33)	4.62 (20.73)	4.11 (15.93)	3.97 (14.80)	3.15 (8.96)	3.21 (9.32)	2.97 (7.88)
May x Black polythene mulch	1.61 (2.33)	1.41 (1.33)	1.48 (1.67)	1.48 (1.67)	1.00 (0.00)	1.00 (0.00)	1.28 (0.80)	1.330 (0.99)	1.25 (0.70)	1.28 (0.80)	1.00 (0.00)	1.00 (0.00)
June x No mulch	9.68 (93.33)	7.31 (52.67)	8.40 (69.67)	5.53 (30.33)	6.82 (45.67)	4.09 (16.00)	5.56 (30.86)	5.15 (25.73)	4.68 (21.30)	3.17 (9.26)	4.32 (17.66)	2.58 5.83)
June x Organic mulch	7.65 (57.67)	5.94 (34.33)	6.13 (36.67)	4.93 (23.33)	5.45 (29.00)	3.34 (10.33)	4.00 (15.02)	4.13 (16.04)	3.81 (13.70)	3.55 (11.66)	3.58 (11.88)	2.32 (4.41)
June x Black polythene mulch	1.33 (1.00)	1.24 (0.67)	1.41 (1.33)	1.00 (0.00)	1.24 (0.67)	1.00 (0.00)	1.04 (0.087)	1.25 (0.700)	1.22 (0.60)	1.00 (0.00)	1.10 (0.23)	1.00 (0.00)
July x No mulch	9.29 (86.67)	8.28 (67.67)	6.37 (39.67)	5.32 (27.33)	5.67 (31.33)	4.07 (15.67)	5.28 (28.59)	4.24 (17.22)	3.99 (15.06)	2.83 (7.06)	3.46 (11.02)	2.52 (5.40)
July x Organic mulch	7.51 (57.33)	5.93 (34.33)	5.84 (33.33)	5.03 (24.67)	4.85 (22.67)	3.54 (11.67)	4.79 (22.20)	3.98 (14.92)	3.31 (10.06)	3.61 (12.40)	2.71 (6.38)	2.28 (4.22)
July x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.73 (2.33	1.24 (0.67)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.39 (1.03)	1.25 (0.70)	1.00 (0.00)	1.00 (0.00)
Aug x No mulch	6.36 (39.67)	5.62 (30.67)	6.20 (37.67)	5.38 (28.00)	5.03 (24.33)	3.86 (14.00)	5.02 (24.23)	3.65 (12.28)	4.66 (21.73)	3.87 (14.07)	3.81 (13.55)	2.81 (7.02)
Aug x Organic mulch	5.68 (31.67)	4.89 (23.00)	5.30 (27.33)	4.10 (16.00)	4.65 (20.67)	3.26 (9.67)	4.25 (17.05)	3.51 (11.37)	4.35 (18.20)	3.57 (11.76)	3.62 (12.22)	2.58 (5.69)
Aug x Black polythene mulch	1.41 (1.33)	1.00 (0.00)	1.48 (1.67)	1.24 (0.67)	1.41 (1.33)	1.00 (0.00)	1.26 (0.73)	1.00 (0.00)	1.32 (0.93)	1.17 (0.43)	1.17 (0.43)	1.00 (0.00)
CD (0.05)	1.04		0.79		0.68		0.86		0.78		0.42	

Table 81. Interaction effect of growing condition, date of planting and mulching on count and dry weight of grasses

Treatments	Count of grasses (no./m^2)						Dry weight of grasses (g/m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		Harvest	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	2.44 (5.00)	1.24 (0.67)	1.41 (1.33)	1.49 (1.33)	1.33 (1.00)	1.55 (1.67)	3.96 (17.61)	1.27 (0.77)	1.34 (1.03)	1.34 (0.87)	1.19 (0.49)	1.35 (1.04)
May x Organic mulch	1.48 (1.67)	1.24 (0.67)	1.24 (0.67)	1.14 (0.33)	1.33 (1.00)	1.14 (0.33)	2.36 (8.32)	1.24 (0.67)	1.14 (0.34)	1.14 (0.33)	1.16 (0.40)	1.05 (0.100)
May x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
June x No mulch	1.88 (3.00)	1.28 (0.67)	1.24 (0.67)	1.38 (1.00)	1.33 (1.00)	1.00 (0.00)	3.19 (11.97)	1.59 (1.70)	1.25 (0.70)	1.30 (0.80)	1.14 (0.34)	1.00 (0.00)
June x Organic mulch	1.66 (2.00)	1.00 (0.67)	1.24 (0.67)	1.24 (0.67)	1.24 (0.67)	1.00 (0.00)	2.31 (5.50)	1.00 (0.00)	1.18 (0.47)	1.17 (0.44)	1.10 (0.23)	1.00 (0.00)
June x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
July x No mulch	1.24 (0.67)	1.93 (3.00)	1.55 (1.67)	1.00 (0.00)	1.27 (0.67)	1.24 (0.67)	1.43 (1.41)	2.15 (3.77)	1.36 (0.95)	1.00 (0.00)	1.08 (0.17)	1.07 (0.17)
July x Organic mulch	1.14 (0.33)	1.489 (1.33)	1.14 (0.33)	1.00 (0.00)	1.14 (0.33)	1.00 (0.00)	1.15 (0.37)	1.33 (0.84)	1.07 (0.17)	1.00 (0.00)	1.03 (0.07)	1.00 (0.00)
July x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Aug x No mulch	1.58 (1.67)	1.24 (0.67)	1.00 (0.00)	1.48 (1.67)	1.38 (1.00)	1.24 (0.67)	1.62 (1.84)	1.27 (0.74)	1.00 (0.00)	1.19 (0.50)	1.25 (0.59)	1.10 (0.24)
Aug x Organic mulch	1.33 (1.00)	1.41 (1.33)	1.00 (0.00)	1.138 (0.33)	1.14 (0.33)	1.00 (0.00)	1.26 (0.74)	1.17 (0.43)	1.00 (0.00)	1.03 (0.07)	1.05 (0.10)	1.03 (0.07)
Aug x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
CD (0.05)	0.34		NS		0.67		1.12		NS		0.99	

Table 82. Interaction effect of growing condition, date of planting and mulching on count and dry weight of sedges

Treatments	Sedge count (no./m^2)						Dry weight of sedges (g /m^2)					
	30 DAP		60 DAP		Harvest		30 DAP		60 DAP		harvest	
	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade	Open	50% Shade
May x No mulch	2.06 (3.33)	1.00 (0.00)	1.00 (0.00)	1.14 (0.33)	1.33 (1.00)	1.14 (0.33)	10.24 (5.32)	1.00 (0.00)	1.00 (0.00)	1.06 (0.13)	1.06 (0.13)	1.06 (0.13)
May x Organic mulch	1.48 (1.67)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	2.36 (8.32)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
May x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
June x No mulch	1.14 (0.33)	1.14 (0.33)	1.38 (1.00)	1.00 (0.00)	1.38 (1.00)	1.00 (0.00)	1.05 (0.10)	1.05 (0.10)	1.20 (0.51	1.00 (0.00)	1.08 (0.17)	1.00 (0.00)
June x Organic mulch	1.24 (0.67)	1.00 (0.00)	1.00 (0.00)	1.14 (0.33)	1.00 (0.00)	1.00 (0.00)	1.06 (0.13)	1.00 (0.00	1.00 (0.00)	1.05 (0.11)	1.00 (0.00)	1.00 (0.00)
June x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00))	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
July x No mulch	1.41 (1.33)	1.38 (1.00)	1.24 (0.67))	1.28 (0.67)	1.38 (1.00)	1.00 (0.00)	1.25 (0.67)	1.49 (1.41)	1.07 (0.17)	1.09 (0.20)	1.06 (0.14)	1.00 (0.00)
July x Organic mulch	1.38 (1.00)	1.24 (0.67)	1.14 (0.67)	1.28 (0.67)	1.24 (0.67)	1.00 (0.00)	1.25 (0.60)	1.30 (0.87)	1.03 (0.07)	1.04 (0.07)	1.03 (0.07)	1.00 (0.00)
July x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
Aug x No mulch	1.63 (1.67	1.38 (1.00)	1.28 (0.67)	1.48 (0.67)	1.58 (1.67)	1.24 (0.67)	1.38 (0.91)	1.20 (0.50)	1.20 (0.47)	1.00 (0.00)	1.14 (0.14)	1.10 (0.23)
Aug x Organic mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.14 (0.67)	1.14 (0.33)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.03 (0.07)	1.00 (0.00)
Aug x Black polythene mulch	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)	1.00 (0.00)
CD (0.05)	0.48		NS		0.38		0.88		NS		0.08	

Table 83. Weed control efficiency and weed index

Treatments	Weed control Efficiency (%)		Weed Index (%)	
	Open	50% Shade	Open	50% Shade
May x No mulch	_	47.62	75.10	72.05
May x Organic mulch	51.09	63.18	69.79	66.10
May x Black polythene mulch	100.00	100.00	_	_
June x No mulch	8.64	67.34	89.63	74.83
June x Organic mulch	39.12	79.51	74.21	35.02
June x Black polythene mulch	98.83	100.00	_	_
July x No mulch	43.01	70.98	84.47	63.76
July x Organic mulch	67.22	78.79	83.88	69.30
July x Black polythene mulch	100.00	100.00	_	_
Aug x No mulch	22.25	58.95	61.28	69.26
Aug x Organic mulch	37.71	71.04	84.19	58.65
Aug x Black polythene mulch	97.82	100.00	_	_

4.4 Cost benefit analysis

The data depicting the economics of cultivation of *Iruveli* under different growing condition, dates of planting and mulching are expressed in Table 84 . The May planted crop with black polythene mulch under open condition recorded higher income of Rs. 13,17,222 and the lower income was observed in August planting with out mulch in shaded condition (Rs. 80,370). A higher B: C ratio of 4.46 was obtained from May planting with black polythene mulching under open condition. Planting in August with organic mulch under shaded condition recorded lower B: C ratio of 0.30.

Table 84. Interaction effect of growing condition, date of planting and mulching on Benefit: Cost ratio

Treatments	Gross income (Rs/ha)	Net income (Rs/ha)	Cost of cultivation (Rs/ha)	B:C ratio
A1B1C1	422963	186663	236300	1.79
A1B1C2	502222	228922	273300	1.84
A1B1A3	1317222	1021706	295516	4.46
A1B2C1	111296	-125004	236300	0.47
A1B2C2	275926	2626	273300	1.01
A1B2C3	1063741	768225	295516	3.60
A1B3C1	91111	-155930	236300	0.39
A1B3C2	120370	-152930	273300	0.44
A1B3C3	515556	220040	295516	1.74
A1B4C1	98519	-137781	236300	0.42
A1B4C2	106313	-186383	273300	0.39
A1B4C3	287037	-8479	295516	0.97
A2B1C1	325741	89441	236300	1.38
A2B1C2	403685	130385	273300	1.48
A2B1C3	1262407	966891	295516	4.27
A2B2C1	170556	-65744	236300	0.72
A2B2C2	457778	184478	273300	1.68
A2B2C3	668333	372817	295516	2.26
A2B3C1	243148	6848	236300	1.03
A2B3C2	201852	-71448	273300	0.74
A2B3C3	691852	396336	295516	2.34
A2B4C1	80370	-145189	236300	0.34
A2B4C2	82963	-190337	273300	0.30
A2B4C3	306296	10780	295516	1.04

- Labour charges Rs. 600/ day
- Cost of polythene sheet – Rs.7/ m^2
- Cost of paddy straw – Rs 6/kg
- Sale price of plectranthus – Rs.45/kg

5. Discussion

5. DISCUSSION

A field experiment entitled "Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma] was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during the year 2018. The major results obtained from the experiment, after further analysis are discussed in this chapter based on literature available.

5.1 Effect of growing condition, planting dates and mulching on growth and yield of *Plectranhus vettiveroides*

5.1.1 Plant height

In general crop planted under 50 per cent shaded condition recorded the greatest plant height, and the plant height observed was 26.67 cm, 3.61 cm and 71.12 cm at 30 DAP, 60 DAP and harvest respectively (Table 4, Fig. 3). Significant decrease in the intensity of light may be the main cause of the increase in height (Table 11). Increased plant height with the treatment could also be attributed to the effect of weather parameters like maximum and minimum temperature and relative humidity. Compared to open condition, under shade the temperature was lower and relative humidity was higher (Table 19).Temperature showed negative correlation with plant height (Table 20 and 21). Boardman (1977) reported that plants when grown in shaded condition compared to open space have elongated stem with large intercellular space and this character was attributed to the activity of auxin. Similar result of increase in plant height of *Plectranthus vettiveroides* under shaded condition was reported by Kumar (2013).

Regarding the date of planting, the results obtained from the experiment indicated that the plant height measured at 30 DAP, 60 DAP and at harvest was significantly affected by different planting dates. Planting on 15th June resulted in taller plants at 30 and 60 DAP. But when it comes to harvest stage, May planted crops recorded maximum height (58.32cm). Significant influence of seasonal

variations on plant height of *Andrographis paniculata* was reported by Sreethu (2019).

Like growing condition and planting dates, mulching also influenced the plant height of *Plectranthus* at different growth stages. Mulching with black polythene recorded the taller plants throughout the crop period followed by organic mulching. Here also, soil temperature and soil moisture were higher in polythene mulched plots. This may be the contributing factor of increased plant height. Kaur (2015) reported the improvement in height of solanum plants due to mulching with polythene. According to Padmadevi*et al*. (2016) mulching would improve the physical condition and moisture status of soil which would increase the growth of crops.

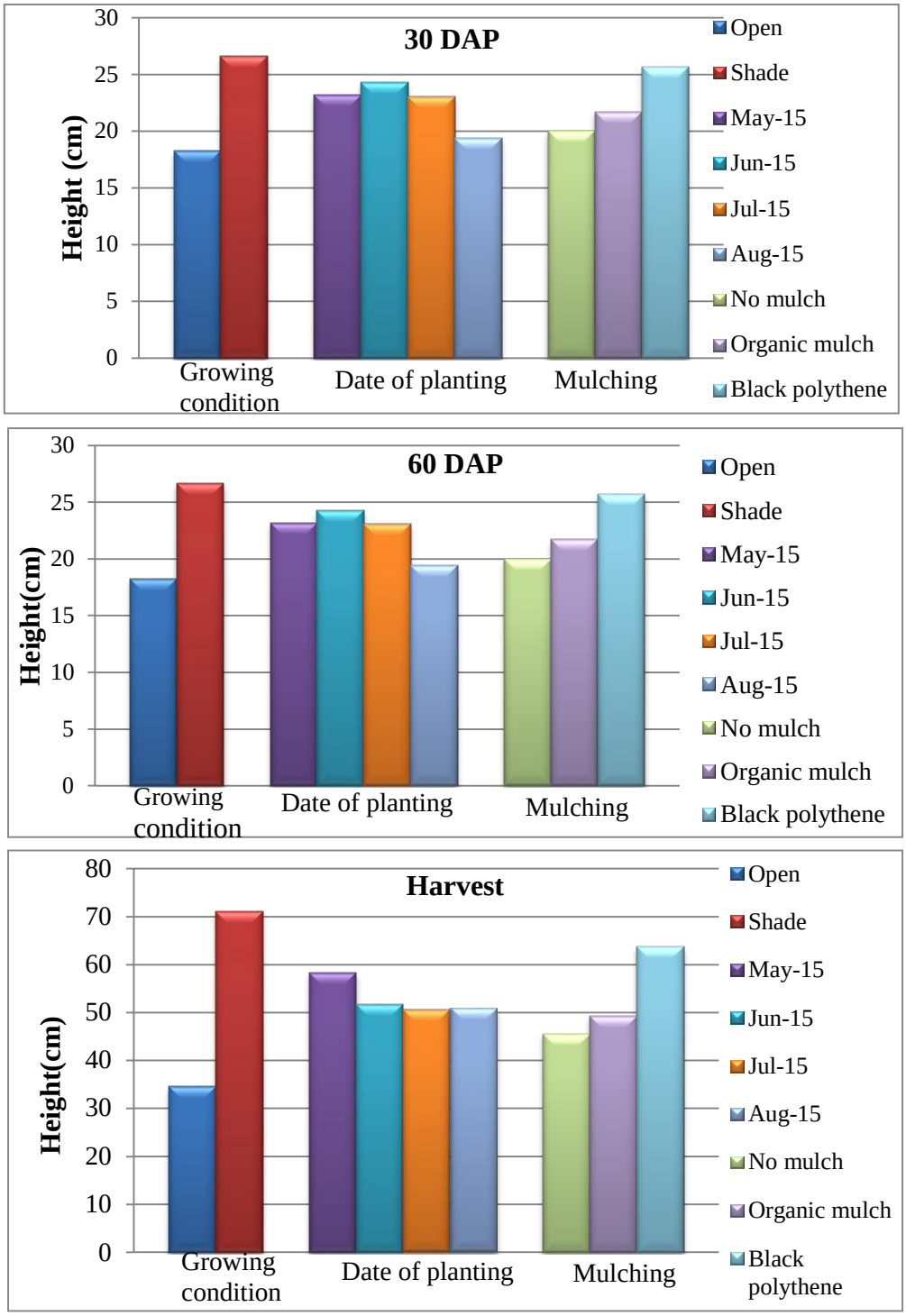


Fig. 3. Effect of growing condition, date of planting and mulching on plant height at different growth stages of *Plectranthus vettiveroides*

5.1.2 Number of branches per plant

The number of branches were higher in open condition than in shaded condition at 30 DAP, 60 DAP and at harvest (Table 5, Fig. 4). The high light intensity and temperature in open area favored the production of more lateral buds resulting in more number of branches while shaded condition favored apical dominance and increased plant height. Also, maximum and minimum temperature were higher under open than shaded condition. A positive correlation could be observed between number of branches with maximum temperature (Table 20).

