Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management

By

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THESIS

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DECLARATION

I, Vidhu Priyadarsini P. T. (2017-11-074) hereby declare that the thesis entitled **"Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management"** 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 **"Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management."** is a record of research work done independently by **Ms. Vidhu Priyadarsini P. T.** (2017-11-074) 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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Introduction

1. INTRODUCTION

Plants accomplish a very vibrant role in sustaining and refining quality of human life. Plants which are commonly used for treating or preventing various ailments are generally considered as medicinal plants. Over the years, the use of medicinal plants has become an important part of daily life in spite of the progress in modern medical industry. Various plant parts like roots, stems, barks, leaves, flowers, fruits, seeds and whole plants are used in various forms of medicines (Kokate *et al.*, 2006).They are now widely used as nutraceuticals, cosmetics, as well as alternative medicines.

Sida is a large genus belonging to the family Malvaceae with about 200 species distributed throughout the world. The genus name *Sida* is from Greek word '*side*' meaning "water plant". Carl Linnaeus adopted the name from the writings of Theophrastus. They are extensively scattered in tropical and subtropical regions. The flora of this genus are commonly known as fan petals or sidas. The plants are also defined in various Ayurvedic reference books like Bhav Prakash Niganthu, Niganthu Ratnakar, Charak Sanhita etc. Different species like *Sida cordifolia*, *Sida acuta*, *S. alnifolia*, *S. spinosa*, *S. carpenifolia*, *S. humilis*, *S. veronicaefolia* were used in Ayurvedic system.

Sida alnifolia is a species found in tropical and subtropical regions of India. There are different common names for the crop like Arrow leaf sida or Sida hemp (English), Bala (Sanskrit), and Kurumthotti (Malayalam). Roots are used in a variety of Ayurvedic medicines and oils to improve strength of bones, muscles and joints. The main Ayurvedic preparations containing *Sida* includes Bala Taila, Balarishta, Balahathadi Taila, Chandanbala lakshaditaila, Sudarshan churna and Balaguduchyadi Taila.

According to National Medicinal Plant Board (NMPB), *Sida* is the 3rd most widely consumed drug in Ayurveda pharmaceutical industry and is mostly collected from the wild. Because of its high commercial value, the crop is included in the group of high volume traded medicinal plants sourced from waste lands. According to

Sasidharan and Muralidharan (2009), annual raw drug consumption of *Kurumthotti* by medicine manufacturing units of Kerala was 11,93,471 tonnes. Considering market potential, the State Medicinal Plant Board of Kerala has recommended this crop for commercial cultivation.

Quality of raw drug is as important as its quantity in medicinal plant cultivation. Since bulk of the present requirement is met by wild collection from natural habitats, when the crop is brought under cultivation, with improved management techniques, it is indispensable to ensure its quality. Cultivating plants under a micro climate similar to its niche original is the found to be the viable solution for ensuring its therapeutic properties.

The most common, unavoidable interaction occurring in plant communities is plant - environment interaction. External factors quantitatively affect the plant's metabolic processes through their effects on plant development, growth rates and partitioning of assimilates into vital metabolites. These factors can also trigger activation of qualitative changes in secondary metabolite production (Lommen *et al.*, 2008).

Studies on growth, root yield and phytochemical responses to light intensities are useful to determine the favourable conditions for the cultivation of medicinal plants. Management methods exhibit great influence on growth and yield of crops by way of modifying physical, chemical and biological properties of soil and plants. Organic manures provide a better environment for crop growth and root development by improving the soil structure, soil physical, chemical, biological properties and supplying plant nutrients including micronutrients. Effective weed management is essential for enhancing production, productivity and quality of medicinal plants.

As the information on influence of management methods on phytosphere variations, growth, yield and quality of *Sida alnifolia* is limited, the present experiment was formulated with the objective of assessing the effect of light intensity, manuring and weed management on phytosphere variations and its consequent effect on growth, yield and quality of Sida hemp [*Sida alnifolia* L.].

Review of literature

2. REVIEW OF LITERATURE

Plants have been used for medicinal purposes long before prehistoric period. Medicinal plants form a numerically large group of economically important plants which provide basic raw materials for medicines, perfumes, flavours and cosmetics. These plants and their products not only serve as rich source of income but also help the country to earn valuable foreign exchange by way of export. According to Burkill (1966) about 75 - 80 per cent of the population of developing countries and about 25 per cent of that of developed countries depend either directly or indirectly on medicinal plants for the first line of treatment.

Sida is a large genus with about 200 species distributed throughout the world. The genus name *Sida* is from the Greek 'side' meaning for "water plant". It was Carl Linnaeus who first adopted the name from the writings of Theophrastus. These species are extensively scattered in tropical and subtropical regions. The floras of this genus are commonly well known as fan petals or Sidas. This genus has pronounced prominence in the Indian traditional system of medicine and is one among the most widely used raw drug in the production of different Ayurvedic formulations for over 2000 years. The plants are also defined in various Ayurvedic reference books like Bhav Prakash Niganthu, Niganthu Ratnakar,Charak Sanhita etc. Different species like *Sida cordifolia*, *Sida acuta*, *S. alnifolia*,*S. spinosa*, *S. carpenifolia*, *S. humilis*, *S. veronicaefolia* were used in Ayurvedic system. These were also quiet inclined to adulteration due to accessibility of number of species and also due to lack of sufficient information (Sasidharan and Muralidharan, 2009).

Sida alnifolia is a species belonging to plant family Malvaceae, found in tropical and subtropical regions of India. There are different common names for the crop like arrow leaf Sida or Sida hemp (English), Bala (Sanskrit), Kurumthotti (Malayalam) and ayurvedic names include *Vatyâlaka, úîtapâki, vâtyodarâhva, bhadraudanî, samangâ, samâmsa* and *svarayastikâ.* According to Nair *et al.* (2005) Sanskrit literature identifies different species of *Sida* namely bala, athibala, nagabala and jysethbala. It is a popular drug used in various Ayurvedic formulations for treating

rheumatic complaints. The name Bala indicates the property of the plant in enhancing 'Bala' (strength) of the body.

2.1 Habitat

Sida alnifolia is a perennial or sometimes annual plant native to the tropic and subtropic areas. It is distributed in a wide variety of habitats including the plains, hill slopes, dry lands, waste lands, farms and even on road sides. It is widely scattered in both hemispheres including Africa, Asia, Australia, North, Central and South America and Pacific islands. Among these, about 17 species are in India, 14 species in China, 7 species in Taiwan, 12 species in Pakistan, 35 species in Australia, 95 species in Brazil, 20 species in Mexico, 24species in Colombia, 27 species in Argentina, 14 species in Bolivia, 20 species in Cameroon, 10 species in Nigeria and 2/3rd of reported species in America (Shaheen *et al.*, 2009; Bovini and Baumgratz, 2016).

2.2 Morphology

These are annual or perennial herbs or shrubs growing 20 centimetres to 2 metres tall. Stems are erect to sprawling and branched, growing 50-120 cm in height, with a woody lower section. The dark green, diamond shaped leaves are arranged alternately along the stem, and are 4-8 cm long, with petioles less than a third of the length of the leaves. The leaf blades are usually unlobed with serrated edges, but may be divided into lobes. They are borne on petioles and have stipules. Flowers are solitary or arranged in inflorescences of various forms. Each has 5 hairy sepals and 5 petals in shades of yellow. There are many stamens and a style divided into several branches. The fruit is a disc-shaped schizocarp up to 2 centimetres wide which is divided into 5 to 12 sections, each containing a seed (Assam *et al.*, 2010).

According to Sasidharan and Ansari (2017), size of *Sida alnifolia* roots were 8-10 mm in diameter, cylindrical in shape and had a number of long wavy thin lateral roots with a large number of wiry rootlets. A few were very small, and tangentially elongated. Slightly prominent lenticels were seen on the upper part of the thick root and the outer surface was not smooth due to the presence of many rootlets. The root was yellowish brown in colour, pleasant in odour and sweet but slightly bitter in taste.