Crop planted in June recorded higher number of branches at 30 DAP (5.40). At 60 DAP higher number of branches was in June planting (7.24) which was on par with August planting (6.53). At harvest August planting recorded higher number of branches (11.97) which was on par with and June planting (11.26). Variations in number of branches in fennel due to difference in planting dates was reported by Al-Dalain *et al*. (2012).

Mulching with black polythene caused positive effect on number of branches throughout the growth stages. During the entire crop period, higher number of branches were observed in polythene mulch, followed by organic mulch. Least branching was observed in no mulch plots (Table 5).As per Shrivastava *et al.* (1994) the mulched tomato plants produced more branches than unmulched plants. Similar to plant height, increase in soil temperature and soil moisture contents might have influenced the number of branches too. A negative correlation was observed between plant height and number of branches. (Table 28).

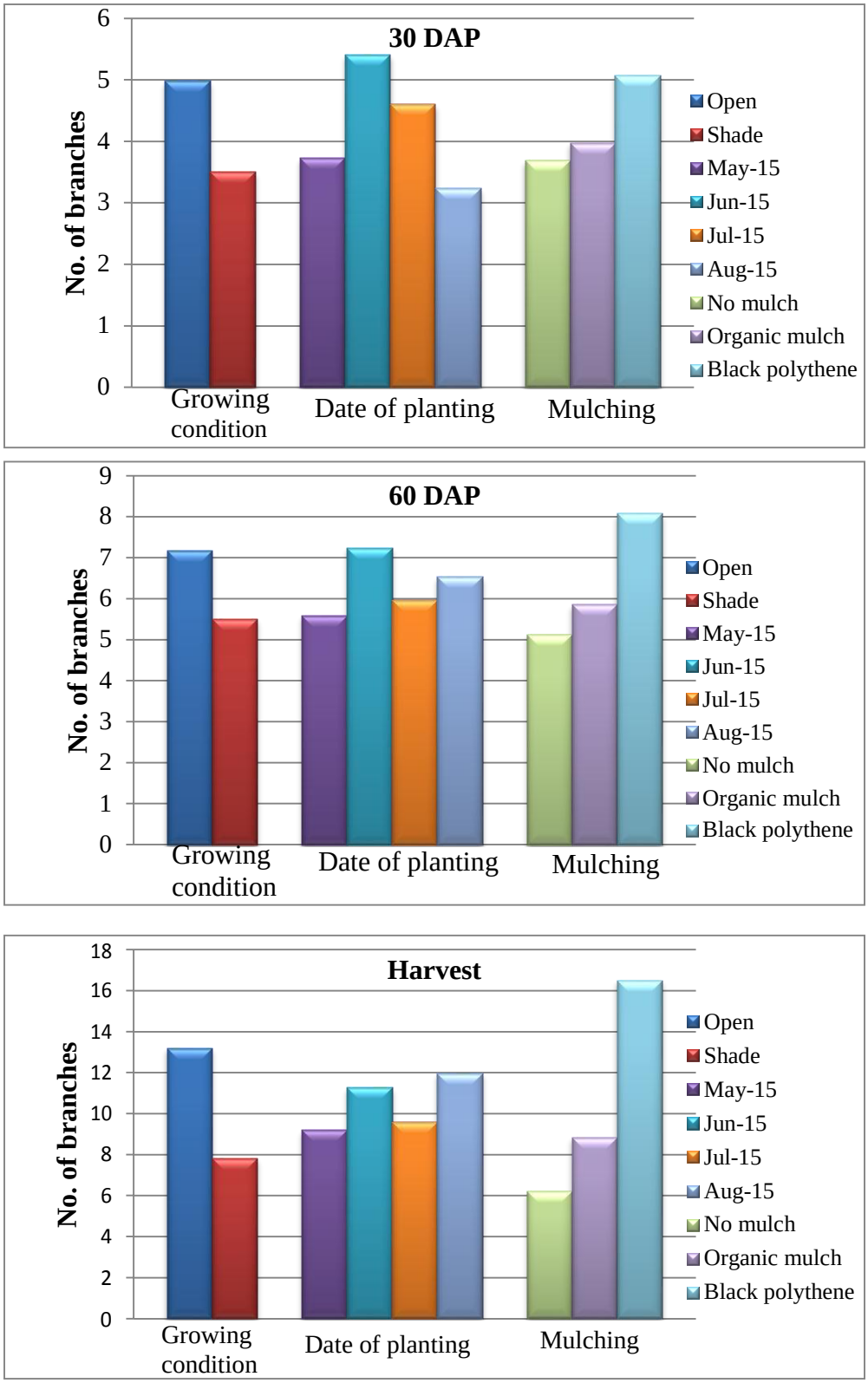


Fig 4. Effect of growing condition, date of planting and mulching on number of branches at different growth stages of *Plectranthus vettiveroides*

5.1.3 Biomass yield

Higher biomass yield was noticed under shaded condition during first two months (Table 6, Fig. 5). However, at harvest higher biomass was observed under open condition indicating that Plectranthus prefers shaded condition during initial stages. But at 3 month stage when the plant was nearing harvest, more dry matter accumulation occurred under open condition. Nisheeda *et al.* (2016) also reported higher biomass accumulation in *Plectranthus vettiveroides* under open condition during later stages of plant growth.

Significant variation was observed for biomass yield with different dates of planting. The highest biomass yield (24.27 g/plant) was obtained in June planting in the first month, but later at 60 DAP (120.27 g/plant) and at harvest (494.68 g/plant) significantly highest biomass was obtained from May planted crop. During the initial stages of May planted crop, the soil temperature was high and soil moisture was less (Tables 9 and 10). This may be the reason for slow growth of May planted crop in the first month. But at the later weeks, the rain fall and temperature were congenial and resulted in better biomass production.

Mulching exhibited significant influence on the biomass yield of *Plectranthus* during all growth stages. Black polythene mulching recorded the highest biomass yield of 20.01 g/plant,111.69 g/plant, 398.50 g/plant, at 30 DAP, 60 DAP, and at harvest respectively. Enhanced soil moisture content, optimum soil temperature and reduced weed count (Tables 9, 10 and 18) might have contributed to the high biomass yield under mulched plots. Also, a significant positive correlation was observed between plant height, number of branches and biomass yield. (Table 28).

5.1.4. Total biomass yield

Total biomass yield of the crop followed the same pattern as that of per plant biomass yield at harvest. The open (10382 kg/ha) condition recorded higher biomass yield during harvest but was significantly on par with shaded condition

(7471 kg/ha) (Table 7 and Fig. 6). Kumar (2013) also observed higher biomass production of *Plectranthus vettiveroides* under open condition than 50 percent shaded condition. Light intensity affect rate of photosynthesis, which in turn influence photosynthetic capacity and production of biomass (Devkota and Jha, 2010). According to them, at different light intensities plants change their morphology and allocation of biomass.

Planting dates and mulching significantly influenced the total biomass yield of *Plectranthus.* Among different dates of planting, May planting recorded the highest total yield of 15694 kg/ha. The lowest yielding treatment was August planting (3315 kg/ha) which was only 21.12 per cent of the highest yield. The highly unfavourable weather condition prevailed during initial stages of crop growth might have led to the lowest yield in August planted crop. A rainfall of 629 mm, which was the highest of the year, was recorded in the initial planting week of August crop (Table 19). This might have detrimentally affected to the total yield of later sown crops.

Among mulches, black polythene mulching had superiority with respect to total yield. There was significant difference in yield between treatments with black polythene mulch (16235 kg/ha) and un mulched plots (4072 kg/ha). As per Lalitha *et al*. (2010), plastic mulch induces the early crop emergence, so that it increased the biomass production at early stages of the crop growth.

Total root yield

The total root yield followed the same trend of total biomass yield. Root yield was higher under open condition than shaded condition (Table 7 and Fig. 7). Kumar (2013) reported the increase in root shoot ratio of *Plectranthus vettiveroides* under open condition than shaded. Increased root yield under open condition might be due to better allocation of photosynthates to roots under open condition.

According to Devkota and Jha (2010), plants under open condition would concentrate more dry weight in roots, compared to shaded crops.

The effect of date of planting on root yield had followed the same trend of biomass yield. The reduction in total biomass yield had visibly reflected in the total root yield also. The May planted crop recorded the highest root yield (2508 kg/ha) and the lowest yield was in July planted crop, which was only 15.8 per cent of the highest yield.

Comparing the mulches, as like biomass yield, the black polythene mulched crop recorded the highest root yield (1827.37 kg/ha). The optimum soil moisture and soil temperature in the polythene mulched plots might have favoured the root growth also. According to Gunasekaran and Shakila (2014) black polythene mulch effectively increased the tuber yield of medicinal coleus (*Coleus forskholli*) in terms of number of tubers per plant, tuber length, girth, volume and fresh weight. The next best treatment was organic mulching, which yielded 986.97 kg/ha of root yield. Ren *et al.* (2018) reported that organic mulching could buffer soil temperature and preserve soil moisture and increase available nitrogen, phosphorus and potassium in soil, which further improved soil fertility and crop growth.

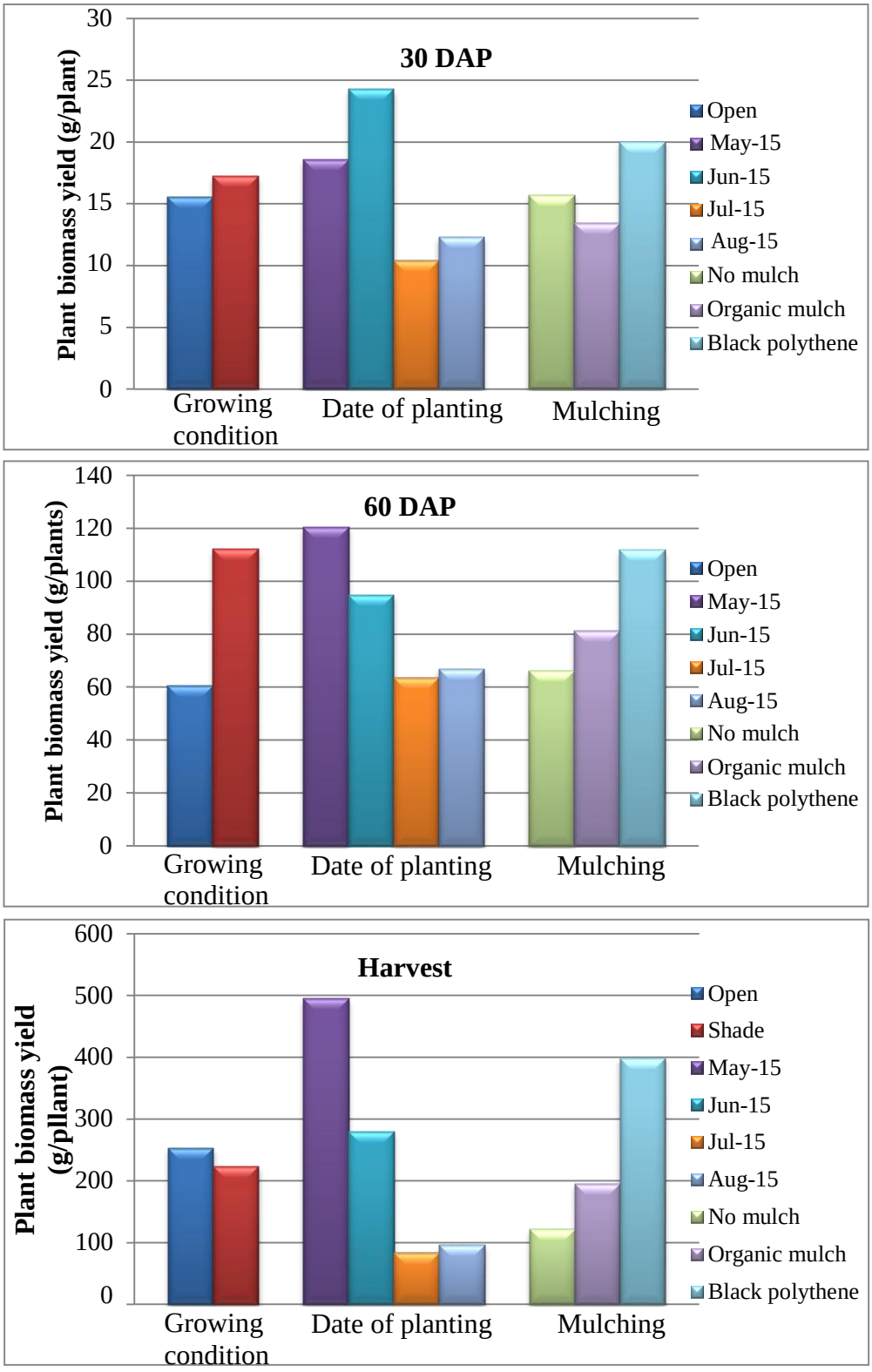


Fig 5. Effect of growing condition, date of planting and mulching on plant biomass yield at different growth stages of *Plectranthus vettiveroides*

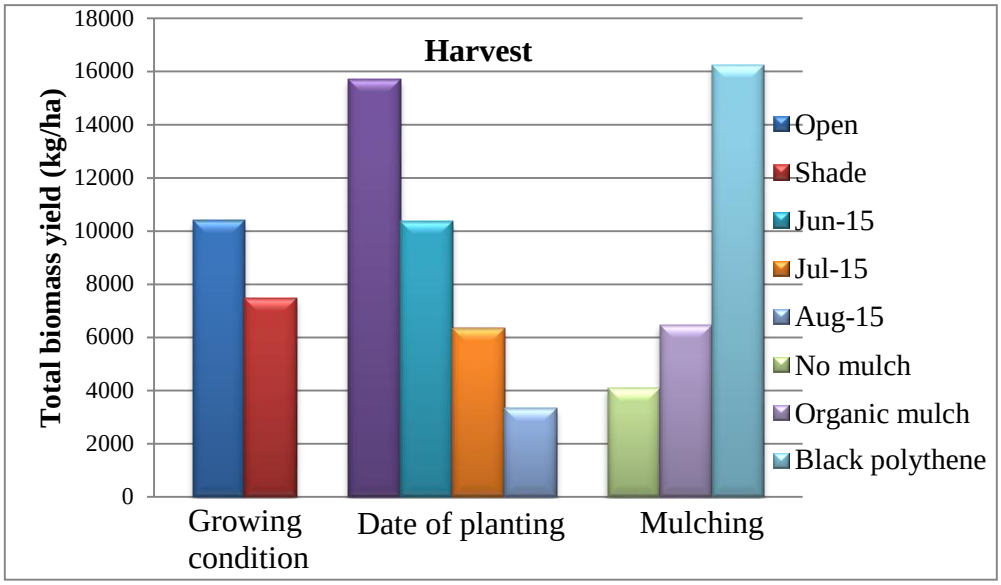


Fig 6. Effect of growing condition, date of planting and mulching on total biomass yield of *Plectranthus vettiveroides*

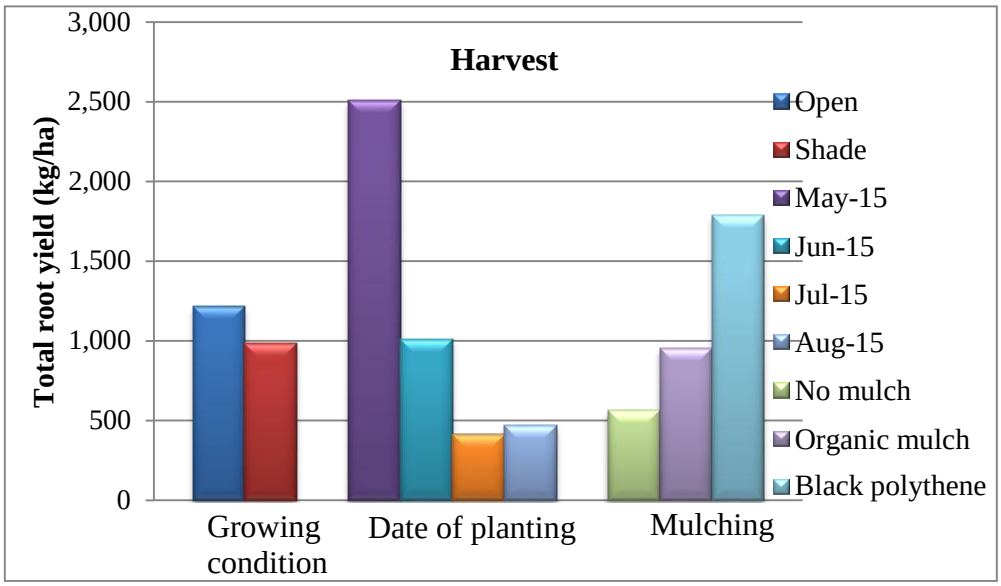


Fig 7. Effect of growing condition, date of planting and mulching on total root yield of *Plectranthus vettiveroides*

5.2 Effect of growing condition, date of planting and mulching on soil chemical properties

Soil pH, organic carbon, available N, P, and K were estimated before and after the experiment. In general soil pH, organic carbon and available N increased after the experiment and K content decreased (Table 8, Fig. 8). No definite trend was observed for available P status of soil. After the experiment, the pH and organic carbon content were not significantly influenced by different treatments. The available N and P content were higher in shaded condition compared to that of open condition. The difference in available K content was not statistically significant. Banchio *et al*. (2009) observed higher microbial activity under shade compared to open space which increased the soil nutrient status. Also the uptake of nutrients from open condition was higher than from shaded plots (Table 21). This might have decreased the soil nutrient status of open plots.

Comparing effect of different dates of planting the N and P contents were higher in July planted plots and lower in May and June planted plots. Available K content in the soil was also lower after the experiment in May planted plots This might be due to higher uptake by plants in May planted crop and resultant higher biomass yield (Table 7 and 21). As a result the nutrient status of May crops have depleted compared to the rest of the treatments.

Comparing different mulches, it was found that available N, P and K contents were higher in organic mulched plots (Fig. 8).According to Khan *et al.* (2002) application of straw mulch would increase available N, P and K status in soil. Agele *et al.* (2000) also reported improved nutrient availability under mulched plots than unmulched plots.

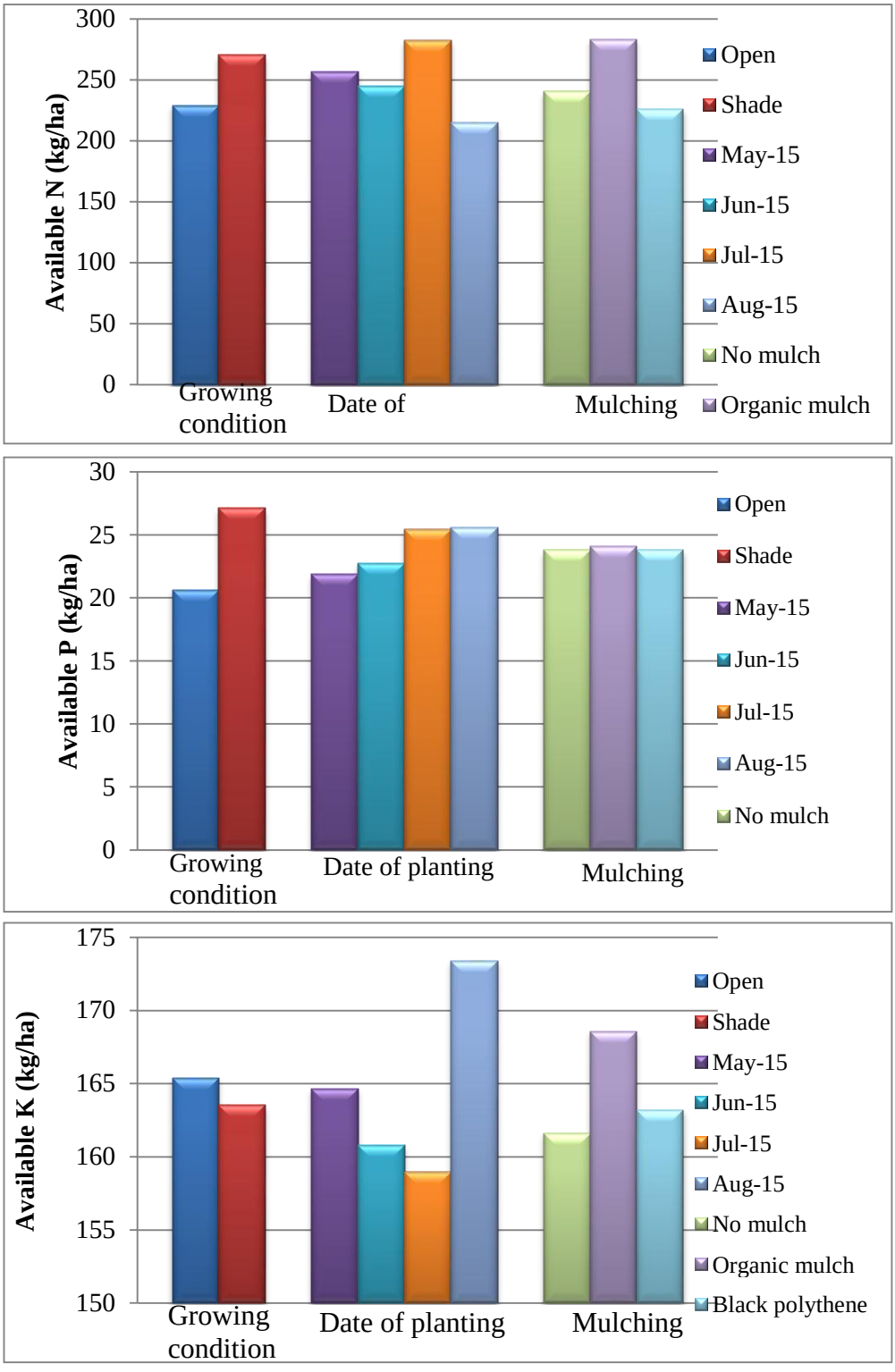


Fig 8. Effect of growing condition, date of planting and mulching on available N, P, K in the soil at harvest

5.3 Effect of growing condition, date of planting and mulching on micrometeorological observations

5.3.1 Soil temperature

Lower soil temperature was observed in shaded condition throughout the growing period (Fig. 9) and the difference was significant during 2nd and 10th weeks.

Comparing planting dates, throughout the crop growth period, the soil temperature recorded varied ranges with highest at first week of May planting and lowest at 2nd week of August planting (Fig. 10).

However, mulching exhibited significant variation with respect to soil moisture. The polythene mulched plots consistently recorded higher temperature (Fig. 11). According to Hu (1995), under polythene mulch, a rise in soil temperature could be observed, due to trapping of solar energy inside the mulch material through greenhouse effect. In groundnut, black polythene mulch increased soil temperature by 4-5 ^{o}C during the crop period (Ghosh *et al.* 2006). Bhardwaj (2013) also reported 2.8^{o}C higher soil temperature at a depth of 2 inch under black polythene compared to bare soil. Plastic mulches have greater permeability to long wave radiation and thus it increased temperature around the plants.

5.3.2. Soil moisture

The difference in soil moisture content at 15 cm depth between open and shaded condition was significant during most of the weeks. Soil moisture content at 15 cm depth was higher under shade throughout the study (Table 10 , Fig. 12). Dodd *et al.* (2005) also observed that higher soil moisture content under shaded condition than open condition. According to Du and Gangshuan (2011) 30 percent shading of the plots could increase the relative soil moisture content at a range of 70 - 80 percent.

Soil moisture content was also significantly influenced by different planting dates (Fig. 13). Soil moisture content varied from 12.55% during 1st week of May planting to 29.65% at 1st week of July planting. The findings of Norwood (2001) revealed that the variation in planting dates had noticeable influence on soil moisture content and this can effect crop growth according to the stage.

Mulching significantly influenced the soil moisture content at 15 cm depth at all of the observed weeks (Fig. 14). The black polythene mulched plots recorded the highest moisture content at all weeks, followed by organic mulching. Compared to no mulching, the treatments with mulching recorded higher moisture content. As per Liakatas *et al.* (1986) plastic mulches had the property of directly affecting the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss. Lalitha *et al*. (2010) also observed higher moisture content under polythene mulch due to reduced evaporation rate. According to Govindappa *et al.* (2015) the practice of mulching is highly desirable in crop production as it can reduce soil moisture loss through transpiration.

5.3.2 Light intensity

Light is one of the basic environmental factor influencing plant growth and development. Different types of plants respond differently to the alteration in light intensity (Ali *et al*. 2009). The growing condition and planting dates reordered significant influence on the light intensities reaching the crop (Fig. 15, 16). The intensity of light was found almost half inside the shade net compared to open condition at all of the observed weeks (Table 11). According to Healey *et al*. (1998) shade nets had the potential to change light intensity, the proportion of diffuse radiation and light quality compared to full sun, depending on the density and colour. Lee *et al*. (1997) also made a similar observation of reduction in solar radiation to 12 to 33% under shaded condition.

Comparing different dates of planting, the light intensity was found to be varied. This is due to the seasonal variations in observed months. Second week of

May planting reported highest light intensity (17784 lux) and fourth week of July planting (9128 lux) recorded the lowest rate. Meena *et al*. (2014) observed that microenvironment could change under shade nets in different seasons. Mulching treatments did not had any significant effect on light intensity.