2.3 Phytochemical constituents

Alkaloids are a class of phytochemicals that contain basic nitrogen atom, although some alkaloids contain oxygen, sulphur and chlorine. Ephedrine is the major alkaloid present in the *Sida spp.* (Nadkarni, 1954). According to Khare *et al.* (2002) roots of Sida hemp comprised alkaloids such as betaphenethylamine, ephedrine, siephedrine, vasicinol, vasicinone, vasicine, choline, hypaphorine, methyl ester, betaine, phytosterols, α-amyrin, starch and ecdysterone. Narendra *et al.* (2011) reported the presence of flavanoids, glycosides, saponins, carbohydrates, proteins and amino acids, tannins, terpenoids and alkaloids in the aqueous and alcoholic extracts of leaves. Alkaloids, flavonoids and ecdysteroids were identified as predominant chemicals among 142 chemical constituents present in *Sida* spp (Dinda *et al.*, 2015). Krishnaveni *et al.* (2018) did the phytochemical screening of the hydroalcoholic extract (70%) of *Sida acuta* leaf powder and revealed the presence of alkaloids, carbohydrates, cardiac glycosides, coumarine glycosides, sterols, saponins, tannins, phenolic compounds, flavonoids, proteins, amino acids, terpenoids, fixed oils, gum, mucilage, quinone, coumarine and resins. They also reported the absence of anthraquinone glycosides, cyanogenetic glycosides, volatile oils, betacyanins, anthocyanins, lecothiocyanins, emodin and pholoptannins in roots of *S. acuta.*

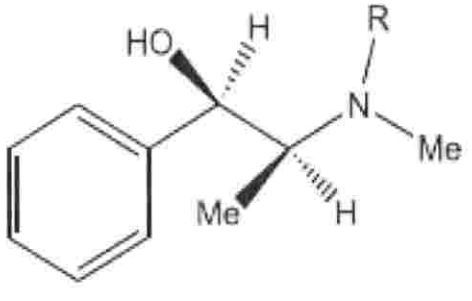


Fig.1. Molecular structure of ephedrine

2.4 Medicinal uses and economic importance

Some of the *Sida sp*. like *Sida alnifolia* L., *S. cordifolia* L., *S. spinosa* L., and *S. veronicaefoila* L. have abundant pharmacological uses. Roots are used in different Ayurvedic medicines and oils to improve strength of bones, muscles and joints. The ethanol extract of *S. alnifolia* possesses hypoglycaemic activity and the ethyl acetate extract of the plant has cytotoxic and anti bacterial activities. These extracts can be used for curing ulcer, leprosy urinary infection and skin diseases. Leaves of Sida hemp possess demulcent and diuretic properties and are used for the treatment of gonorrhea. It is also used as anti tubercular agent in Europe. Rheumatic pain, strengthening of cardiac ailments and biliary problems in children can be treated using the decoction of the plant.

Aqueous extract, aerial parts and powdered roots are hepatoprotective agents. Themethanolic extracts of Sida hemp have anti inflammatory properties. According to Nadkarni(1982), *S. alnifolia* was very effective for the treatment of gonorrhea, piles, gout and rheumatism and as nutritive tonic, diuretic and aphrodisiac. According to Abat *et al*. (2017), ethnopharmacological properties of *Sida* spp. included analgesic, anti-inflammatory, antidiabetic, antiobesity, antioxidant, antimicrobial, anxiolytic, cardioprotective, cytotoxic, hepatoprotective and nephroprotective properties. According to Krishnaveni *et al*. (2018) the plant displayed numerous pharmacological activities such as antibacterial, antimicrobial, larvicidal, repellent, gastric anti ulcer, insecticidal, hypoglycemic, antipyretic, anthelmintic, antioxidant, thrombolytic, electrolytes and organ function parameters, diuretic and anti urolithiatic, *invitro* stability and aggregatory, anti inflammatory, alpha amylase inhibitory, hepataprotective, calcium oxalate crystal growth inhibitory, corrosion inhibitory, antiplasmodial, analgesic, anti venom, anti malarial, antiulcer, wound healing, cytototoxicity, cardiovascular, antifungal and anticancer.

Sida hemp is widely used in traditional medicines to treat malaria, chest pain, fever and abdominal pain (Khare *et al*., 2002). According to them Ayurvedic medicinessuch as Baladikwath, Baladyaghirt, Baladyarista, Chandanbalalakshaditaila, Sudarshan churna and Kukuvadi churna are prepared by *Sida alnifolia* and *Sida*

cordifolia which are used to alleviate pain and swelling in rheumatic disorders, muscular weekness, tuberculosis, heart diseases, bronchitis, wounds in urinary tract and neurological problems. Ajithabai *et al.* (2012) reported that *Sida alnifolia* has been used as abortive and in the treatments of asthma and other chest ailments.

Considering the market potential, the State Medicinal Plant Board of Kerala recommended this crop for commercial cultivation. According to Sasidharan and Muralidharan (2009) annual raw drug consumption of *Kurumthotti* by medicine manufacturing units in Kerala was 1193471 tonnes and that of small units in Kerala was 42620 tonnes.

2.5 Effect of growing condition on plant growth, root yield and total alkaloid content of medicinal and aromatic plants

Light is a physical factor which can influence growth, yield and secondary metabolites production. According to Naoya *et al.* (2008), light is one of the fundamental environmental factors that considerably influence plant development, growth and, yield and quality.

Light intensity affects various plant characteristics. Under low light intensity, plants were more susceptible to photo inhibition (Long *et al.*, 1994). This helped the plants to grow under full light intensity, to capture maximum available light and meet the photosynthesis demand (Steinger *et al.*, 2003).

Growth of basil increased under full sunlight (Chang *et al.*, 2006). According to Saravanan *et al.* (2008), *Andrographis paniculata* recorded higher fresh weight, dry weight and leaf respiration under open condition, however, plant height reduced up to 32% under full light intensity. Omar *et al.* (2016) observed tallest plants of *Andrographis paniculata* under 50% shade.

According to Neerakal *et al.* (2009), root:shoot ratio of adalodakam (*Adhatoda beddomei*) was higher under shaded condition. Latha and Radhakrishnan (2015) reported that yield and yield attributing characters of *Sida cordifoila* were higher under full sunlight. They observed better root:shoot ratio under open condition.

According to Schaedle (1975), higher chlorophyll content in leaves under shade helped in trapping the available incident light effectively. Geetha (2004), reported increased proline content in leaves of *Alpinia calcarata, Pogostemon patchouli* and *Kampferia galangal* under open condition. Petritan *et al.* (2007) recorded increased chlorophyll content and decreased chl a/b ratio under low light in *Fraxinuslatifolia.* Valladares and Niinemetes (2008) observed increased chlorophyll content under shade in shade tolerant species. According to Hou *et al.* (2010), plant height, chlorophyll content and specific leaf area increased under low light intensity.

Salvinia officinalis produced highest essential oil content of 0.38 per cent in 45 percent full sunlight (Li *et al.*, 1996). Solasodine production increased by 10-12 times depending on light intensity in *Solanum lacinatum* (Jaggi and Kapoor, 1997). Biosynthesis and metabolism of bioactive compounds affected by light intensity (Zavala and Ravetta, 2001). Oleoresin content in *Kampferia galangala* (kacholam) increased with increased light intensity (Jessykutty, 2003). Hossain *et al.* (2009) reported that, growth, yield and curcumin content in turmeric were higher under full sunlight. Zhang *et al.* (2015) reported that in some medicinal plants, under reduced light intensity carbon based defense compounds were decreased. Latha and Radahakrishnan (2015) reported higher ephedrine content in *Sida cordifolia* under open condition. The alkaloid and guanosine content in *Pinellia ternata* increased higher under full light intensity (Chen, *et al.*, 2017).

2.6 Effect of manuring on plant growth, root yield and soil microflora

FYM application enhanced the soil environment for root development. An increased rice root length and root volume with FYM application was reported by Ibrahim *et al.* (2010). Dejene and Lemlem (2012) reported improved crop growth under FYM application by supply of plant nutrients including micronutrients.

Ayisha (1997) reported that available N, P and K were enhanced by the application of FYM. Uptake of N, P and K increased in *Stevia rebandiana* with the application of FYM (Chalapathi *et al.*, 1999). Under drought condition, reduced wilting was observed in plots applied with FYM (Singh and Singh, 2006). Another

advantage of FYM application in soil was faster water infiltration (Bhattacharyya *et al.*, 2008). Ahmad *et al.* (2009) reported higher CGR and RGR under FYM applied plots in potato. Naing *et al.* (2010) also reported higher CGR and NAR with the application of FYM. According to them, it was due to higher leaf area with application of FYM which resulted in higher radiation use efficiency.

Organic matter decomposition and nutrient recycling were regulated by soil microbial population. Nannipieri and Badalucco (2003) reported that 80 - 90% of the soil processes were mediated by microorganisms. Yassen *et al.* (2010) indicated that with FYM application, activity of soil microorganisms increased. Dejene and Lemlem (2012) also reported improved biological properties in soil with the application of FYM. De Forest *et al.* (2012) reported that, organic manure addition could enhance the microbial population in soil.

Marinari *et al.* (2000) reported that FYM could enrich the soil organic matter. Soil enzymatic activity increased with the application of FYM as well as in organic fertilizers (Saha *et al.*, 2008). According to Watts *et al.* (2010) microbial and biochemical condition of soil determined the soil fertility. Babu *et al.* (2017) reported that highest soil microbial biomass carbon, nitrogen and phosphorus were recorded with combined application of FYM and inorganic nutrients.

2.7 Weed management in medicinal plants

In medicinal plant cultivation, organic management was recommended. Organic cultivation practices enhanced their quality for which buyers were often willing to pay higher price. In such situations, weed management was the foremost constraint. As in other crops, in medicinal and aromatic plants also, weeds functioned as crop competitors. The presence of weeds had significant effect on plant metabolic pathways and negatively affected the market value of the crops (Gill and Vijayakumar, 1969).

Weed infestation created problems for mechanised harvest and altered the quality when mixed with the harvested product. Weed infestation reduced the essential oils and other secondary metabolites in plants (Carrubba and Militello, 2013).

According to Upadhay *et al.* (2011) weed infestation reduced the quality of medicinal plants by adulteration or mixing of weeds during postharvest processing. According to them, the root of *Cyperus rotundus* reduced the quality of root crops like *Asparagus, Chlorophytum*, etc. Under organic cultivation, the most effective method of weed control was mulching (Cirujeda *et al.*, 2012).