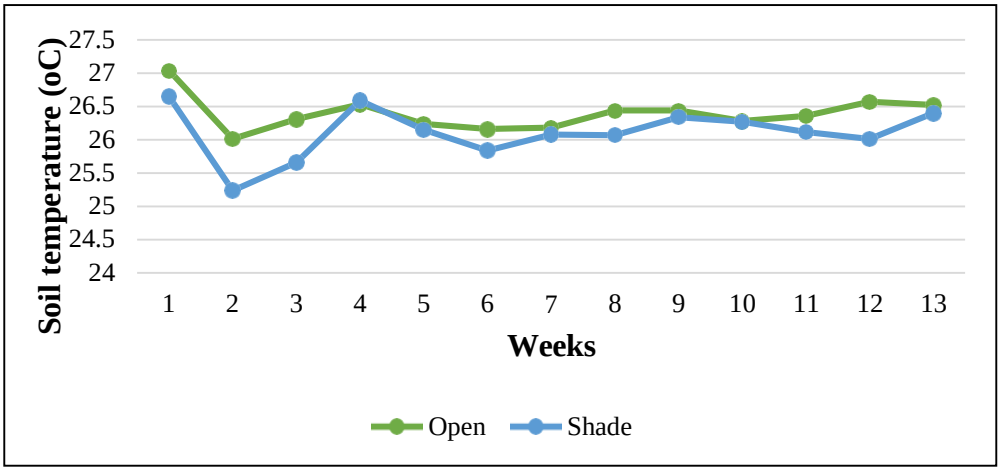


Fig 9. Effect of growing condition on soil temperature

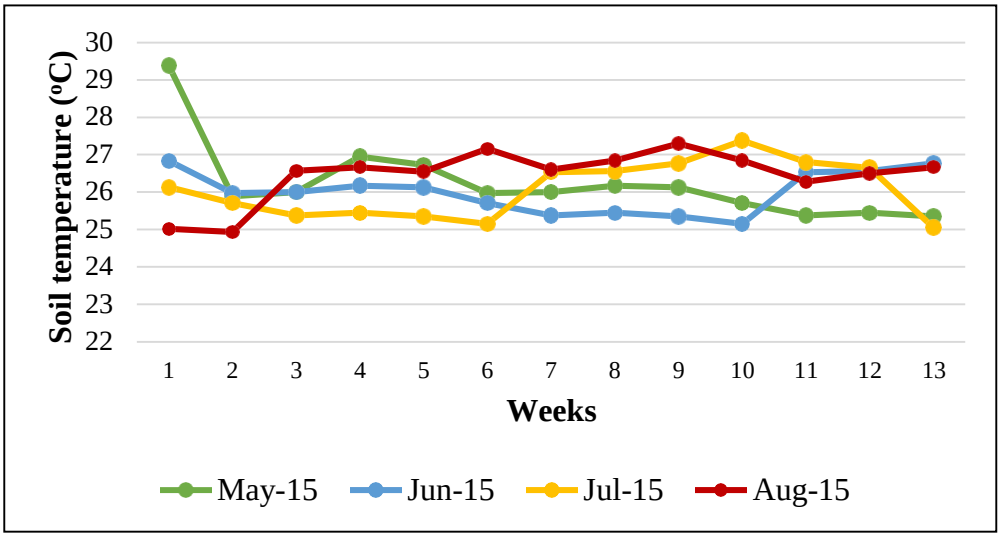


Fig 10. Effect of date of planting on soil temperature

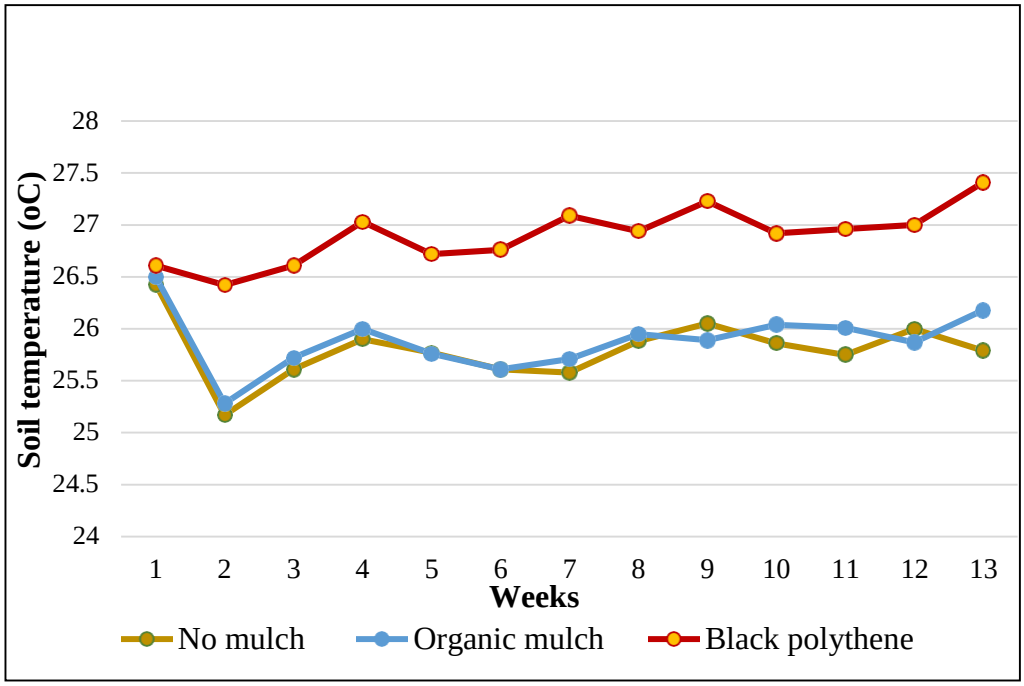


Fig 11. Effect of mulching on soil temperature

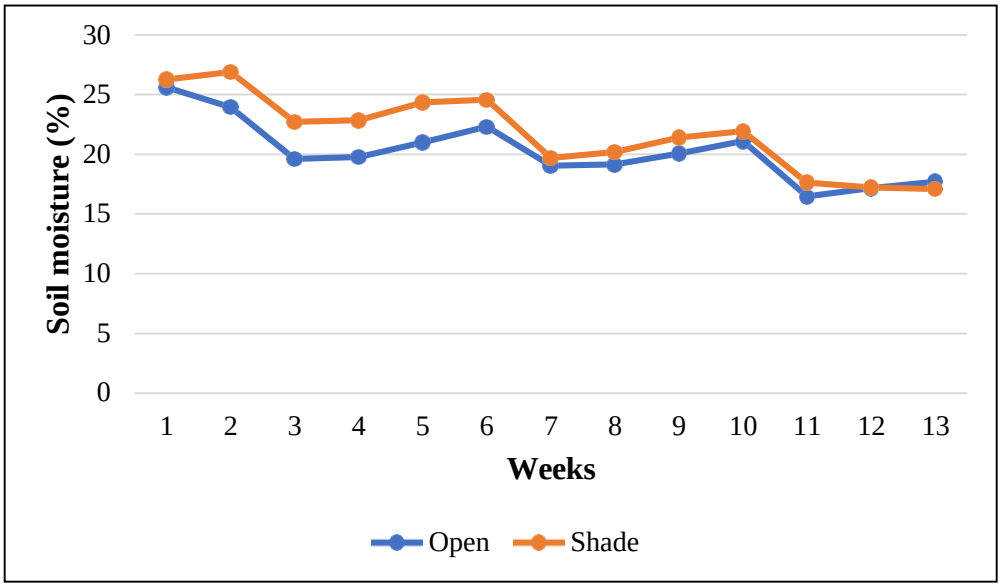


Fig 12. Effect of growing condition on soil moisture

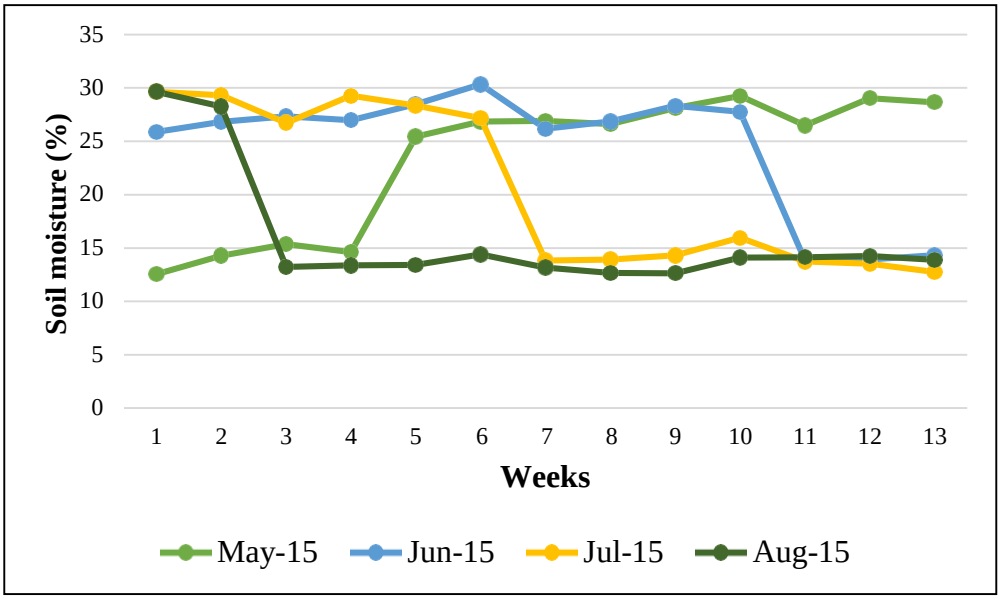


Fig 13. Effect of date of planting on soil moisture

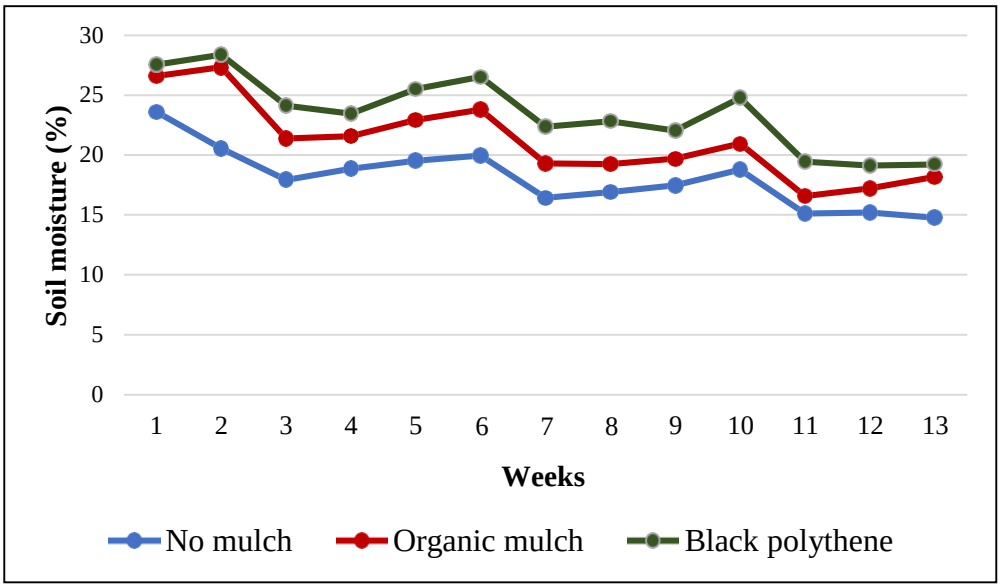


Fig 14. Effect of mulching on soil moisture

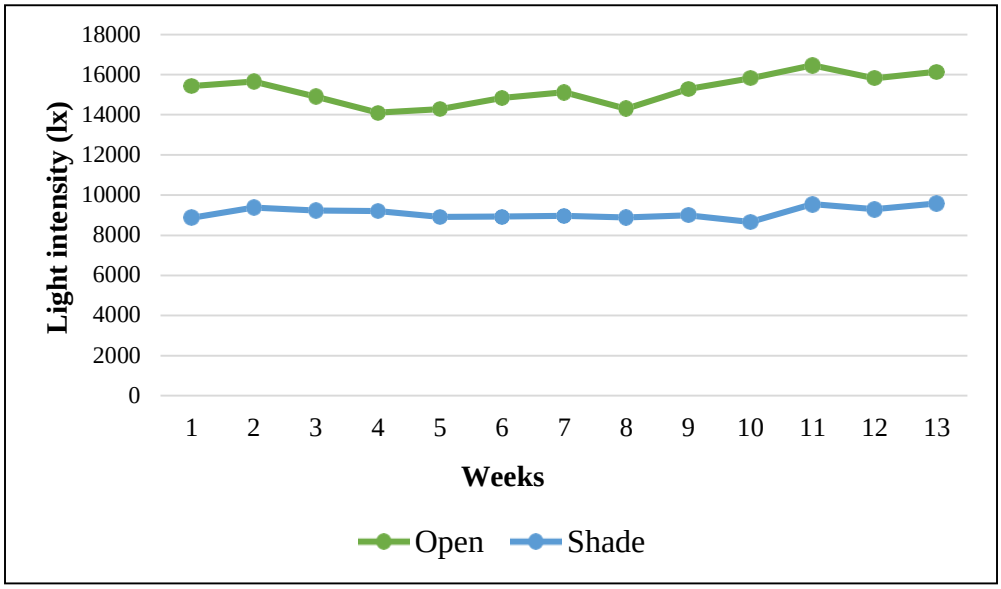


Fig 15. Effect of growing condition on light intensity

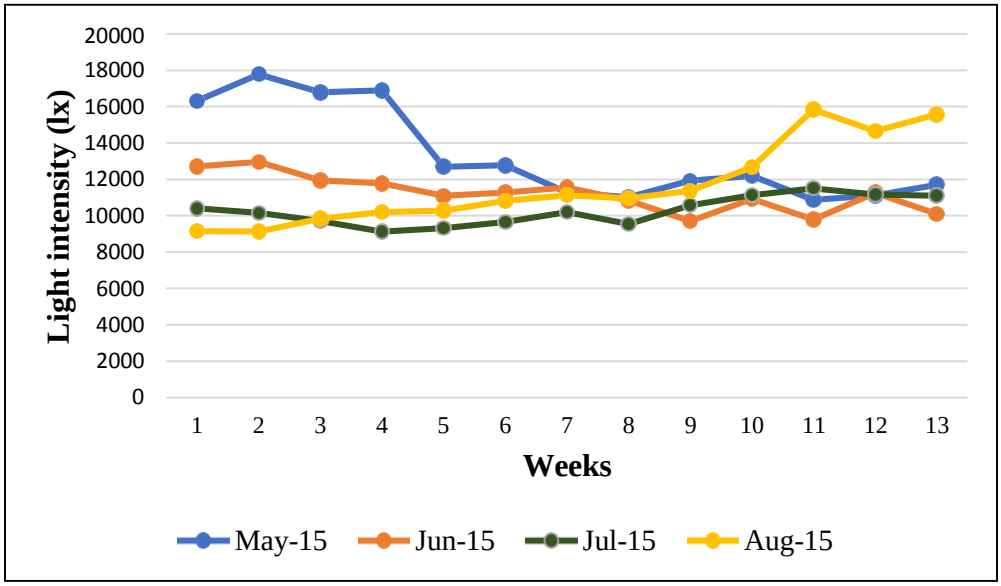


Fig 16. Effect of planting dates on light intensity

5.4 Effect of growing condition, date of planting and mulching on physiological, chemical and biochemical observations

5.4.1. Total chlorophyll

The analysis on total chlorophyll content at different growth stages revealed that different treatment conditions had significant influence. The total chlorophyll content in shaded condition was higher in all stages and the difference was significant during 60 DAP and at harvest. (Table 12, Fig. 17). According to Johnston and Onwueme (1998) under shade an increase in chlorophyll content helps in trapping the available light more efficiently. As per Palaniswamy (2003), crops grown under partial shade had 53 per cent higher chlorophyll content than the crops under open condition. This might be due to high light intensity which decreased chlorophyll content in plants by inhibiting chloroplast formation. Similar results of increased chlorophyll content under shade was also reported by Dai *et al.* (2009). Hou *et al.* (2010) stated that low light intensity could cause decreased leaf thickness, photosynthesis and biomass yield, but increased leaf area and chlorophyll concentration.

Planting dates had significant influence on the chlorophyll content of *Plectranthus vettiveroides.* At 30 DAP, the highest chlorophyll content was recorded in August planting. At 60 DAP the highest chlorophyll was recorded by June planting and during harvest, it was by May planted crops. Influence of planting dates on total chlorophyll content was reported by Ran *et al. (*2007). He identified the total chlorophyll content as a parameter for crop yield.

Mulching influenced chlorophyll content in all the growth stages. At all stages of growth higher chlorophyll content was exhibited by plants grown with black polythene mulch followed by organic mulch. Ashrafuzzaman *et al.* (2011) observed high amount of chlorophyll content in plants with black plastic mulch. Similar result was also reported by Panchal *et al.* (2001) and according to them black plastic mulch was the best for total chlorophyll content compared to other mulches tried. Higher biomass yield in black polythene mulched plots can be

correlated with increased chlorophyll contents at all stages of crop growth (Table 12).

5.4.2 Essential oil content

The essential oil analysis of *Plectranthus vettiveroides* revealed significant influence of light on essential oil content. Highest oil content was obtained under open condition (1.77%) compared to shade (1.31%). (Table 14, Fig. 18) According to Kurata *et al.* (1997) change in light intensity could cause change in morphological and physiological characters which in turn affected the quality of produce. As per Graham (1998) change in light could alter the secondary metabolite production in herbs. Ali *et al.* (2009) reported that light could influence the production of primary and secondary metabolites. Data presented in revealed that open condition produced higher biomass yield and total root yield. Kumar *et al.* (2013) reported higher amount of essential oil content in *Plectranthus vettiveroides* under 100 percent light intensity.

Planting dates also showed significant influence on essential oil content. Crop planted in May showed highest oil content. Tanguturi (2013) also observed variations in secondary metabolite andrographolide in *Andrographis paniculata* due to changes in planting season. According to him environmental factors *viz.* temperature, humidity, light intensity, and the supply of water, influence the growth of a plant and secondary metabolite production.

Comparing essential oil content under different mulching treatments, significantly higher oil content was recorded from plants with black polythene mulching (1.81 %) and was minimum in no mulch condition (Fig. 18). Loughrin and Kasperbauer (2001) reported that sweet basil plants grown under mulch treatments had got higher phenol content than that plants grown in open condition. In an experiment conducted to evaluate the effect of planting dates and mulching on yield and quality of strawberry under poly house condition, Das *et al*. (2013) observed variations in physico - chemical properties of fruits by modifying dates of planting and providing mulches.

5.4.3 Crop growth rate and Relative growth rate

Growing condition exhibited significant influence on crop growth rate. At first month CGR was non significant. But at 60 DAP crop growth rate under shaded condition was higher (1.636 g/m^2/day). When it reached the harvest stage, highest CGR was observed in open condition (3.57 g/m^2/day). The same pattern of CGR was observed in the case of RGR also. It was non significant at 30 DAP. When it reached 60 DAP higher RGR was in shaded plots and at harvest stage, higher RGR was observed at open condition.

CGR and RGR were significantly different while comparing different dates of planting. At 30 DAP, CGR and RGR were highest in June planted crop. But at 60 DAP and at harvest, it was highest in May planted crop (Table 13, Fig. 19, 20). The weather stress observed at initial weeks of May planting might be the cause of reduced growth initially in May planted crop. Favorable weather parameters observed later during the crop period might have contributed to better values in May planting.

Different mulch treatments had influenced CGR and RGR significantly. Mulching with black polythene sheet recorded higher CGR and RGR at all stages. This could be attributed to the effective weed control (Table 18). Meena *et al.* (2017) had found similar results of increased CGR and RGR in weed free plots compared to unweeded control.

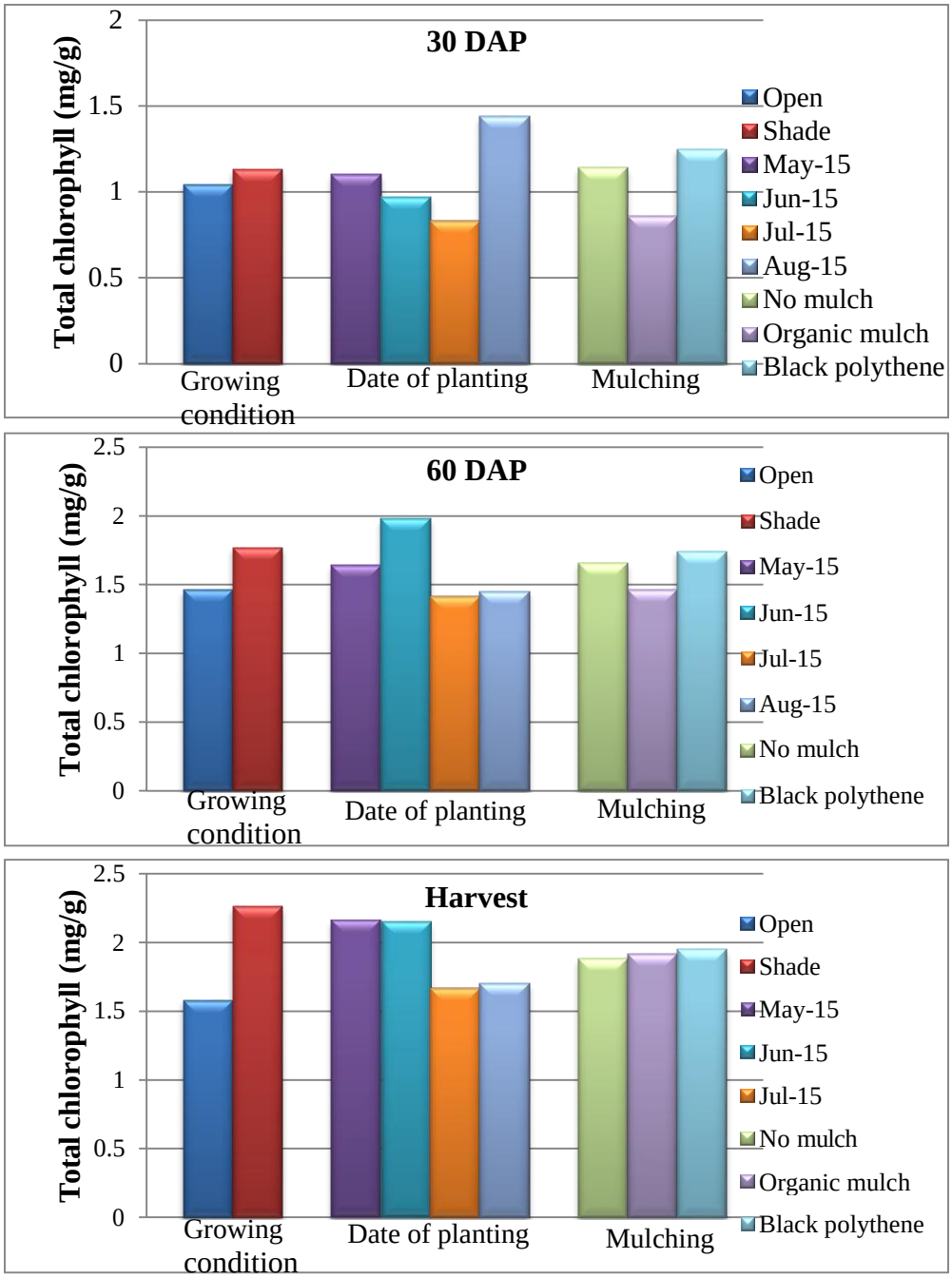


Fig 17. Effect of growing condition, date of planting and mulching on total chlorophyll content at different growth stages of *Plectranthus vettiveroides*

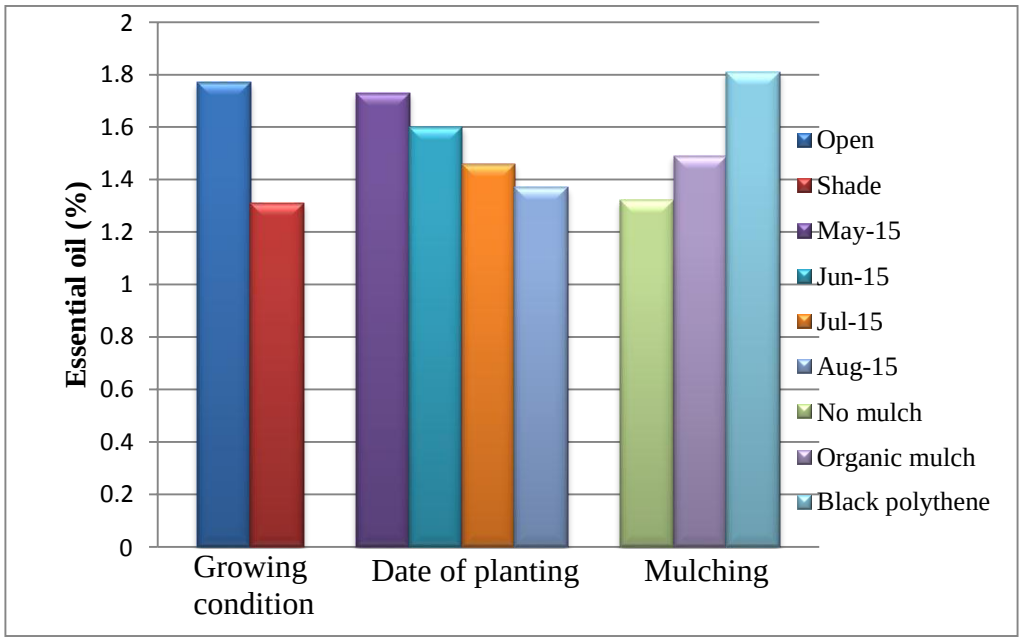


Fig 18. Effect of growing condition, date of planting and mulching on essential oil content of *Plectranthus vettiveroides*

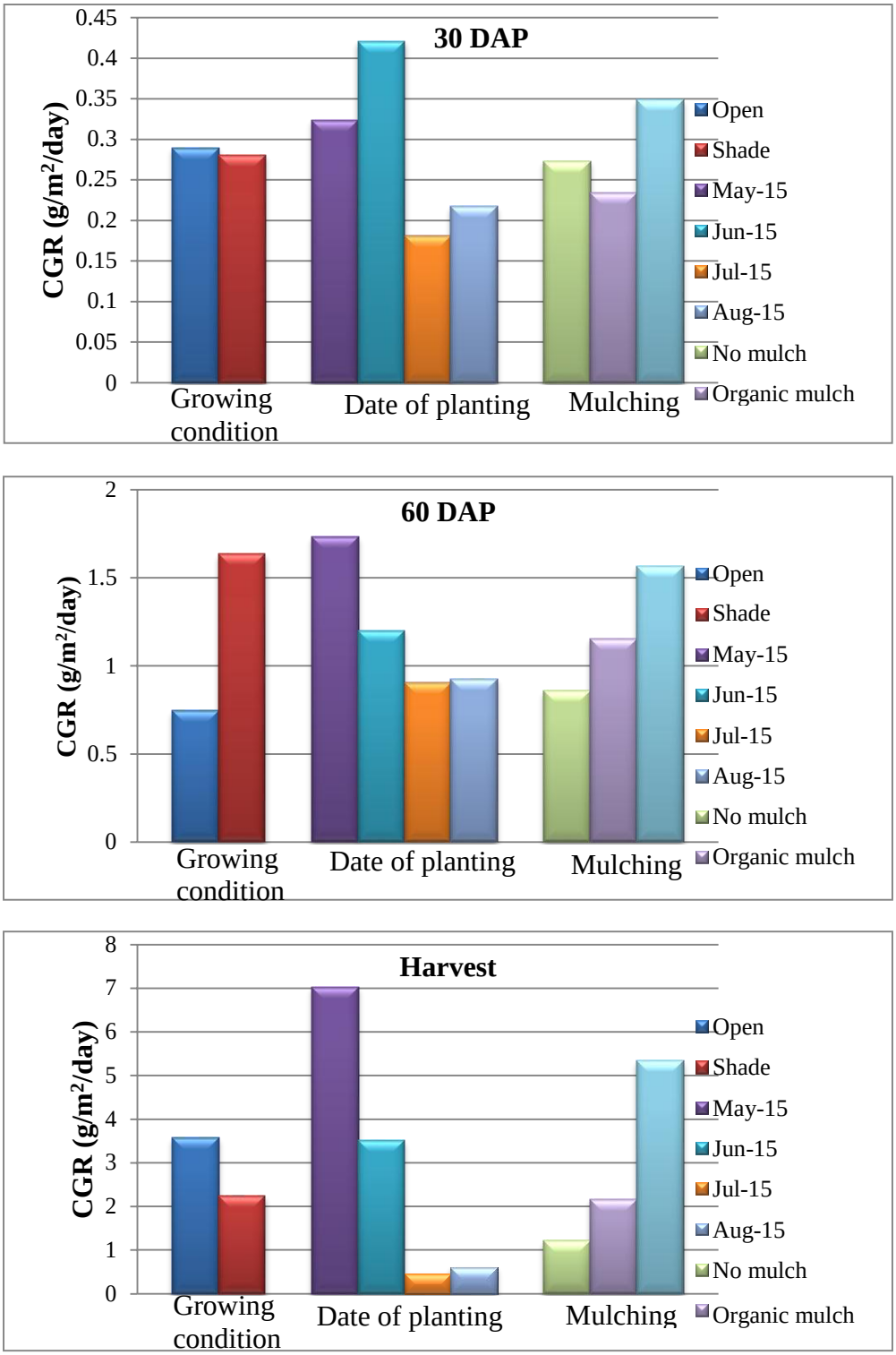
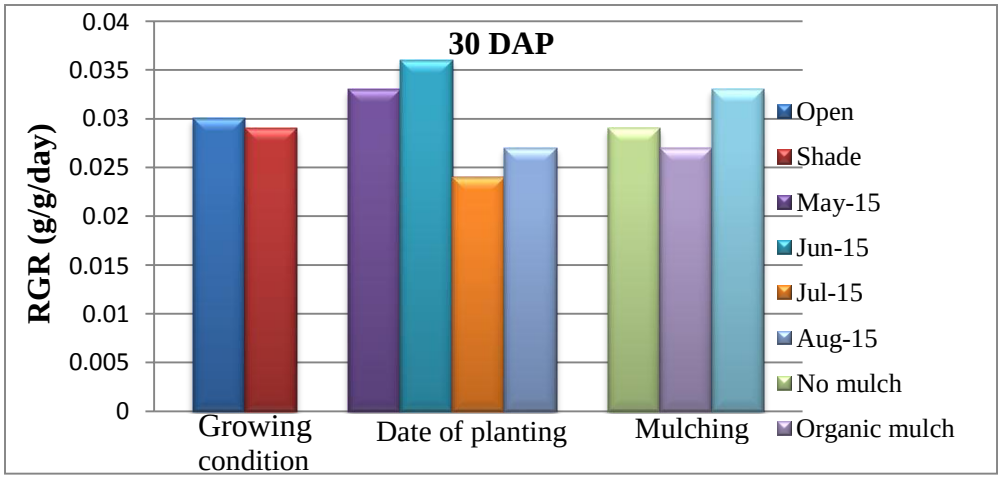
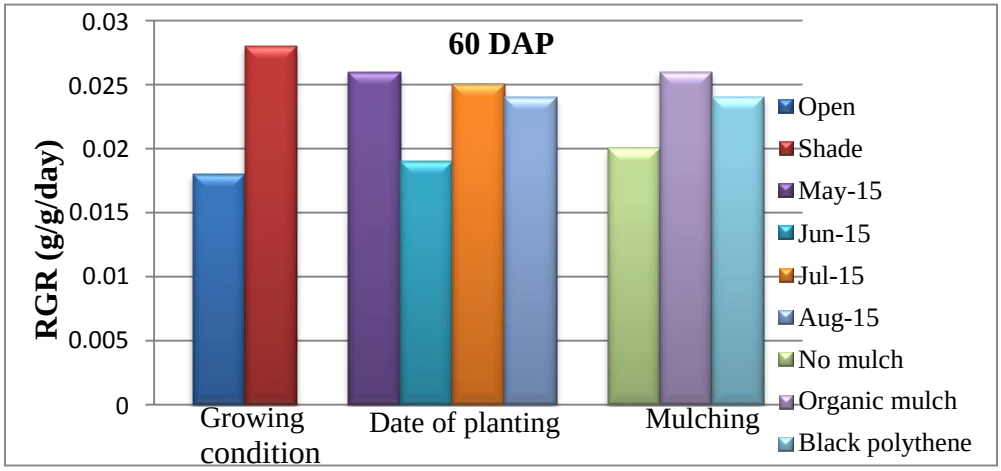


Fig 19. Effect of growing condition, date of planting and mulching on crop growth rate at different growth stages of *Plectranthus vettiveroides*





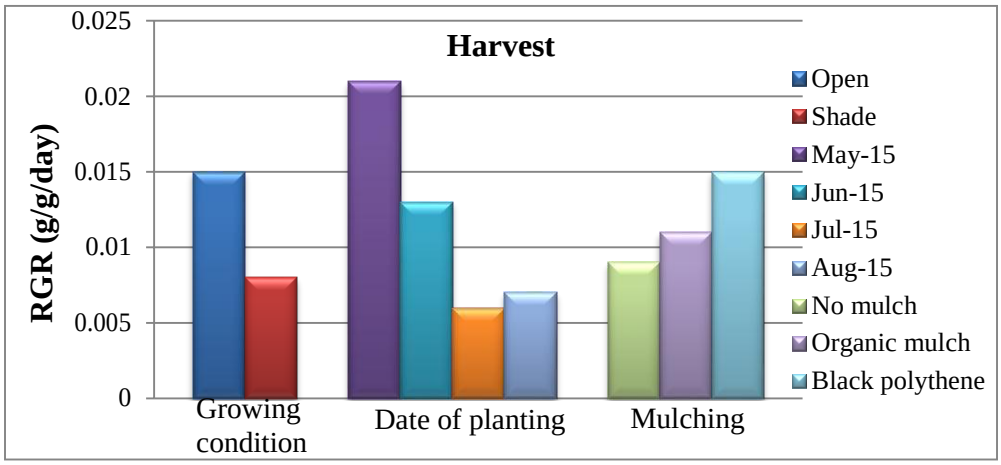


Fig 20. Effect of growing condition, planting dates and mulching on relative growth rate at different growth stages of *Plectranthus vettiveroides*

5.4.4. Nutrient uptake by plants.

After the harvest of crop, when the nutrient uptake by the plants were studied, the N and P uptake were found higher under open condition (Table 14, Fig. 21),however, K uptake was found as statically at par. Kumar *et al.* (2013) reported higher N, P and K nutrient uptake in *Plectranthus vettiveroides* under open condition compared to 50 per cent and 25 per cent light intensities. The increased nutrient uptake clearly indicated the efficient utilization of available nutrients and increased vegetative growth and herbage yield. Under increased light intensity metabolic activities of the plants would be higher and this in turn resulted in the increased uptake of nutrients. The lower available status of N and P in the post experimental soil under open condition indicated higher uptake by the crop. Madhura and Chandini (2000) reported the influence of light intensity on nutrient uptake by bush pepper plants.

The May planted crop recorded significantly highest amount of N, P and K uptake. The favourable weather condition which prevailed in the season helped to increase the metabolism and active uptake of nutrients from the soil. Kumar and Kumawat (2014) reported that change in season affected the microclimate and soil microbial activity. Neenu *et al.* (2017) also reported that date of sowing could significantly influence the nutrient uptake by the plants.

Analysing the nutrient uptake by plants grown under different mulch treatments, black polythene mulched plants recorded the highest nutrient uptake. This might be due to the reduction of weeds in the plots mulched with black polythene. The temperature difference in the soil under mulch might have increased the growth of micro organisms which fasten the degradation of organic materials and thus increase the nutrient uptake.