Both polythene mulching and organic mulching had positive impact on weed management in medicinal plants. According to Bononi *et al.* (2006), in cultivation trials of *Artemisia absinthium*, mulching resulted in a 5 % increase in average plant weight. Lavender (*Lavandula angustifolia* Chaix), thyme (*Thymus vulgaris* L.), and rosemary (*Rosmarinus officinalis* L.) also have showed significant increase in mean plant height and diameter with mulching (Fontana *et al.*, 2006).

2.8 Effect of weed management on plant growth, root yield and soil microflora

Weed management practices are designed to favour the growth of crops with optimum requirement of nutrients and moisture. Weed control in medicinal plants is essential because weed competition reduce the vigour, quality and overall yield of the crop. Several methods are used to control weeds. Weed control methods like black polythene mulching, organic mulching and hand weeding are reviewed here. Hand weeding is a conventional method of weed management. However, it is laborious due to long hours of human work required. Mulching is simple and valuable technique that control weeds, saves time and reduces labour.

Mulching modifies the microenvironment around the crops. Nagalakshmi *et al* (2002) reported that mulching stimulated the microbial activity and suppressed weed growth. Mulching was useful for controlling various weeds and conserving moisture. According to Sharma and Kathiravan (2009), competition between main crop and weeds reduced due to mulching. Mulching smothered weed growth and it acted as a physical barrier to photosynthetic activity of weeds and hindered the growth. Adekiya *et al.* (2017) reported that porosity, moisture content and soil temperature increased, and bulk density decreased, with mulching.

sowing (Samui and Ambhore, 2000). They also reported higher root dry weight in mulched plot than in non mulched plots at 60 days after sowing. Plant height, number of tillers $hill^{-1}$, leaf area index (LAI) and dry matter production of finger millet was significantly influenced by that paddy straw mulching (Nagarajan and Wahab, 2001). As per Sunil *et al.* (2008), paddy straw mulching produced significantly higher plant height and nodules in summer green gram.

Mulches were used to control weeds and increase the yield of different vegetable crops (Srivastava *et al.*, 1994). Enhanced growth and yield of plant by improving the soil physical aeration were effected with paddy straw mulches (Rao and Pathak, 1998).The mean cob yield and stover yield were considerably advanced in paddy straw mulch than saw dust, coir dust, rice husk and control (Kulkarni *et al.*, 1998). Singh (2012) reported that essential oil content and nitrogen use efficiency of rosemary were enhanced with organic mulching.

Hand weeding

Hand weeding is of specific significance in all environments where mechanised systems are incompatible or there is lack of technical knowledge on use of other methods of weeding (Anobah, 1993). Hand weeding combined with mechanical inter row weeding were effective against weeds left in the crop row (Ionescu *et al.*, 1996). According to Saimbhi *et al.* (2000), even though weed dry weight was decreased in onion with hand weeding, highest bulb yield of 12.25 t ha^{-1} was produced. Qasem (2006) reported that hand weeding in onion significantly reduced the weeds biomass.

One of the effective weed control methods for non chemical weed control in medicinal and aromatic plants was hand weeding (Carrubba and Militello, 2013). Janmohammadi *et al.* (2016) reported that highest chlorophyll content of Moldavian balm (*Dracocephalum moldavica*) was recorded in plants grown under successive hand weeding and followed by two hand weeding. According to them, plants under consecutive and two hand weeding had the higher number of leaves.

Fortnum *et al.* (1995) reported increased shoot weights (27%), root weight (32%), and leaf area (20%) of tomato plants over white mulch than plants grown over black mulch. The use of coloured mulches had been able increase growth and yield in some plants. The best vegetative growth of cucumber was observed under black polythene mulch (El-Nemr, 2006). Aniekwe (2015) reported 100% weed control under black polythene mulching as compared to no mulching.

Medicinal plants grown under plastic mulch were more vigorous than those grown on bare ground without herbicide treatments (Ricotta and Masiunas, 1991). A 5 % increase in average plant weight was observed by mulching in *Artemisia absinthium* (Giorgi *et al.* 2005). Lavender (*Lavandula angustifolia* Chaix), thyme (*Thymus vulgaris* L.), and rosemary (*Rosmarinus officinalis* L.) showed significant increase in mean plant height and diameter with mulching (Fontana *et al.*, 2006).

Gunasekaran and Shakila (2014) reported higher tuber number per plant, tuber length, girth, fresh weight and lowest weed biomass were higher under black polythene mulch in medicinal coleus (*Coleus forskholli*). Effective weed control in sweet basil with maximum oil and herbage yield by mulching was observed by Giri *et al.* (2016).

Organic mulching

Organic mulches includes plant and animal materials such as straw, compost saw dust, wood chips, grass clippings, newspaper, hulls, leaf mould and animal manures (Bhardwaj, 2013).

Growth characters of maize variety CO-1 and finger millet CO-13 were increased with the application of coir pith either raw or composted (Wang and Li, 1987). According to them dry matter production in rapeseed was improved owing to paddy straw mulching. In maize, dry matter production with paddy straw mulch was higher by 13% than the from the control plot (Kulkarni *et al.*, 1998). Adetunji (1999) reported that stover mulch significantly enhanced vegetative growth of onion crop. In maize, the plant height and crop growth rate were improved under paddy straw mulch as compared to saw dust coir dust, rice husk and no mulch (Pramanik, 1999). In groundnut, the shoot dry weight was higher in mulched plots at 30 and 60 days after

Mulching could enhance the soil moisture and soil temperature and there by improved the vegetative and flowering properties of the plant (Agele *et al.*, 2000). According to Rathinasabapathi (2005), mulching buffered the soil temperature, increased yield and quality, enhanced water and fertilizer use efficiency and decreased pest incidence. Govindappa *et al.* (2015) reported mulching as highly desirable management practice in crop production. Thakur *et al.* (2019) reported that mulching could improve the yield and productivity by the enhancement of soil temperature, soil moisture, weed control and reduction in leaching of fertilizers

Mulching had effect on improving the microbiological properties of soil. Since organic mulches such as paddy straw and rice husk were rich in carbon content, population of microbes in soil also increased (Gargi *et al.*, 2007). Mulches provided different kinds of ecological niches in the subsystem of crop environment and they encourage the multiplication of beneficial microorganisms (Yadav *et al.* 2008). Muhammed *et al.* (2015) observed higher microbial population in paddy straw mulched plots as compared to other organic mulches such as mango leaves, coconut leaves and newspaper.

Polythene mulching

In organic and conventional systems, plastic mulching is the most widely used method for weed control. It is one of the most accepted methods for commercial crop production. Poly vinyl chloride or poly ethylene films are used as plastic mulch.

As per Suwon and Judah (1985), soil temperature increased with the use of plastic mulch. Park *et al.* (1987) reported that polythene mulches permitted part of the radiation to leak through it but embodied as obstacles against withdrawing thermal radiation. Unevenness of soil temperature in the upper few centimetres of the soil was possible due to the hue of the mulch (Fortnum *et al.*, 2000). According to Lalitha *et al.* (2010), moisture content, bulk density, aggregate stability, soil temperature and nutrient availability increased under plastic mulching. Ashrafuzzaman (2011) observed maximum surface temperature above black plastic mulch, followed by blue and transparent mulches.

According to Upadhyay *et al.* (2011), hand weeding was the common weed control method among the physical methods, which was economical while integrated with IWM. They also reported that hand weeding at 20 and 40 days after sowing or days after planting was most effective for weed control in *Andrographis paniculata* and *Asparagus racemosus*, since the early stage was most sensitive for weed competition.

Materials & Methods

3. MATERIALS AND METHODS

A field experiment entitled, "Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management" was conducted during the period May - Dec 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° 32'N latitude and 76° 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 4.65. The physico chemical properties are presented in Table1.

Season

The experiment was conducted during the period from May - December 2018 (Fig. 1 and Appendix 1).

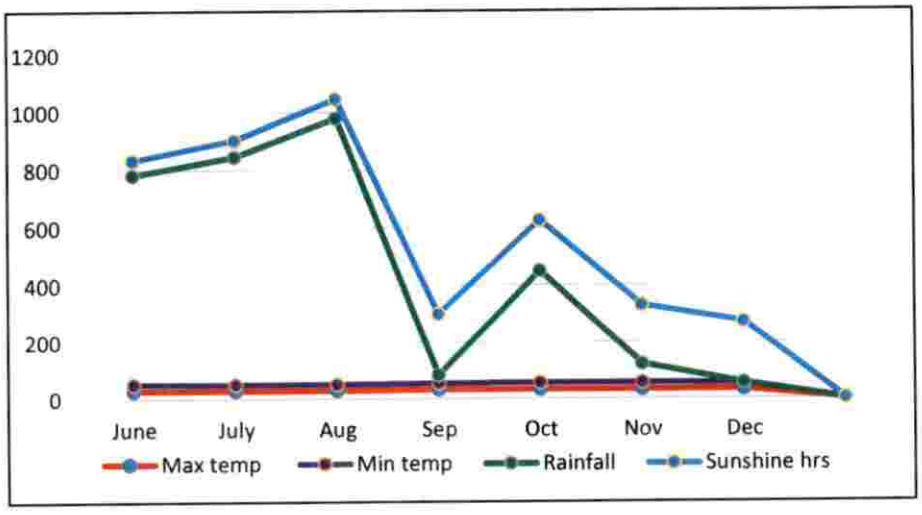


Fig. 1. Mean monthly weather data of atmospheric temperature, rainfall and sunshine hours during crop period

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. **Chemial properties**		
pH	4.62	1: 2.5 soil water suspension (Jackson, 1958)
Organic carbon (%)	1.07	Walkley and Black method (Jackson, 1958)
Available N (kg ha^{-1})	112.90	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg ha^{-1})	30.65	Ascorbic acid reduced molybdo phosphoric blue colour method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965)
Available K (kg ha^{-1})	247.52	Neutral normal ammonium acetate extraction and estimation using flame photometry (Jackson, 1958)

Crop

A local variety of sida hemp commonly called *Vella kurumthotti* in Malayalam was used for the experiment. These are annual or perennial herbs or

shrubs growing 20 centimetres to 2 meters tall. The leaf blades are usually unlobed with serrated edges, but may be divided into lobes. They are borne on petioles and have stipules. Flowers are solitary or arranged in inflorescences of various forms. Each has 5 hairy sepals and 5 petals in shades of yellow. There are many stamens and a style divided into several branches. The fruit is a disc-shaped schizocarp up to 2 centimetres wide which is divided into 5 to 12 sections, each containing a seed.

Cropping history of the experimental site

The experimental area had been under cultivation with kiriyath during the previous year.

3.2 Experimental details

The experiment was laid out in Randomized Block Design with factorial concept (FRBD), with 16 treatment combinations and three replications. The plot size was 3 m x 2 m, with plant spacing of 50 cm x 25 cm. The treatment details are given in Table 2.

Treatments

Factor A : Growing condition

1. Open
2. 50 per cent shade

Factor B: Manuring

1. No manures
2. FYM @ 10 t/ha

Factor C: Weed management

1. Mulching with polythene sheet (30 micron silver top black bottom polythene)
2. Organic mulch @ 5t/ha followed by hand weeding at 3rd month
3. Hand weeding at 1st, 3rd and 5th months
4. No weeding

Same set of experiments was repeated under open and 50% shaded condition

Table 2. Details of treatments

S.No.	Treatment combinations	Treatment details
1	$A_1B_1C_1$	Open + No manures + Mulching with polythene sheet
2	$A_1B_1C_2$	Open + No manures + Organic mulch
3	$A1B_1C_3$	Open + No manures + Hand weeding
4	$A_1B_1C_4$	Open + No manures + No weeding
5	$A_1B_2C_1$	Open + FYM@10 t/ha + Mulching with polythene sheet
6	$A_1B_2C_2$	Open + FYM@10 t/ha + Organic mulch
7	$A_1B_2C_3$	Open + FYM@10 t/ha + Hand weeding
8	$A_1B_2C_4$	Open + FYM @10 t/ha + No weeding
9	A_2B_1C1	50% Shade + No manures + Mulching with polythene sheet
10	$A_2B_1C_2$	50% Shade + No manures + Organic mulch
11	$A_2B_1C_3$	50% Shade + No manures + Hand weeding
12	$A_2B_1C_4$	50% Shade + No manures + No weeding
13	$A_2B_2C_1$	50% Shade + FYM@10 t/ha + Mulching with polythene sheet
14	$A_2B_2C_2$	50% Shade + FYM@10 t/ha + Organic mulch
15	$A_2B_2C_3$	50% Shade + FYM@10 t/ha + Hand weeding
16	$A_2B_2C_4$	50% Shade + FYM @10 t/ha + No weeding

Layout

The layout plan of the experimental field is given in Fig.2.

Land preparation and sowing

The seeds were collected from AICRP on Medicinal & Aromatic Plants, College of Horticulture Vellanikkara. The seeds were pre soaked for 12 hours. A nursery bed of 5 m x1 m was prepared in the agronomic farm and sown the seeds and watered. The experimental field was prepared by thorough ploughing with a disc plough followed

by working with cultivator to brought the field fine tilth. The plots were laid out as per the layout plan (Fig.1. and Plate.1.). Beds were prepared and as per treatments, mulch materials were spread uniformly on respective plots. Circular holes of 5cm diameter made at spacing of 50 cm x 25 cm for planting in polythene mulched plots.

Details of shading

Shade was introduced artificially by providing green colour shade net with 50% permeability of sunlight.

Planting

One month old healthy, uniform sized seedlings were selected from the nursery bed and transplanted in the main field at a spacing of 50 cm between rows and 25 cm between the plants and the plots were irrigated immediately.

Manures and fertilizers

FYM @ 10 t/ha as basal was applied in half of the plots as per treatments.

Weed management

Weed management was done as per the treatments. No weed management measures was done in no weeding plots

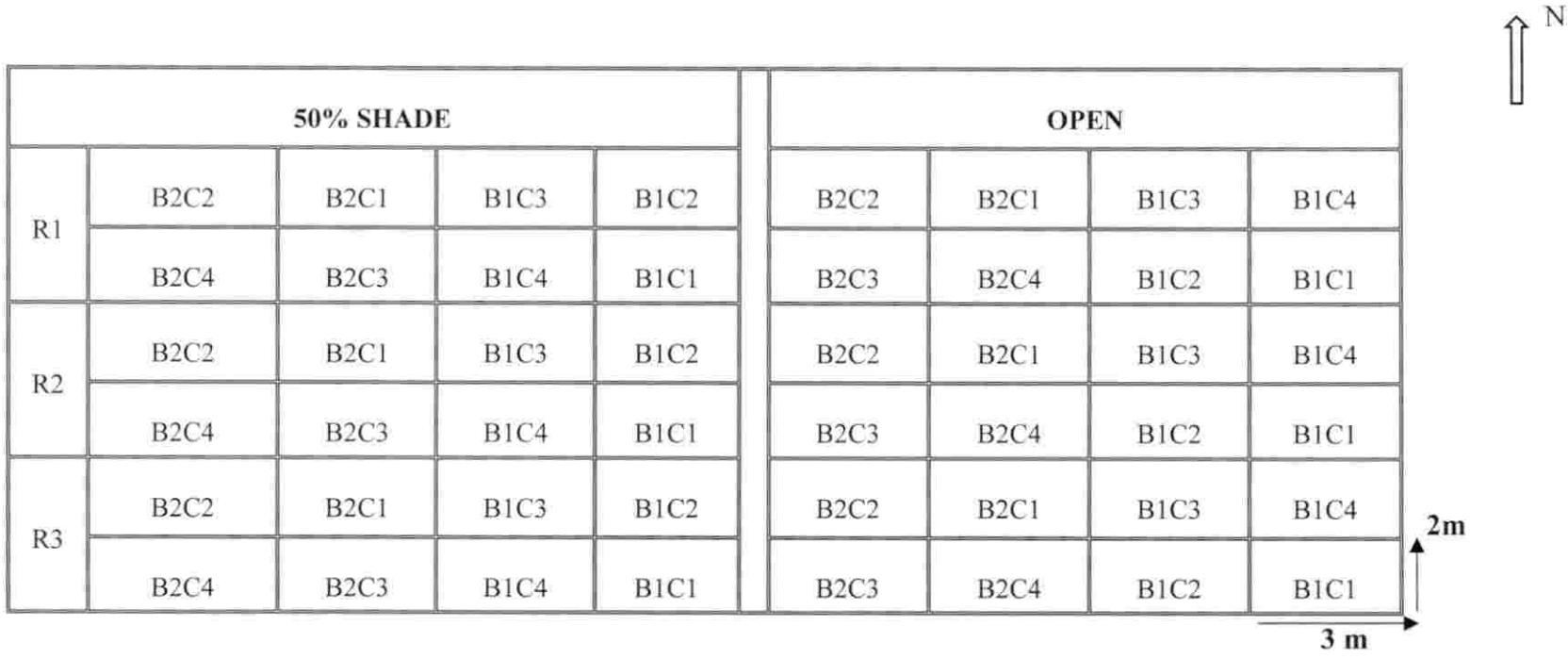
Plant protection

No plant protection measures were taken because no serious disease or pest attack was observed in the experimental area during the cropping period.

Harvesting

The harvesting of crop was done after six months of planting at seed maturation stage by uprooting of whole plants.

Fig 2. Lay out of experimental field



B1 – No manure

B2 – FYM @10 t/ha

C1- Black polythene mulch

C2- Organic mulch

C3- Hand weeding

C4- No weeding

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, air 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.

3.3.2. Microclimate studies

Soil temperature

Soil temperature at 10 cm depth was recorded at weekly intervals using 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

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

Pw = Percentage of soil moisture by weight Wm = Weight of moist sample

Wd = Weight of oven dry sample

Light intensity

Light intensity was recorded at weekly intervals using a lux meter and the mean was worked out.

3.3.3. Soil microflora

Total population of bacteria, fungi, actinomycetes, nitrogen fixers, P solubilizers, fluorescent pseudomonads, and *Trichoderma* sp., root colonization (%) by AM fungi and soil microbial biomass of the soil were analysed at sowing, 4th month after planting and at final harvest. Total population of microflora was enumerated by serial dilution and plate count technique (Wollum,1982). Per cent root colonization of AM fungi was done by the method of Giovanetti and Avio (1985). Microbial biomass carbon was analysed by fumigation and extraction method (Jenkinson and Powlson, 1976). The soil samples were collected from the root zone of the crop and the details of media used for the enumeration are presented in Table 3.