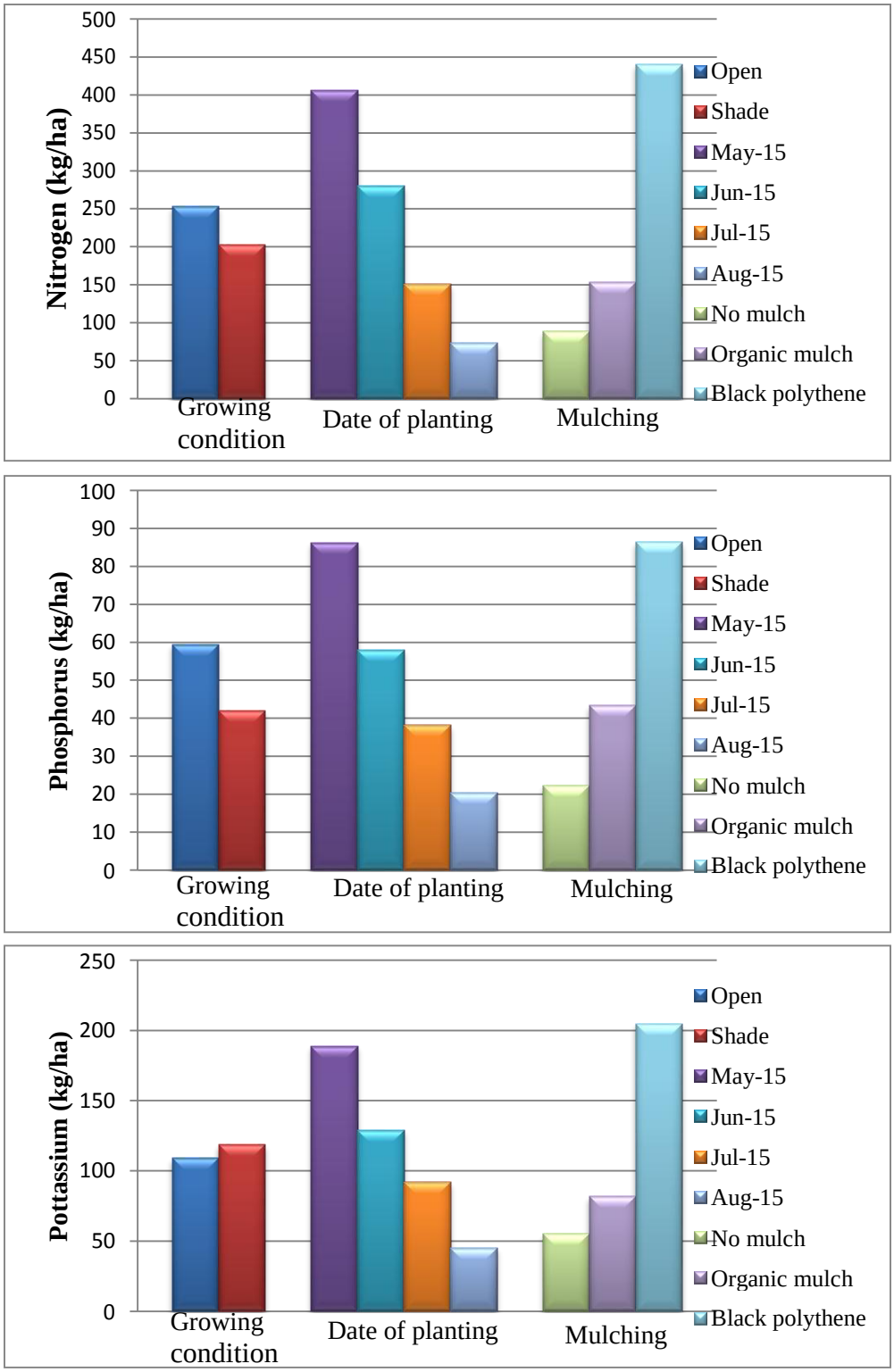


Fig 21. Effect of growing condition, date of planting and mulching on N, P K uptake of *Plectranthus vettiveroides*at harvest

5.5. Effect of growing condition, planting dates and mulching on weed growth

The major weeds found in the experiment site were *Alternanthera bettzickiana, Scoparia dulcis, Eleusine indica, Ischaemum indicum, Borreria hispida, Mollugo disticha, Emilia sonchifolia, Phyllanthus amara, Cyperus rotundus* and *Fimbristylis miliaceae.* The major group were broad leaf weeds followed by grasses and then sedges. All the three types of weeds responded to different growing conditions in the same pattern. Growing condition significantly influenced the total weed count and weed dry weights at 30 and 60 DAP and harvest. Compared to open condition, lower weed count and dry weights were observed under shaded condition (Fig 22, 23, 24, 25). This could be due to reduced light interception hindering the active growth of weeds. Also the reduced light availability to weeds due to taller crop plants might be the reason for reduced weed growth under shade.

Regarding date of planting, May planted plots recorded higher weed count and weed dry weight at 30 and 60 DAP and at harvest. This may be due to the favorable weather period obtained for the weeds as well as the crop plants. The count and dry weight of sedges did not follow any specific trend.

Very few weeds were noticed in plots with black polythene mulch and only those weeds which germinated through holes made for planting could be noticed. At 30 DAP, 60 DAP and at harvest, lower weed density and dry weight were observed in black polythene mulching for all types of weeds (Table 18).Superiority of black polythene sheet in controlling weed growth in medicinal coleus was reported by Gunasekaran and Shakila (2014). According to them, weed suppression by mulching was by increasing the soil temperature and killing the weed seeds in the early stages and also by acting as a physical barrier between sunlight and soil. The next better treatment considering lower weed density and dry weight was organic mulching. Ramakrishna *et al*. (2006) reported significant reduction in weed density and dry weight by the application of organic mulch. Use of polythene mulch

had proved to be the best practice in controlling weeds throughout growing period compared with the other treatments. Among the mulching treatments higher weed control efficiency and lower weed index were under the treatment combinations with black polythene mulch. Giri *et al.* (2016) reported similar result of lowest weed index in weed free treatment in sweet basil. Velmurugan *et al.* (2017) reported 100 per cent weed control efficiency in cassava under black polythene mulched treatment.

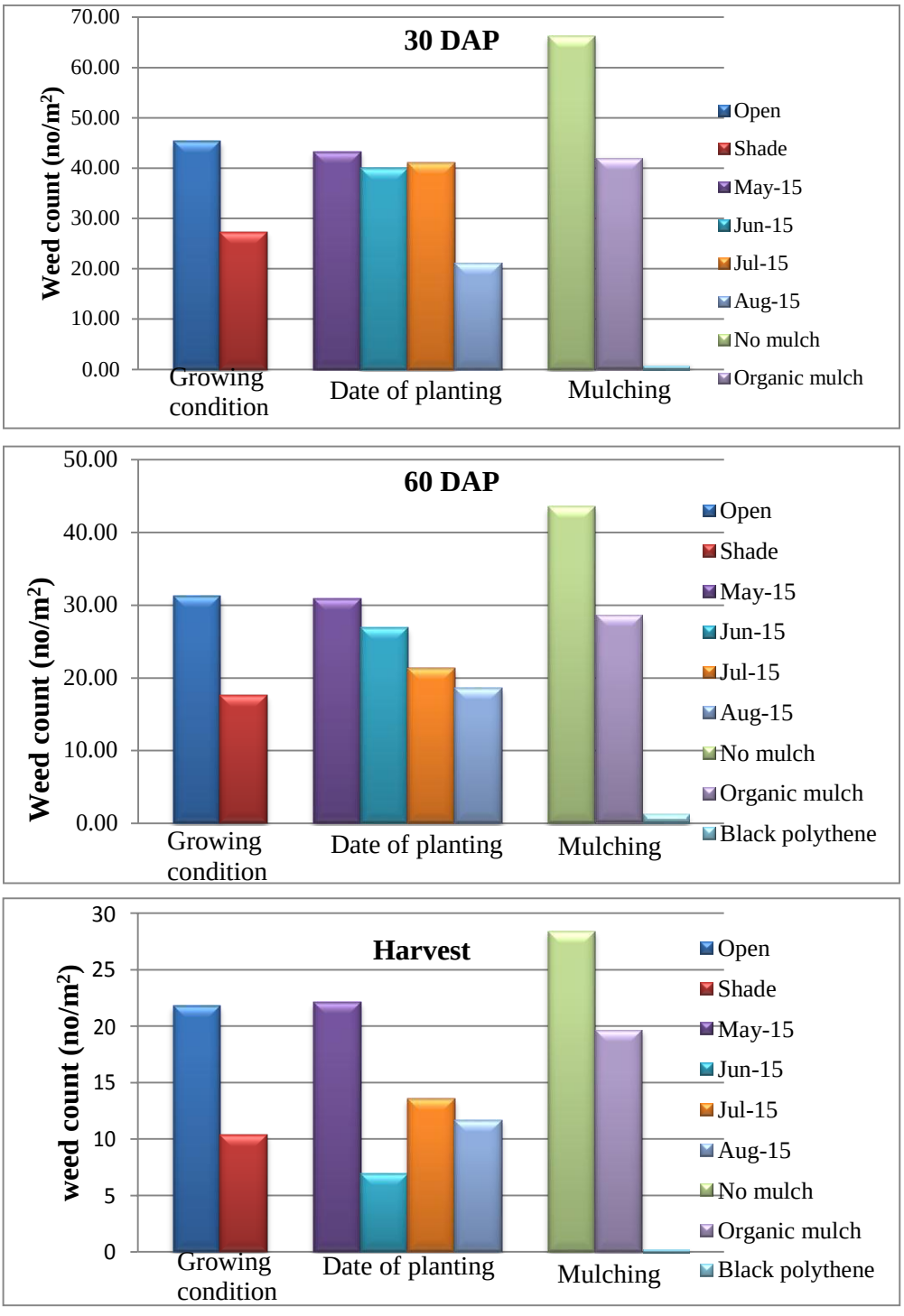


Fig 22. Effect of growing condition, date of planting and mulching on weed count of broad leaf weeds at different growth stages of *Plectranthus vettiveroides*

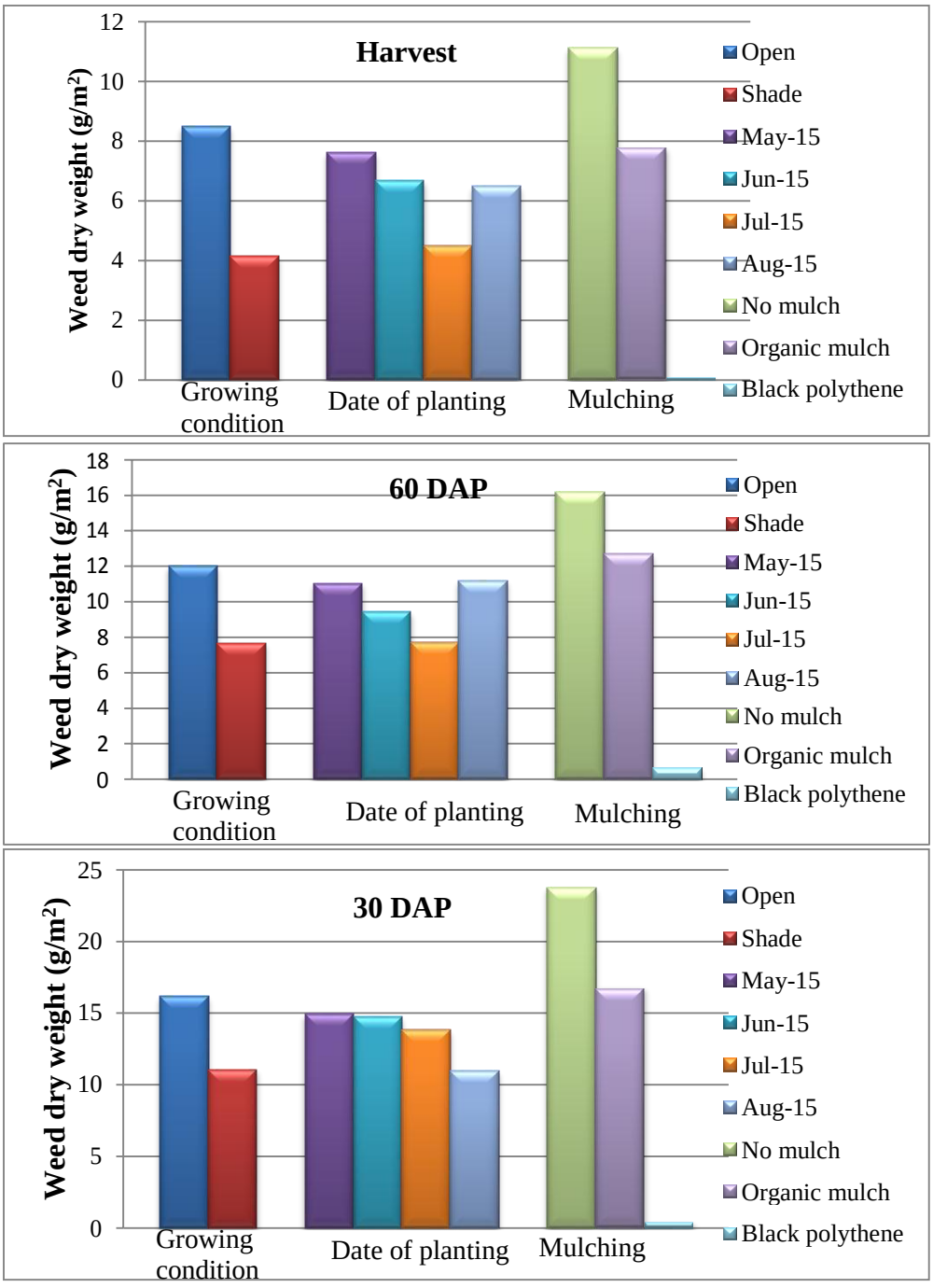


Fig 23. Effect of growing condition, date of planting and mulching on weed dry weight of broad leaf weeds at different growth stages of *Plectranthus vettiveroides*

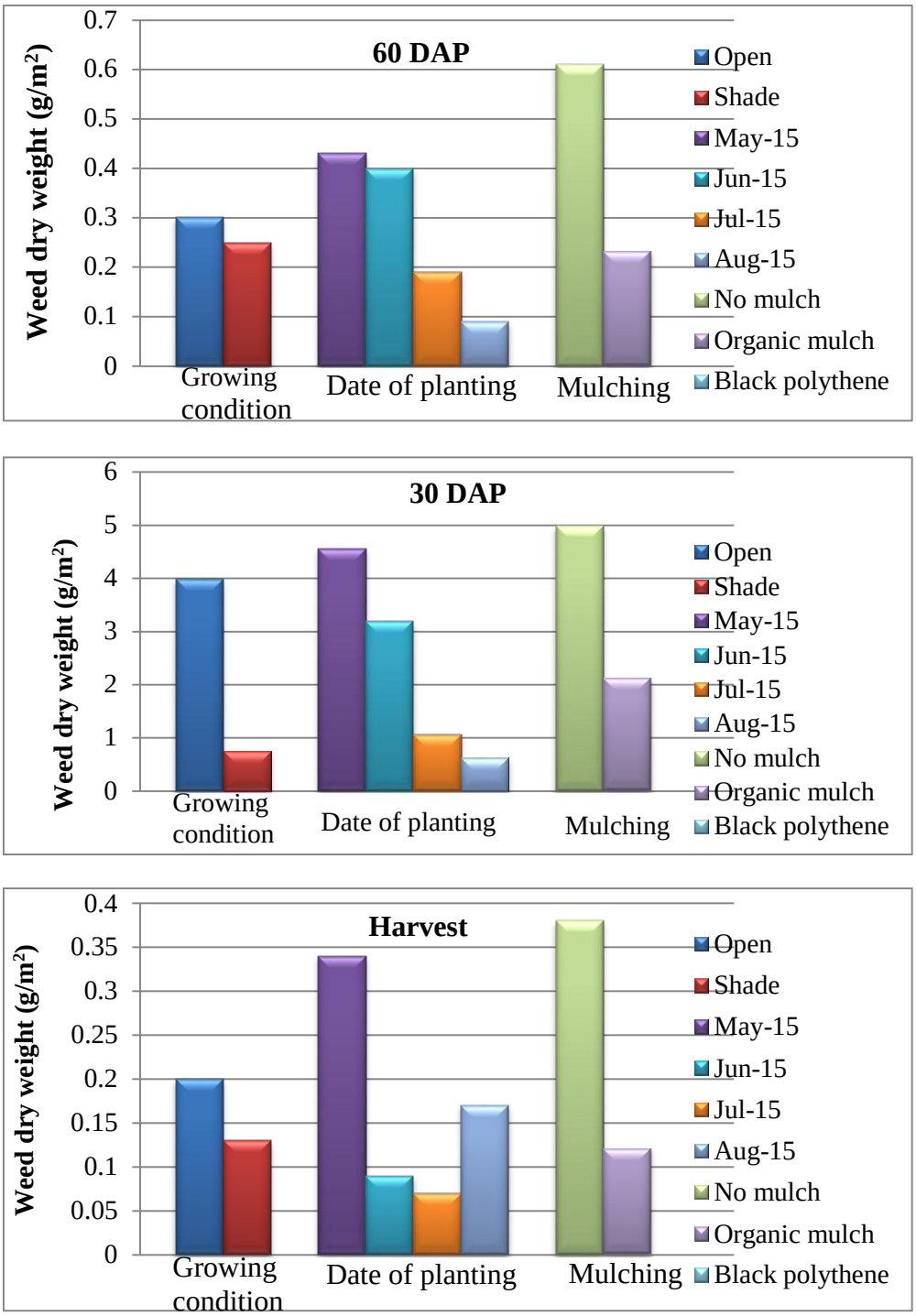


Fig 24. Effect of growing condition, date of planting and mulching on weed dry weight of grasses at different growth stages of *Plectranthus vettiveroides*