Table 3. Media used for enumeration of microorganisms in soil

Sl No.	Microbes	Medium	Reference
1	Bacteria	Nutrient agar	Agarwal and Hasija (1986)
2	Actinomycetes	Kenknight's agar	
3	Fungi	Martin's Rose Bengal agar	
4	*Trichoderma*sp.	Potato dextrose agar	
5	Nitrogen fixers	Jenson's N free agar	Jensen (1955)
6	Phosphorus solubilizers	Pikovskya's agar	Pikovskya (1948)
7	Fluorescent pseudomonads	King's medium B agar	Gould *et al.* (1985)

3.3.4 Biometric observations

Randomly selected five plants per treatment per replication were tagged and the following observations were recorded:

1. Plant height at 1st , 3rd , 5th months after planting and at harvest
2. Biomass yield at 1st , 3rd, 5th months after planting and harvest
3. Root yield per plant at 1st , 3rd, 5th months after planting and harvest
4. Root shoot ratio at 1st , 3rd, 5th months after planting and harvest

Plant height

Plant height was measured from the ground level to the growing tip of plants at 1st , 3rd, 5th months after planting and at harvest, and averages were expressed in cm.

Fresh weight

Randomly selected plants in each treatment and replication were uprooted at 1st , 3rd, 5th months after planting and at harvest, their fresh weight was recorded and average fresh weight per plant were calculated and expressed in grams. Then fresh weight of shoot and root was recorded separately.

Dry weight

Plants used for fresh weight determination at 1st , 3rd, 5th months after planting 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.

Incidence of pest and diseases

Incidence of pest and disease was monitored and recorded.

3.3.5. Physiological, chemical and biochemical observations

1. Chlorophyll content at 1^{st}, 3^{rd}, 5^{th} months after planting and at harvest
2. Crop growth rate at 1^{st}, 3^{rd}, 5^{th} months after planting and at harvest
3. Relative growth rate at 1^{st}, 3^{rd}, 5^{th} months after planting and at harvest
4. Total alkaloid content of roots at harvest

Chlorophyll content

Chlorophyll content in the leaves was estimated at 1^{st}, 3^{rd}, 5^{th} months after planting and at harvest using Dimethyl sulphoxide (DMSO) Chlorophyll extraction technique of Hiscox and Israelstam (1979).

Crop growth rate (CGR)

Crop growth rate indicates the rate at which the crop is growing *i.e.* whether the crop is 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 $day^{-1}m^{-2}$ (Watson, 1952).

$$\text{CGR (g day}^{-1}\text{m}^{-2}) = \frac{w_2 - w_1}{t_2 - t_1}$$

Where w_1 and w_2 are dry weights of plants at time t_1 and t_2, respectively

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^{-1} day^{-1}:

$$RGR\ (g\ g^{-1}\ day^{-1}) = \frac{\log_e w_2 - \log_e w_1}{t_2 - t_1}$$

Where w_1 and w_2 are dry weights of plants at time t_1 and t_2, respectively

Total alkaloid content

Total alkaloid content was determined using the method of Harborne (1973). 5g of the sample was weighed in to a 250 ml beaker and 200 ml of 10 % acetic acid in ethanol was added and covered and allowed to stand for 4 hours. This was filtered and the extract was concentrated on a water bath to one quarter of the original volume. Concentrated ammonium hydroxide was added drop wise to the extract until the precipitation was complete. The whole solution was allowed to settle and the precipitate was collected and washed with dilute ammonium hydroxide and then filtered. The residue is the alkaloid, which was dried and weighed.

3.3.6. Observation on weeds

1. Weed count at 1st, 3rd, 5th months after planting and at harvest
2. Weed dry weight at 1st, 3rd, 5th months after planting and at harvest
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 1st, 3rd, 5th months and at harvest by placing the quadrant in each plot at random. The count was expressed in no. m^{-2}.

Dry weight of weeds

Weeds collected from the quadrat were uprooted, cleaned, air dried and oven dried at 80 ± 5°C 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).

$$WCE = \frac{\text{Weed dry weight in unweeded plot - Weed dry weight in treated plot}}{\text{Weed dry weight in unweeded plot}} \times 100$$

Weed index

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

$$WI = \frac{A - B}{A} (x100)$$

A = Yield from treatment with lowest weeds

B = Yield from 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 'OPSTAT' (Sheoran *et al.*, 1998). The data on weed biomass, microbial count and root colonization of arbuscular mycorrhizal fungi, which showed wide variation were subjected to square root ($\sqrt{x} + 0.5$), logarithmic and arc sin transformation respectively to make the analysis of variance valid (Gomez and Gomez, 1984).

Plate 1. Field view under open growing condition

Plate 2. Field view under shaded condition

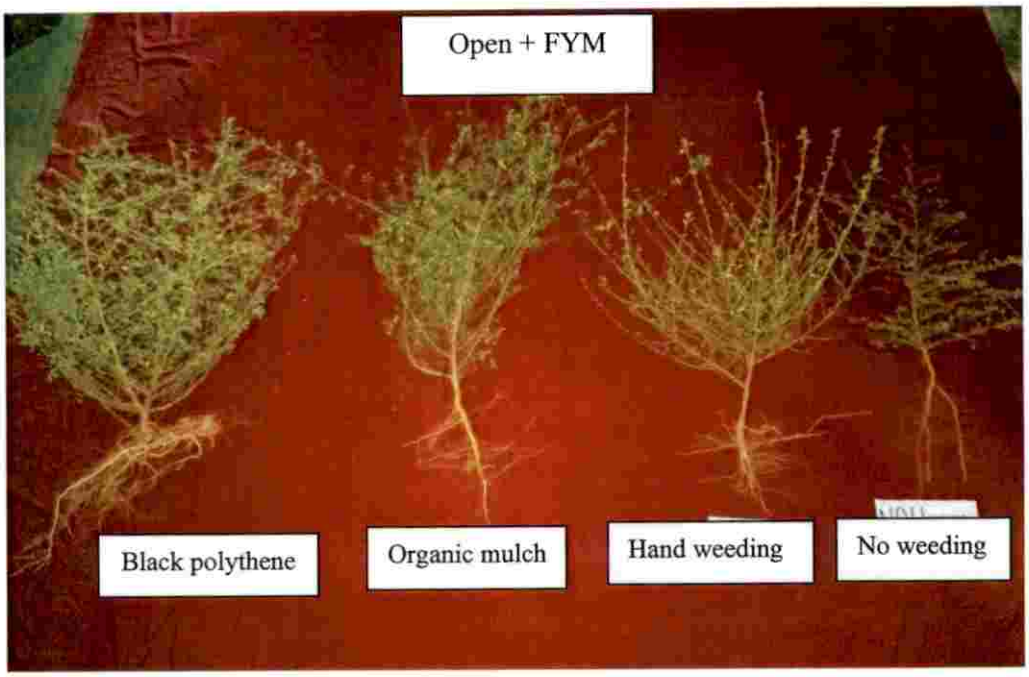


Plate 3. Root growth of Sida hemp under different weed management in open condition

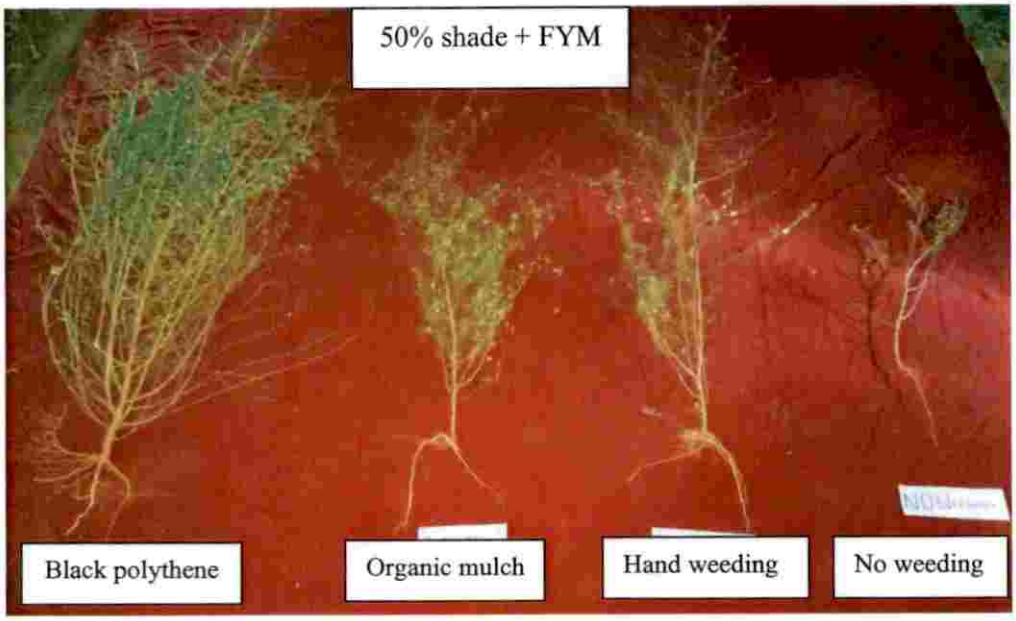


Plate 4. Root growth of Sida hemp under different weed management in shaded condition

Results

4. RESULTS

4.1. Direct effect of treatments

4.1.1. Biometric observations

Plant height at 1, 3, 5 MAP and at harvest

All the three factors such as growing condition, manuring and weed management significantly influenced the plant height of Sida hemp at all growing stages (Table 4). At 1 MAP, the crop planted under 50% shaded condition recorded the tallest plants (12.07 cm), where as plant height in open condition was 9.28cm only. Plants fertilized with FYM @ 10 t/ha showed plant height of 11.22cm. The height recorded by plants grown without addition of manure was 10.13cm. Among different weed management methods, the taller plants were observed in treatment with black polythene mulching (12.49 cm) and it was on par with hand weeding (11.26 cm). The shortest plants were noticed in plots without any weeding (8.78 cm).

At 3 MAP, taller plants (91.69 cm) were observed under shaded condition and the shortest plants were in open condition (67.42 cm). While considering the effect of manuring, plots with FYM @ 10 t/ha recorded the tallest (85.61 cm) plants. Among different weed management methods, black polythene recorded the taller plants (102.75 cm), followed by organic mulching (89.89 cm) and the shortest plants were noted in the no weeding plots (49.81 cm).

Similar trend was noticed with respect to plant height at 5 MAP and at harvest. During 5 MAP and at harvest, the greatest plant heights were observed under shaded condition (100.19 cm at 5MAP and 106.07 cm at harvest), FYM @10 t/ha (95.12 cm at 5MAP and 100.73 cm at harvest) and black polythene mulch (113.04 cm at 5MAP and 118.20 cm at harvest).

Biomass yield per plant at 1, 3, 5 MAP and at harvest

Plants grown in open condition showed significantly higher biomass yield per plant (6.99 g) as compared to plants under shade (6.09 g) at 1 MAP (Table 5). Influence of manuring on biomass yield per plant was not significant at one month after planting. Among different weed management practices, the highest biomass per plant was

recorded in the treatment with black polythene mulch (9.65 g) followed by organic mulch (6.38 g) and hand weeding (5.41 g). The plant with no weeding showed the lowest biomass yield per plant (4.72 g).

During 3 MAP also open condition continued its superiority with respect to biomass yield per plant (24.09 g). However, at this growth stage, manuring significantly influenced the biomass yield per plant. The highest biomass yield per plant was observed in plots fertilized with FYM @ 10 t/ha (22.36 g). Weed management with black polythene sheet recorded the highest biomass yield per plant (33.80 g) and the lowest biomass yield per plant was observed in the plots without weeding (13.17 g).

At 5 MAP, plants under open condition recorded 42.39 g biomass yield per plant. While considering the effect of manuring, the highest biomass yield per plant was seen in plots with FYM @ 10 t/ha (40.45 g). Plants mulched with black polythene sheet recorded the highest biomass yield per plant (71.01g).

Similarly at harvest stage, plants grown in open condition recorded the highest biomass yield of 58.91g. Regarding the effect of manuring, the highest biomass yield per plant was observed in FYM @ 10 t/ha (56.22 g). Among different weed management practices, the highest biomass yield per plant was observed in black polythene mulching (91.17g) and the lowest was in no weeding treatment (24.97 g).

Root yield per plant at 1, 3, 5 MAP and at harvest

The direct influence of different growing conditions, manuring and weed management on root yield per plant at different growth stages are given in Table 6.

Crop planted in open condition recorded the highest root yield per plant (3.51 g) at 1 MAP. Manuring did not exhibited significant influence on root yield per plant at this stage. Among different weed management practices, the highest root yield per plant was noticed in black polythene mulching (3.69 g).

At 3 MAP, the highest root yield per plant was observed in open condition (4.19g) and the FYM @ 10 t/ha (4.19 g). With respect to different weed management

practices, the black polythene mulch recorded the highest root yield of 4.36g and the lowest was in plots without weeding (3.53 g). Same trend was followed at 5 MAP also. At 5MAP, the highest root yield per plant was observed under open condition (5.25g), FYM @ 10 t/ha (5.06 g) and with black polythene mulch (6.57 g).

At harvest, the highest root yield per plant was observed in open condition (6.84 g), FYM @ 10 t/ha (6.53 g) and black polythene mulching (8.30 g).

Total root yield

The influence of growing condition, manuring and weed management on total root yield at harvest is given in Table 6. Highest total root yield was obtained from open condition (882.33 kg ha^{-1}), FYM @ 10 t/ha (825.63 kg ha^{-1}) and black polythene (1111.40 kg ha^{-1}). Among different weed management methods, lowest yield was from plots without weeding (598.53 kg ha^{-1}).

Root:shoot ratio at 1, 3, 5 MAP and at harvest

The data on root:shoot ratio are presented in Table 7. Growing condition exhibited significant effect on root:shoot ratio. At 1 MAP, higher root:shoot ratio was recorded by plants grown in open condition (0.15). However, manuring did not exhibit any significant influence on root:shoot ratio. Plants under different weed management practices showed significant variations with respect to root:shoot ratio at 1 MAP. The highest root:shoot ratio(0.15) was recorded in weed management with black polythene sheet which was on par with organic mulch (0.14) and hand weeding (0.13). The lowest root:shoot ratio was observed in no weeding plots (0.12).

At 3 MAP, growing condition, manuring and weed management caused significant difference in root:shoot ratio. The highest root:shoot ratio was noticed in open condition (0.26). Among manuring, FYM @ 10 t/ha recorded higher root:shoot ratio (0.26). Among different weed management practices, black polythene mulch recorded higher root:shoot ratio (0.29) and was on par with organic mulch (0.26). The lowest root:shoot ratio was recorded by un weeded plots (0.20).

At 5 MAP, open condition continued its superiority with respect to root:shoot ratio (0.35). FYM @ 10 t/ha resulted in the highest root:shoot ratio (0.34) and weed management with black polythene sheet recorded the highest root:shoot ratio (0.38).

Similar trend was noticed in case of root:shoot ratio at harvest also. At harvest, highest root:shoot ratio was noticed in open condition (0.42), FYM @ 10 t/ha (0.42) and black polythene sheet (0.44).

Table 4. Effect of treatments on plant height of Sida hemp at different growth stages

Treatments	Plant height (cm)			
	1 MAP	3 MAP	5 MAP	Harvest
Growing condition				
Open	9.28	67.42	79.41	88.12
50% Shade	12.07	91.69	100.19	106.07
CD (0.05)	1.01	1.18	1.39	1.82
Manuring				
No manure	10.13	73.50	84.48	93.46
FYM @10 t/ha	11.22	85.61	95.12	100.73
CD (0.05)	1.01	1.18	1.39	1.82
Weed management				
Black polythene	12.49	102.75	113.04	118.20
Organic mulch	10.17	89.89	97.38	103.12
Hand weeding	11.26	75.76	87.38	98.13
No weeding	8.78	49.81	61.39	68.93
CD (0.05)	1.43	1.67	1.97	2.58

Table 5. Effect of treatments on biomass yield per plant of Sida hemp at different growth stages

Treatments	Biomass yield per plant (g)			
	1 MAP	3 MAP	5 MAP	Harvest
Growing condition				
Open	6.99	24.09	42.39	58.91
50% Shade	6.09	16.45	29.15	42.20
CD (0.05)	0.80	1.16	1.16	1.37
Manuring				
No manure	6.20	18.17	31.09	44.89
FYM @ 10 t/ha	6.88	22.36	40.45	56.22
CD (0.05)	NS	1.16	1.16	1.37
Weed management				
Black polythene	9.65	33.80	71.01	91.17
Organic mulch	6.38	18.60	30.63	47.69
Hand weeding	5.41	15.50	24.71	38.39
No weeding	4.72	13.17	16.74	24.97
CD (0.05)	1.14	1.64	1.64	1.93

Table 6. Effect of treatments on root yield per plant and total root yield of Sida hemp at different growth stages

Treatments	Root yield per plant (g)				Total root yield (kg ha^{-1})
	1 MAP	3 MAP	5 MAP	Harvest	Harvest
Growing condition					
Open	3.51	4.19	5.25	6.84	882.33
50% Shade	3.39	3.58	4.24	5.39	657.67
CD (0.05)	0.09	0.13	0.59	0.86	20.29
Manuring					
No manure	3.41	3.56	4.42	5.71	714.67
FYM @ 10 t/ha	3.49	4.19	5.06	6.53	825.63
CD (0.05)	NS	0.13	0.59	0.94	18.29
Weed management					
Black polythene	3.69	4.36	6.57	8.30	1111.40
Organic mulch	3.44	4.01	4.80	6.38	711.07
Hand weeding	3.39	3.65	3.83	5.09	659.00
No weeding	3.28	3.53	3.76	4.71	598.53
CD (0.05)	0.127	0.18	0.84	1.21	14.55

Table 7. Effect of treatments on root:shoot ratio of Sida hemp at different growth stages

Treatments	Root:shoot ratio			
	1 MAP	3 MAP	5 MAP	Harvest
Growing condition				
Open	0.15	0.26	0.35	0.42
50% Shade	0.13	0.23	0.29	0.38
CD (0.05)	0.01	0.02	0.01	0.01
Manuring				
No manure	0.13	0.23	0.31	0.38
FYM @ 10 t/ha	0.14	0.26	0.34	0.42
CD (0.05)	NS	0.02	0.01	0.01
Weed management				
Black polythene	0.15	0.29	0.38	0.44
Organic mulch	0.14	0.26	0.34	0.41
Hand weeding	0.13	0.23	0.31	0.40
No weeding	0.12	0.20	0.36	0.33
CD (0.05)	0.02	0.03	0.02	0.02

4.1.2. Microclimate studies

Soil temperature at 10cm depth

Growing condition and weed management had significant effect on soil temperature during most of the period (Table 8). However, manuring did not influence soil temperature. Higher temperature was recorded in open condition throughout the growing period. Among weed management methods, black polythene mulch showed higher soil temperature, and it was par with hand weeding in some weeks. The highest temperature was recorded in 16th week (28.4 °C) in black polythene mulch and lowest temperatures were recorded in 9th and 11th week (24.6 °C) in no weeding plots.