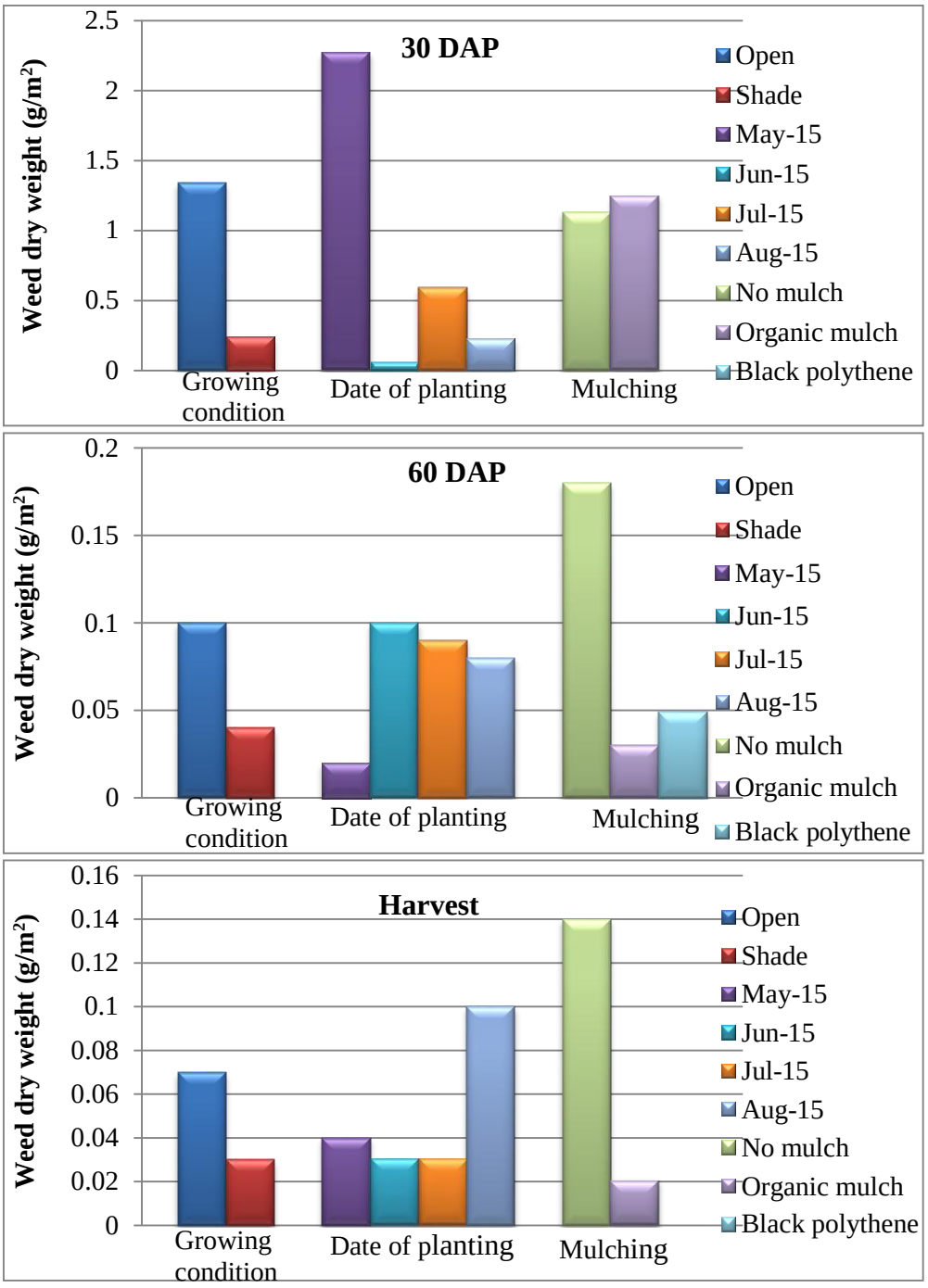


Fig 25. Effect of growing condition, date of planting and mulching on weed dry weight of sedges at different growth stages of *Plectranthus vettiveroides*

5.6 Crop weather correlations observed during the experiment

The correlation between important morphological, yield and quality characters and mean weekly weather and microclimatic parameters like surface air temperature, relative humidity (forenoon and afternoon), rainfall, soil temperature, soil moisture and light intensity were worked out during the experiment.(Tables 20, 21, 22, 23, 24, 25, 26, and 27) The results indicated that maximum temperature had negative correlation with plant height, positive correlation with number of branches, biomass yield at later growth stages, root yield and essential oil content(Table 20). Hikosaka *et al.* (1999) reported that optimum temperature during the growth stages would affect the growth and development of plants by influencing the rate of photosynthesis Chang *et al.*, (2008) studied the effect of temperature on basil (*Ocimum basilicum* L.) and found that up on shading, the photo synthates assimilation would be reduced which eventually reduce the production of secondary metabolites.

Minimum temperature also exhibited negative correlation with plant height, total biomass yield and essential oil content during the later stage of crop growth (Table 21). Positive correlation was observed with number of branches and total biomass yield. Sattar *et al*. (2014) reported positive correlation of minimum temperature with yield of sugarcane.

Forenoon and afternoon relative humidity had positive correlation with plant height, and biomass yields, root yield and oil content at harvesting stage (Tables 22 and 23). The correlation of rain fall with biomass yield, root yield and essential oil was found negative initially but later it was found positive (Table 24). Hang *et al.* (2005) report that better meteorological conditions, such as sufficient sunshine, stable and suitable temperature, moderate rainfall and rational distribution, are essential for the growth of medicinal plants in terms of dry matter production and accumulation of active constituents.

The light intensity has got positive correlation with number of branches, biomass yield, total root yield and essential oil content initially. At later stages, this was found non significant (Table 25).As discussed earlier the increased light intensity in open condition might have increased rate of photosynthesis during the vegetative period thus producing higher biomass yield in open condition. Similarly soil temperature had strong positive correlation with number of branches, total biomass, root yield and essential oil content during the initial period of crop growth (Table 25). With soil moisture, the correlation of biomass yield, root yield and essential oil content was negative during initial weeks, but later the correlation was significantly positive. (Table 26). The optimum soil temperature and moisture could increase the soil microbial activity and thus could effectively enhance the soil mineralisation of nutrients. This might have affected the crop yield positively.

Comparing the correlation between plant biometric characters and quality parameters, a positive correlation could be observed between height and number of branches. The relation between height, number of branches and total yield with the quality characters were found positive.(Table 28)

5.7. Economic of cultivation

Highest B:C ratio was obtained from May planted crop with black polythene mulch under open condition followed by May planting with black polythene mulch under shaded condition (Fig. 26). Higher B: C ratio under open condition indicated that open condition is better for planting Plectranthus. Also planting in the month of May and mulching with black polythene sheet was found as highly economic. Lower B:C ratio was obtained from August planting with organic mulch under shade. This might be due to lower yield combined with high cost of organic mulching.

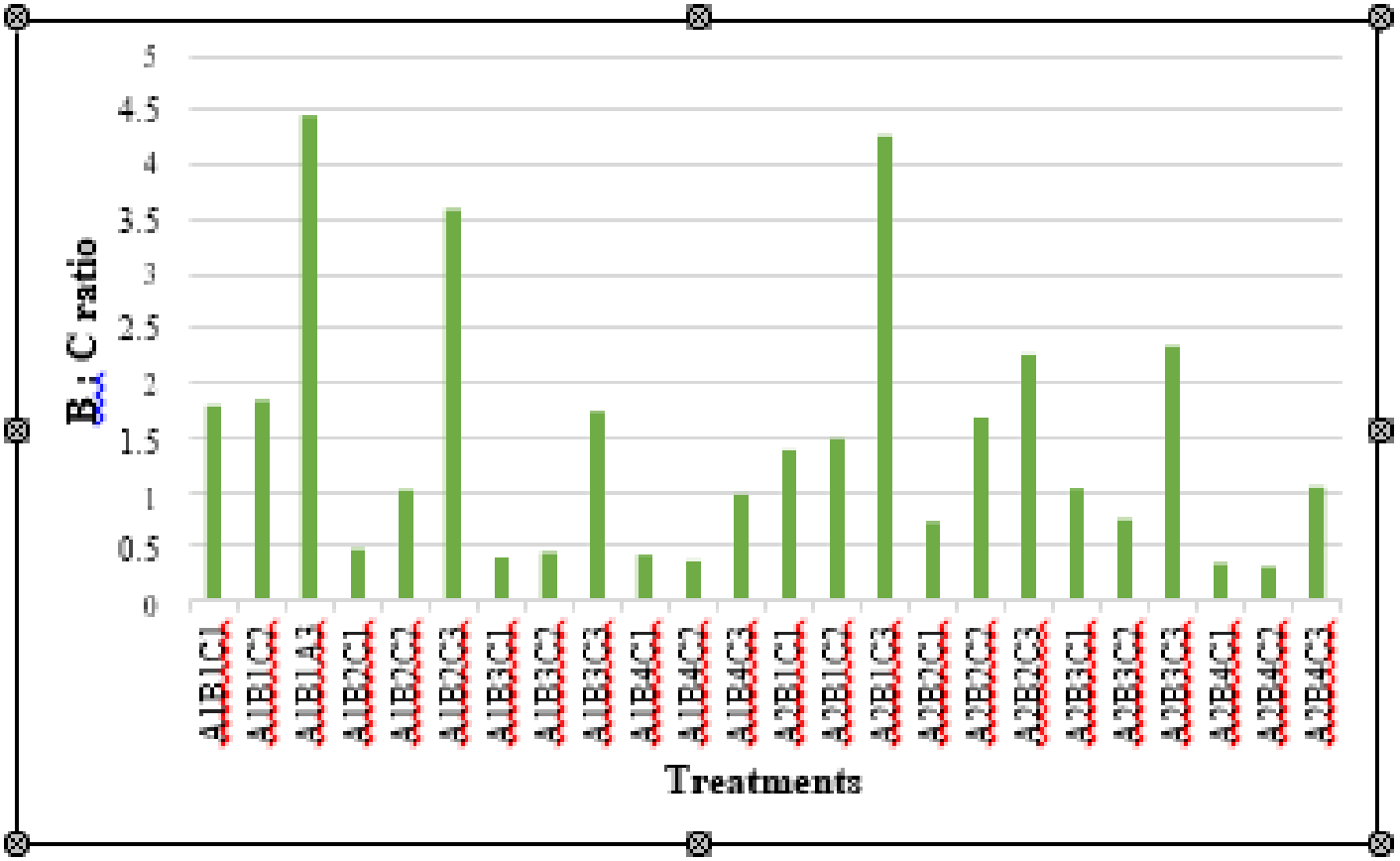


Fig 26. Interaction effect of growing condition, date of planting and mulching on economics of cultivation.

6. *Summary*

6. SUMMARY

The present work entitled "Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]" was carried out to study the effect of light intensity, time of planting and mulching on yield and quality of *Iruveli* (*Plectranthus vettiveroides*). The experiment was conducted at the Agronomy farm, Department of agronomy, College of Horticulture, Vellanikkara, Thrissur. The experiment was laid out in factorial RBD replicated thrice. The treatments consisted of two growing conditions viz., open and 50 per cent shade, four dates of planting viz., 15th May, 15th June, 15th July and 15th August and three mulching viz., no mulching, organic mulching and black polythene mulching. Observations were taken on biometric characters, micro meteorological parameters, soil characters, physiological, chemical and biochemical analysis of plants and observations on weeds. Economics cultivation was also worked out. The salient features of the research are summarized and listed here under.

6.1. Effect of growing condition

- Growing condition had significant influence on performance of crop. Plant height was higher under 50 percent shaded condition and open condition greatly favoured the number of branches at all the stages of growth.
- Fresh biomass yield and root yield at harvest were higher under open condition.
- Growing condition favoured available N and P content in soil and it was higher in shaded condition.
- Considerable effect of growing condition on soil microclimatic observations like soil temperature and soil moisture and light intensity were noticed.
- Soil temperature and light intensity were higher in open condition where as higher moisture was observed in shaded condition.
- At 60 DAP and at harvest, plants under shade showed higher total chlorophyll content.
- At 60 DAP, crop growth rate and relative growth rate were higher in shaded condition while at harvest it was higher in open condition.
- The uptake of N and P were highest in open condition.
- Essential oil content was also higher in open condition. The growth of weeds including grasses, sedges and broad leaf weeds were significantly lower in shaded condition.

6.2. Effect of date of planting

- Plant height was significantly influenced by different planting dates at 30 DAP, 60 DAP and at harvest.
- Crop planted in July recorded taller plants during initial stages of crop growth, while May planted crop had maximum plant height at harvest stage.
- Maximum number of branches were observed in June planted crop during initial stages. At harvest stage the number of branches were higher in June planting which was on par with August planting.
- Per plant biomass yield was higher in June planted crop at 30 DAP, while at later stages, May planted crop recorded highest per plant biomass yield.
- Highest total biomass yield and root yield was found with May planted crops.
- Available N content in soil after the experiment was higher in July planted plots while available P and K content was higher in August planted plots.
- Soil temperature was influenced by planting dates only in a few weeks. However, there was significant variation in soil moisture contents and light intensity.
- Higher chlorophyll content was noticed in August planting at 30 DAP, June planting at 60 DAP and May planting during harvest.
- Crop planted in June recorded significantly higher CGR and RGR during 0 to 30 DAP. At the stages of 30 to 60 DAP and 60 DAP to harvest, CGR and RGR were higher in May planted crops.
- Essential oil content was significantly higher in May planting. The crop planted in May recorded the highest weed count and weed dry weight at different growth stages.

6.3. Effect of mulching

- Black polythene mulching greatly influenced on increasing plant height, number of branches and fresh biomass at different growth stages.
- Total biomass yield and total root yield were higher in black polythene mulched plots.
- Available N and K contents were higher in organic mulched plots.
- Mulching with black polythene exhibited higher soil temperature and soil moisture throughout the crop growth period.
- Total chlorophyll content was higher in black polythene mulched plots at 30 and 60 DAP.

- Higher CGR was found in plants with black polythene mulch at different growth periods and RGR was found higher in black polythene mulch during 30 DAP and at harvest. During 30 to 60 DAP, higher RGR was found in organic mulched plots.
- Essential oil content was significantly higher in plants with black polythene mulching.
- The uptake of N, P and K were higher in black polythene mulched plots.
- Black polythene mulching was the best treatment for weed control, followed by organic mulching.

6.4. Effect of interaction between growing condition, date of planting and mulching

- At harvest, interaction between growing condition, planting dates and mulching had significant influence on, per plant biomass yield, total biomass yield and total root yield.
- The crop planted in open condition in the month of May with black polythene mulch recorded the highest per plant biomass yield, total yield and root yield.
- After harvest, the available N content in the soil was significantly higher in July planting with organic mulch under shaded condition and available P in the soil was higher in August planting without mulch under shade.
- Interaction between growing condition, planting dates and mulching significantly influenced the essential oil content.
- Highest content of essential oil was found in May planted crop under polythene much in open condition.
- Highest uptake of N was in shade grown crop with black polythene mulch during May and highest P uptake was in black polythene mulched plot planted in May under open condition.
- Highest weed count and weed dry weight were found in May planting with black polythene mulch under open condition. The lowest weed count and dry weight were found in shaded condition under black polythene mulch.

6.5. Crop weather relations

- Maximum and minimum temperature had negative correlation with plant height, positive correlation with number of branches, biomass yield at later growth stages, root yield and essential oil content.
- Forenoon and afternoon relative humidity had positive correlation with plant height, and biomass yields, root yield and oil content at harvesting stage.

- The correlation of rain fall with biomass yield, root yield and essential oil was negative initially but later become positive.
- The light intensity had positive correlation with number of branches, biomass yield, total root yield and essential oil content and negative relation with height.
- Soil temperature had positive correlation with number of branches, total biomass, root yield and essential oil yield during the initial period of crop growth.
- With soil moisture, the correlation of biomass yield, root yield and essential oil content has got negative correlation during initial weeks , but later the correlation is significantly positive.
- A positive correlation existed between height and number of branches, The relation between height, number of branches and total yield with the quality characters was positive.