Soil moisture at 10cm depth

Data on effect of different treatments on soil moisture are depicted in Table 9. Growing condition had significant effect on soil moisture except in the 2nd to 13th week with higher moisture level in plots under 50% shade. However, manuring did not influence soil moisture contents at any stage of observation. Weed management practices had significant influence on soil moisture content, with higher moisture level in plots mulched with black polythene.

Light intensity

Data on effect of different treatments on light intensity are presented in Table 10. Growing condition had significant influence on light intensity with the higher light intensity under open condition throughout growth stages. However, manuring and weed management had no significant effect on light intensity. Light intensity was decreased from 2nd week to 9th week and then increased.

Table 8. Effect of treatments on soil temperature (^{0}C) at 10 cm depth

Treatments	Soil temperature (^{0}C)														
	Weeks														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Growing condition															
Open	26.6	27.2	26.8	26.3	26.0	26.3	26.0	25.6	25.2	25.3	25.1	25.3	26.3	26.6	26.8
50% Shade	25.1	26.5	26.2	25.7	25.8	25.8	25.7	25.3	25.2	25.1	25.2	24.9	25.9	26.0	26.2
CD (0.05)	1.0	0.9	0.8	0.8	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.9	0.9
Manuring															
No manure	25.8	26.6	26.5	25.8	25.8	26.0	25.8	25.7	25.9	25.1	25.1	25.1	26.3	26.4	26.8
FYM 10 t/ha	25.9	27.0	26.6	26.1	26.1	25.9	25.8	25.3	25.8	25.3	25.2	25.1	26.2	26.2	26.6
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management															
Black polythene	27.2	28.2	27.7	27.2	27.0	26.9	26.6	26.3	26.1	25.9	25.9	25.6	27.6	27.6	28.1
Organic mulch	25.4	26.6	26.2	25.4	25.5	25.6	26.0	25.5	24.8	24.9	24.8	24.8	25.5	25.5	26.1
Hand weeding	26.1	26.3	26.2	26.1	25.9	26.2	25.6	25.7	25.4	25.4	25.4	25.3	26.4	26.3	26.2
No weeding	25.4	26.2	25.9	25.4	25.2	25.1	25.1	24.9	24.6	24.7	24.6	24.7	25.4	25.7	26.4
CD (0.05)	1.1	1.3	1.2	1.1	1.1	NS	NS	NS	NS	NS	0.4	0.6	1.3	1.4	0.9

Treatments	Soil temperature (^{0}C)									
	Weeks									
	16	17	18	19	20	21	22	23	24	25
Growing condition										
Open	27.8	26.3	26.1	26.7	26.8	26.6	26.6	26.6	26.7	26.8
50% Shade	27.1	26.8	26.7	25.7	26.1	26.8	25.1	26.0	26.1	26.3
CD (0.05)	0.9	0.8	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.8
Manuring										
No manure	26.8	26.5	26.3	25.9	26.3	25.8	25.8	26.2	26.3	26.6
FYM 10 t/ha	27.2	26.6	26.5	26.6	26.5	25.9	25.9	26.4	26.5	26.5
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management										
Black polythene	28.4	27.9	27.8	27.7	27.8	26.9	26.9	27.7	27.8	27.9
Organic mulch	26.3	25.5	25.5	24.9	25.5	25.5	25.3	25.5	25.5	25.5
Hand weeding	26.7	26.3	26.4	26.9	26.4	25.7	26.1	26.3	26.4	26.3
No weeding	26.4	26.5	25.9	25.4	26.3	25.2	25.0	25.7	25.9	26.5
CD (0.05)	1.1	1.2	1.4	1.3	1.3	1.5	1.5	1.4	1.4	1.2

Table 9. Effect of treatments on soil moisture (%) at 10 cm depth

Treatments	Soil moisture (%)														
	Weeks														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Growing condition															
Open	14.3	31.9	33.5	31.3	33.5	33.5	32.5	31.9	33.5	33.5	31.3	33.5	33.5	14.3	13.5
50% Shade	15.7	32.3	33.6	32.3	33.6	33.6	32.9	32.6	33.6	33.6	32.3	33.6	33.6	15.7	14.9
CD (0.05)	1.1	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.1	0.9
Manuring															
No manure	14.4	32.2	33.8	32.2	33.8	33.8	32.8	32.2	33.7	33.3	32.2	33.8	33.8	15.1	14.4
FYM 10 t/ha	14.7	32.1	33.3	32.1	33.3	33.3	32.6	32.3	33.3	33.8	32.1	33.3	33.3	15.0	14.9
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management															
Black polythene	15.3	32.7	33.4	32.7	34.1	34.4	32.8	32.8	33.5	34.0	32.7	34.1	34.4	15.6	14.9
Organic mulch	14.5	32.3	33.2	31.8	33.2	33.2	32.3	31.6	33.2	33.5	31.8	33.2	33.2	14.2	13.7
Hand weeding	13.8	32.1	33.1	31.8	33.1	33.2	32.2	31.6	33.2	33.4	31.8	33.1	33.2	13.5	12.9
No weeding	14.5	32.3	33.3	32.2	33.5	33.9	32.4	31.7	33.3	33.6	32.2	33.5	33.9	15.3	14.0
CD (0.05)	1.8	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.5	1.5

Treatments	Soil moisture (%)									
	Weeks									
	16	17	18	19	20	21	22	23	24	25
Growing condition										
Open	13.5	13.9	13.7	14.3	13.5	13.2	13.5	13.4	13.2	13.9
50% Shade	15.8	15.8	15.4	15.7	14.9	14.3	15.8	14.4	14.6	15.8
CD (0.05)	1.1	1.1	1.1	1.1	0.9	0.8	1.1	0.9	1.0	1.1
Manuring										
No manure	14.4	14.9	14.7	15.1	14.4	13.8	14.2	13.7	13.8	13.8
FYM 10 t/ha	14.9	14.8	14.3	15.0	14.9	13.8	14.1	14.2	14.0	14.4
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management										
Black polythene	15.6	14.9	15.4	15.6	14.9	14.7	15.6	14.7	14.9	15.6
Organic mulch	14.2	13.7	14.5	14.2	13.7	13.9	14.2	13.9	13.7	14.2
Hand weeding	13.5	12.9	13.2	13.5	12.9	12.9	13.5	13.3	12.9	13.5
No weeding	15.3	14.0	15.0	15.3	14.0	13.4	15.3	14.6	14.0	15.3
CD (0.05)	1.5	1.5	1.5	1.5	1.5	1.1	1.5	1.1	1.5	1.5

Table 10. Effects of treatments on light intensity

Treatments	Light intensity (lux)														
	Weeks														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Growing condition															
Open	19507.1	19499.6	19486.3	19460.9	14382.4	11297.7	10275.6	9273.5	8775.6	10329.8	11275.6	14507.1	19499.6	19583.8	19583.7
50% Shade	4209.0	4203.9	4187.8	4167.8	3085.5	2995.4	1961.7	960.1	461.7	2019.2	2961.7	3709.0	4203.8	4260.6	4260.5
CD (0.05)	21.90	22.60	15.90	4.40	4.50	4.60	26.00	25.90	26.00	26.30	26.00	21.90	22.50	11.90	11.90
Manuring															
No manure	11857.9	11849.9	11841.1	11830.9	8750.6	7157.7	6134.3	5130.9	4634.3	6191.1	7134.3	9107.9	11849.9	11939.3	11939.2
FYM 10 t/ha	11858.2	11853.4	11832.9	11797.9	8717.3	7135.3	6103.0	5102.8	4603.0	6157.9	7103.0	9108.2	11853.4	11905.1	11905.0
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management															
Black polythene	11844.1	11834.9	11813.2	11793.7	8708.2	7120.9	6102.9	5101.4	4602.9	6158.6	7102.9	9094.1	11834.9	11933.9	11933.9
Organic mulch	11810.7	11805.0	11793.9	11774.7	8695.5	7108.6	6085.5	5084.2	4585.5	6141.4	7085.5	9060.7	11805.0	11916.7	11916.7
Hand weeding	11885.9	11881.1	11865.9	11835.7	8761.1	7173.8	6149.0	5148.6	4649.5	6205.5	7149.0	9135.9	11881.1	11963.7	11963.7
No weeding	11891.5	11885.9	11875.2	11853.6	8771.1	7182.8	6137.3	5133.1	4637.3	6192.6	7137.3	9141.5	11885.8	11874.2	11874.2
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Treatments	Light intensity (lux)									
	Weeks									
	16	17	18	19	20	21	22	23	24	25
Growing condition										
Open	19529.6	19595.9	19553.3	19595.9	19553.3	19583.7	19595.9	19641.2	19578.2	19596.3
50% Shade	4219.8	4282.1	4252.5	4282.0	4253.3	4260.5	4282.1	4345.2	4276.2	4282.1
CD (0.05)	27.60	12.90	2.20	12.80	2.20	11.90	12.80	4.10	6.30	12.90
Manuring										
No manure	11891.8	11952.9	11919.2	11953.1	11919.2	11939.3	11952.9	12003.1	11941.2	11953.1
FYM 10 t/ha	11857.6	11925.1	11886.6	11925.0	11887.6	11905.0	11925.1	11988.2	11911.4	11925.2
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Weed management										
Black polythene	11861.9	11949.6	11923.9	11949.6	11923.9	11933.9	11949.6	12001.2	11946.1	11949.2
Organic mulch	11844.9	11934.3	11905.6	11934.2	11905.5	11917.1	11934.3	11989.3	11927.2	11934.6
Hand weeding	11903.4	11980.8	11940.7	11981.0	11940.6	11963.7	11980.3	12035.2	11964.2	11981.2
No weeding	11888.5	11891.4	11841.4	11891.1	11841.4	11874.2	11891.4	11951.2	11871.2	11891.2
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.3. Soil analysis