6.6. Cost benefit analysis

A higher B: C ratio of 4.46 was obtained from May planting with black polythene mulching under open condition. Planting in August with organic mulch under shaded condition recorded lower B: C ratio.

From the experiment it can be concluded that optimum growing condition, planting date and mulch for *Plectranthus* is open, 15th May and black polythene mulch respectively.

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Appendices

APPENDICES

Appendix 1. Monthly weather data during experimental period (May 2018-November 2018)

Months	Max temp (^{0}C)	Min temp (^{0}C)	RH forenoon (%)	RH afternoon (%)	Rainfall (mm)	Sunshine hours
May	33.2	22.6	91	66	483.6	4.8
June	29.8	23.2	95	83	708.0	4.8
July	29.6	22.5	96	80	795.2	1.9
Aug	29.2	22.2	96	78	928.0	2.2
Sep	32.2	22.5	91	60	29.0	7.2
Oct	32.8	22.9	90	62	383.0	5.7
Nov	32.7	23.3	82	54	63.9	5.8

Appendix 2. Daily weather data during experimental period (May 2018-Novemberr 2018)

Days	Max temp (^{0}C)	Min temp (^{0}C)	RH forenoon (%)	RH afternoon (%)	Rainfall (mm)	Sunshine hours
15-05-18	32.5	23.8	87	50	1.6	0.0
16-05-18	36.6	21.0	95	64	8.4	60.6
17-05-18	32.9	22.6	93	68	2.9	1.3
18-05-18	33.4	22.1	92	69	5.5	12.0
19-05-18	31.8	23.9	93	64	2.7	0.0
20-05-18	33.0	22.0	88	67	5.8	0.0
21-05-18	32.4	22.6	92	64	7.6	0.0
22-05-18	32.5	21.0	93	67	3.6	22.0
23-05-18	33.7	23.7	92	72	5.7	0.0
24-05-18	33.0	22.3	93	68	5.6	10.7
25-05-18	31.7	20.2	92	87	0.0	80.3
26-05-18	28.4	21.9	89	55	0.0	0.4
27-05-18	34.1	22.4	92	67	6.2	0.0
28-05-18	33.7	24.3	79	85	3.2	43.5
29-05-18	30.0	24.3	98	92	0.5	69.6
30-05-18	28.7	23.4	98	75	0.2	55.4
31-05-18	30.2	23.6	90	71	0.9	25.2
01-06-18	32.0	23.9	89	71	2.2	0.0
02-06-18	32.0	24.9	90	71	3.2	0.4
03-06-18	32.1	24.5	86	90	7.2	0.4
04-06-18	28.0	23.9	98	97	0.5	22.0
05-06-18	28.4	23.7	95	71	0.0	4.7
06-06-18	31.3	23.8	93	66	3.3	0.0
07-06-18	33.0	23.8	98	99	8.3	23.2
08-06-18	29.1	23.4	98	94	0.0	39.7
09-06-18	30.0	22.5	98	82	0.0	85.9
10-06-18	29.7	24.0	97	81	0.0	55.2
11-06-18	30.5	23.7	93	78	0.4	25.8
12-06-18	29.9	23.9	99	82	0.0	41.8
13-06-18	29.9	23.7	98	98	0.0	29.1
14-06-18	27.4	23.0	99	98	0.0	128.2
15-06-18	26.9	23.7	98	84	0.0	10.2
16-06-18	28.9	23.4	92	72	0.0	0.2
17-06-18	32.2	23.7	95	70	8.8	0.7
18-06-18	30.3	23.4	98	72	0.1	7.1
19-06-18	31.4	22.2	99	95	5.1	46.7
20-06-18	29.1	22.2	96	97	0.7	66.2
21-06-18	27.6	23.0	96	91	0.0	3.5
22-06-18	26.9	22.3	95	98	0.0	5.3
23-06-18	28.8	22.4	96	81	0.6	12.5
24-06-18	23.6	22.4	95	70	0.6	1.4
25-06-18	31.0	23.2	95	76	4.5	8.1

26-06-18	31.4	22.3	96	75	3.9	15.3
27-06-18	30.7	23.5	95	74	1.4	3.5
28-06-18	30.6	21.9	98	92	0.0	40.4
29-06-18	26.0	22.3	96	95	0.0	26.0
30-06-18	29.0	21.7	91	68	0.4	4.5
01-07-18	31.8	23.4	95	70	7.9	0.2
02-07-18	31.8	23.7	97	61	7.3	0.5
03-07-18	32.3	23.2	95	67	7.4	2.2
04-07-18	32.1	22.9	90	62	5.8	0.0
05-07-18	32.7	23.4	90	57	8.7	0.0
06-07-18	32.1	21.9	96	69	7.7	9.0
07-07-18	30.7	24.3	89	83	2.7	0.2
08-07-18	30.6	21.5	98	75	0.2	53.6
09-07-18	29.7	22.5	98	95	0.0	40.2
10-07-18	25.0	22.4	99	88	0.0	49.0
11-07-18	28.8	21.5	98	97	0.0	87.8
12-07-18	25.6	21.7	98	90	0.0	48.1
13-07-18	30.0	22.2	98	75	1.1	12.1
14-07-18	29.5	22.1	96	74	0.1	32.1
15-07-18	30.5	21.3	98	93	1.1	34.9
16-07-18	26.7	20.7	98	92	0.0	95.2
17-07-18	28.9	20.4	98	93	0.0	34.6
18-07-18	29.9	20.8	98	91	0.1	70.7
19-07-18	28.0	22.5	93	95	0.0	15.9
20-07-18	27.1	22.1	96	89	0.0	26.7
21-07-18	27.6	23.4	95	75	0.0	12.5
22-07-18	30.0	22.7	92	75	0.2	0.5
23-07-18	30.1	22.7	93	87	0.3	14.9
24-07-18	29.1	22.3	95	82	0.6	39.2
25-07-18	28.1	22.7	97	79	0.0	23.6
26-07-18	28.8	23.2	96	71	0.0	22.7
27-07-18	29.9	22.5	96	70	0.7	1.8
28-07-18	30.3	23.4	95	75	1.9	1.9
29-07-18	30.1	23.9	98	76	2.2	6.4
30-07-18	30.5	23.8	97	84	1.5	17.3
31-07-18	29.9	23.1	98	97	0.0	41.4
01-08-18	27.8	22.7	98	74	0.0	14.3
02-08-18	30.0	23.3	98	66	3.2	3.5
03-08-18	31.4	22.7	95	69	4.7	13.1
04-08-18	30.4	23.5	95	75	1.3	0.0
05-08-18	29.8	23.0	98	75	0.0	14.0
06-08-18	30.2	23.3	93	74	1.4	0.6
07-08-18	30.0	21.7	98	87	2.2	33.6
08-08-18	28.9	21.7	98	86	0.0	110.6
09-08-18	27.9	22.3	98	81	0.0	29.5
10-08-18	28.6	22.8	95	78	0.4	6.7
11-08-18	29.9	22.0	98	92	0.0	13.5
12-08-18	28.3	21.5	96	84	0.0	14.1

13-08-18	27.3	22.3	98	80	0.3	26.5
14-08-18	27.9	22.3	96	98	0.0	8.3
15-08-18	26.9	21.9	95	98	0.0	140.6
16-08-18	24.0	21.4	96	95	0.0	253.6
17-08-18	25.3	21.0	96	93	0.0	148.4
18-08-18	28.8	21.5	97	95	0.0	23.6
19-08-18	27.9	21.3	96	72	0.0	28.0
20-08-18	28.9	22.3	98	75	3.1	2.6
21-08-18	29.8	22.5	96	74	1.6	1.7
22-08-18	30.5	22.3	90	68	7.5	7.1
23-08-18	30.7	21.9	96	68	6.7	1.5
24-08-18	30.9	22.3	95	64	5.7	0.0
25-08-18	31.0	21.8	97	65	9.3	0.0
26-08-18	31.0	21.9	95	67	6.1	0.0
27-08-18	30.3	22.5	95	82	5.6	0.0
28-08-18	29.1	22.3	95	79	0.1	9.7
29-08-18	29.1	21.2	98	70	0.2	22.4
30-08-18	30.1	22.4	93	69	2.4	0.2
31-08-18	30.7	23.5	95	72	6.6	0.3
01-09-18	30.5	23.3	97	65	1.7	0.0
02-09-18	31.0	22.9	90	67	3.4	0.0
03-09-18	31.0	23.2	92	53	5.7	0.0
04-09-18	31.9	23.0	92	65	10.1	0.0
05-09-18	31.0	22.2	95	59	9.5	0.0
06-09-18	31.4	22.3	92	62	9.3	0.0
07-09-18	31.0	21.8	90	60	7.6	0.0
08-09-18	31.8	21.9	90	57	10.0	0.5
09-09-18	31.8	21.0	95	60	10.2	0.0
10-09-18	32.0	21.7	88	51	10.3	0.0
11-09-18	32.5	21.7	90	61	10.4	0.0
12-09-18	31.9	22.7	92	60	9.2	0.0
13-09-18	32.3	22.4	90	52	8.4	0.0
14-09-18	31.9	21.6	93	57	8.3	0.0
15-09-18	32.1	22.5	83	57	7.4	0.0
16-09-18	32.8	23.1	88	75	9.4	0.0
17-09-18	29.9	23..4	96	62	0.2	0.3
18-09-18	32.0	22.5	93	60	6.6	0.0
19-09-18	31.9	23.2	95	60	5.9	0.4
20-09-18	31.5	23.1	93	47	5.3	0.2
21-09-18	33.2	21.4	92	55	8.4	0.0
22-09-18	32.4	22.0	85	53	9.2	0.0
23-09-18	33.4	22.8	93	61	9.6	0.0
24-09-18	33.1	21.8	91	65	8.4	1.5
25-09-18	33.0	21.7	95	56	3.3	1.2
26-09-18	33.3	22.9	93	58	7.2	0.0
27-09-18	34.4	23.2	90	60	8.3	0.0
28-09-18	34.3	22.5	81	65	5.3	0.0
29-09-18	34.4	22.6	95	75	5.6	24.9

30-09-18	32.8	23.4	90	64	2.0	0.0
01-10-18	32.8	20.9	96	61	3.0	32.1
02-10-18	34.3	22.3	89	56	7.4	0.0
03-10-18	34.3	20.8	96	67	4.6	4.3
04-10-18	33.8	18.0	94	73	5.3	39.9
05-10-18	30.4	23.7	83	63	0.5	2.5
06-10-18	32.8	24.6	80	63	6.5	52.2
07-10-18	33.0	25.2	83	70	4.0	0.0
08-10-18	34.0	23.8	92	78	5.7	0.0
09-10-18	32.3	22.6	96	81	3.3	52.1
10-10-18	30.0	23.3	95	71	0.4	0.0
11-10-18	32.1	24.8	93	68	8.9	0.0
12-10-18	33.1	25.0	95	66	7.3	0.3
13-10-18	35.4	25.0	97	72	7.2	0.0
14-10-18	32.5	23.6	95	64	4.2	13.3
15-10-18	32.0	23.7	97	71	3.8	1.3
16-10-18	31.8	24.5	95	91	3.0	0.0
17-10-18	30.4	22.2	96	62	1.9	31.8
18-10-18	31.0	23.7	90	58	8.3	0.0
19-10-18	33.8	22.4	98	67	8.3	51.0
20-10-18	32.7	23.0	98	69	3.2	40.8
21-10-18	30.9	22.6	98	56	2.8	21.6
22-10-18	33.1	23.8	95	85	6.2	2.8
23-10-18	32.4	21.7	95	48	3.2	37.0
24-10-18	33.6	22.2	85	48	7.8	0.0
25-10-18	33.3	23.4	92	46	9.4	0.0
26-10-18	33.3	23.2	66	47	6.0	0.0
27-10-18	33.4	22.7	67	41	9.5	0.0
28-10-18	33.4	21.8	66	26	9.1	0.0
29-10-18	33.9	21.3	83	58	9.7	0.0
30-10-18	32.9	21.8	95	46	5.7	0.0
31-10-18	34.3	23.1	90	58	9.4	0.0
01-11-18	33.8	24.1	95	57	7.0	0.0
02-11-18	31.0	24.3	78	64	3.8	0.0
03-11-18	31.4	25.3	78	63	3.1	0.0
04-11-18	32.3	23.6	75	45	4.4	1.0
05-11-18	33.6	24.3	81	48	9.5	0.0
06-11-18	33.9	23.4	77	53	9.1	0.0
07-11-18	32.7	22.3	78	45	5.8	0.0
08-11-18	33.9	22.9	79	49	6.5	0.0
09-11-18	33.8	23.4	82	57	6.0	0.0
10-11-18	33.5	22.6	80	45	4.3	0.0
11-11-18	33.8	21.9	82	40	9.9	0.0
12-11-18	34.0	23.3	90	55	8.6	0.0
13-11-18	32.6	22.9	95	61	7.3	0.0
14-11-18	33.4	23.0	92	48	6.6	0.0
15-11-18	34.1	21.8	88	41	8.7	0.0

Crop - weather relations on yield and quality of *Iruveli* [*Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma]

By

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ABSTRACT OF THE THESIS

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ABSTRACT

In India, about 7500 species of medicinal plants are being used in different traditional systems of medicines like Ayurveda, Siddha, Unani, Homeopathy, folklore etc. In medicinal plant cultivation, both yield and quality are equally important, and therefore, it is necessary to identify optimum growth factors that can ensure high yield and quality. *Plectranthus vettiveroides* (K. C. Jacob) N. P. Singh and B. D. Sharma (Syn. *Coleus vettiveroides*) is an important herbaceous medicinal plant belonging to the family Lamiaceae, where the root is the major economic part.

The present study was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara to assess the effect of variations in intensity of light, time of planting and mulching on yield and quality of *Plectranthus vettiveroides* known as *Iruveli* in Malayalam. The trial was laid out in randomized block design, replicated thrice. The treatments consisted of two growing conditions *viz*., open and 50 per cent shade, four dates of planting *viz*., May 15, June 15, July 15, and August 15 and three mulching treatments, *viz.,* black polythene mulching, organic mulching, and no mulching.

Growing condition, date of planting and mulching had significant influence on plant characters such as height, number of branches, total biomass yield and total root yield. The highest biomass yield and root yield were obtained from open condition (10382 kg/ha biomass and 1216 kg/ha root), May planting (15694 kg/ha biomass and 2508 kg/ha root) and black polythene mulching (16235 kg/ha biomass and 1786 kg/ha root). Interaction between growing conditions, date of planting and mulching was also significant with the highest biomass yield in the treatment combination of May planting under open condition with black polythene mulching (34715 kg/ha).

The management methods also influenced the soil chemical properties. Available N and P were higher in 50 per cent shaded condition. Among mulching,

available N and K were higher under organic mulching. Higher available N was found in July planting, whereas available P and K were higher in August planting.

Among different micro climatic factors studied, soil temperature and soil moisture were significantly influenced by growing condition and mulching. Higher soil temperature was observed under open condition and black polythene mulching. However, higher soil moisture was under shaded condition and black polythene mulching

Physiological, chemical and biochemical parameters were significantly influenced by growing condition, date of planting and mulching. Higher CGR and RGR values were observed under May planting, open condition and with black polythene mulching. Total chlorophyll content at the time of harvest was higher under shade (2.26 mg/g) and May planting (2.16mg/g). Higher essential oil content was recorded from open condition (1.77%), May planting (1.73%) and with black polythene mulch (1.81%). Combination of May planting, black polythene mulching and open condition resulted in the higher essential oil content of 2.35 %. Weed count and weed dry weights were significantly influenced by the treatments. Lower weed count and weed dry weight were observed under shade and black polythene mulching whereas higher growth was observed in open condition and no mulching.

Correlation studies showed a positive correlation of total biomass, root yield and essential oil content with maximum temperature, relative humidity, rainfall and soil temperature. Essential oil content had significant positive correlation with light intensity, soil temperature, and soil moisture at initial stages of growth. There was also a positive correlation between biomass yield, total root yield and essential oil content.

A higher B: C ratio was obtained from May planting with black polythene mulching under open condition. Planting in August with organic mulch under shaded condition recorded lowest B: C ratio.

From the experiment it can be concluded that planting on 15th May in open condition under black polythene mulch as the optimum requirement for *Iruveli.*