Soil pH

Data on direct effect of treatments on soil pH are furnished in Table 11. The pre experimental data showed that the soil was acidic in nature with a mean pH of 4.62. After the experiment there was a decreasing trend in soil pH. However, the differences in soil pH among the treatments were non significant.

Organic carbon

Growing condition, manuring and weed management did not show any significant effect on organic carbon content of soil after the experiment (Table 11).

Available nitrogen

The direct effect of growing condition on the available N was non significant, where as manuring and weed management showed significant effect (Table 11). Plots with FYM @ 10 t/ha (132.82 kg/ha) and organic mulching (157.29 kg/ha) showed significantly higher available N after the harvest of crop.

Available phosphorus

The data pertaining to the effect of treatments on available soil phosphorus are given in Table 11. Growing condition, manuring and weed management significantly influenced the available P content. Significantly higher value for available P were obtained under 50% shaded condition (31.71 kg/ha), FYM @ 10 t/ha (31.07 kg/ha) and Organic mulching (35.72kg/ha).

Available potassium

The data on available K are given in Table 11. Significantly higher available K was observed under open condition (220.17kg/ha), FYM @ 10 t/ha (253.46 kg/ha) and plots with organic mulch (292.89 kg/ha).

Table 11. Effects of treatments on soil pH, organic carbon, available N, P and Kafter harvest of Sida hemp

Treatments	pH	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Growing condition					
Open	4.54	1.02	127.72	27.29	220.17
50% Shade	4.53	1.07	116.74	31.71	216.35
CD (0.05)	NS	NS	NS	2.05	1.07
Manuring					
No manure	4.57	1.02	111.64	27.92	183.06
FYM @ 10 t/ha	4.50	1.08	132.82	31.07	253.46
CD (0.05)	NS	NS	12.49	2.05	1.07
Weed management					
Black polythene	4.48	1.05	121.66	25.39	174.01
Organic mulch	4.55	1.11	157.29	35.72	292.89
Hand weeding	4.51	0.96	117.19	26.52	131.60
No weeding	4.60	1.06	92.77	30.36	274.53
CD (0.05)	NS	NS	17.67	2.89	1.52
Pre experimental	4.62	1.07	112.90	30.65	247.52

4.1.4. Physiological, chemical and biochemical parameters

Chlorophyll content at 1, 3, 5 MAP and at harvest

The data on the effect of treatments on the chlorophyll and total alkaloid contents are presented in Table 12. At 1 MAP, there was no significant difference in total chlorophyll content due to growing condition, manuring and weed management.

At 3 MAP, higher content of total chlorophyll was observed in plants under shaded condition (11.29 mg g^{-1}) and FYM @ 10 t/ha (10.50 mg g^{-1}). Weed management methods did not exhibit any significant effect on total chlorophyll content at any stage. Similar trend was followed at 5 MAP and at harvest also, with the highest chlorophyll contents in plants under shade (12.01 mg g^{-1}at 5 MAP and 12.28 mg g^{-1}at harvest) and FYM @ 10 t/ha (11.29 mg g^{-1} at 5 MAP and 11.45 mg g^{-1} at harvest).

Total alkaloid (%) at harvest

Growing condition significantly influenced the total alkaloid content of Sida hemp at harvest (Table 12). Significantly higher total alkaloid content was observed in open condition (3.13%) where as in shaded condition it was only 2.80%. However, manuring and weed management did not exhibit any significant influence on total alkaloid content.

Crop growth rate (CGR)

Crop growth rate at 0-1 MAP was significantly affected by growing condition (Table 13). The highest CGR was noticed under open condition (6.86 $gm^{-2}day^{-1}$). Manuring did not show any significant effect on CGR at 0-1 MAP. Among weed management practices, black polythene mulch recorded the highest CGR (9.24 $gm^{-2}day^{-1}$).

At 1-3 MAP also, the highest CGR was noticed under open condition (8.62 $gm^{-2}day^{-1}$). Manuring had significant effect on CGR at 1-3 MAP. The highest CGR was recorded by plants which received FYM @ 10 t/ha (7.81 $gm^{-2}day^{-1}$). Among different weed management methods, mulching with black polythene

recorded the highest CGR of 12.28gm^{-2}day^{-1} and the lowest CGR (4.22gm^{-2}day^{-1}) was recorded by plants without weeding.

Similar trend was observed at 5MAP and at harvest. At 3-5 MAP, the highest CGR was recorded in open condition (9.16 gm^{-2}day^{-1}), FYM @ 10 t/ha (9.05gm^{-2}day^{-1}) and black polythene mulching (18.61gm^{-2}day^{-1}). At 5 MAP to harvest the highest CGR was observed in open condition (16.51gm^{-2}day^{-1}), FYM @ 10 t/ha (15.77gm^{-2}day^{-1}) and black polythene mulching (20.15gm^{-2}day^{-1}).

Relative growth rate (RGR)

Data on effect of different treatments on RGR are depicted in Table 13. RGR was found the highest in (0.81 gg^{-1}day^{-1}) open condition. RGR at 0-1 MAP was unaffected by manuring. Among weed management methods, black polythene mulching recorded the highest RGR (0.95 gg^{-1}day^{-1}) and the lowest was in plots with no weeding (0.67gg^{-1}day^{-1}). Similar results were observed at 1-3 MAP and 3-5 MAP. At 1-3 MAP, the highest RGR was recorded in open condition (0.58gg^{-1}day^{-1}), FYM @ 10 t/ha (0.55gg^{-1}day^{-1}) and black polythene mulch (0.67gg^{-1}day^{-1}).At 3-5 MAP, the highest RGR was recorded in open condition (0.55gg^{-1}day^{-1}), FYM @ 10 t/ha (0.54gg^{-1}day^{-1}) and black polythene mulch (0.77gg^{-1}day^{-1}).

At 5 MAP to harvest also, the higher RGR was recorded by open condition (1.19gg^{-1}day^{-1}) and FYM @ 10 t/ha (1.16 gg^{-1}day^{-1}). Among weed management methods, significantly higher RGR was recorded by black polythene (1.30 gg^{-1}day^{-1}) and was on par with organic mulching (1.22gg^{-1}day^{-1}) and the lowest RGR was recorded by plants with no weeding (0.84gg^{-1}day^{-1}).

Table 12. Effect of treatments on total chlorophyll at different growth stages and total alkaloid (%) content in roots of Sida hemp

Treatments	Total chlorophyll (mg g^{-1})				Total alkaloid content in roots (%)
	1 MAP	3 MAP	5 MAP	Harvest	Harvest
Growing condition					
Open	8.36	8.64	9.30	9.42	3.13
50% Shade	9.39	11.29	12.01	12.28	2.80
CD (0.05)	NS	0.96	0.99	1.12	0.20
Manuring					
No manure	8.47	9.43	10.12	10.24	2.92
FYM 10 t/ha	9.28	10.50	11.29	11.45	3.02
CD (0.05)	NS	0.96	0.99	1.12	NS
Weed management					
Black polythene	9.78	10.87	11.63	11.68	3.02
Organic mulch	8.75	9.83	10.59	10.86	2.98
Hand weeding	9.11	10.04	10.42	10.55	2.96
No weeding	8.85	9.13	10.17	10.30	2.90
CD (0.05)	NS	NS	NS	NS	NS

Table 13. Effect of treatments on CGR (g $m^{-2}day^{-1}$) and RGR (g $g^{-1}day^{-1}$) of Sida hemp at different growth stages

Treatments	0- 1 MAP		1 MAP-3 MAP		3 MAP-5 MAP		5 MAP-Harvest	
	CGR	RGR	CGR	RGR	CGR	RGR	CGR	RGR
Growing condition								
Open	6.86	0.81	8.62	0.58	9.16	0.55	16.51	1.19
50% Shade	6.02	0.76	5.22	0.49	6.35	0.47	13.05	1.05
CD (0.05)	0.80	0.05	0.71	0.03	0.69	0.03	1.87	0.07
Manuring								
No manure	6.12	0.77	6.03	0.51	6.46	0.47	13.79	1.03
FYM @ 10 t/ha	6.75	0.80	7.81	0.55	9.05	0.54	15.77	1.16
CD (0.05)	NS	NS	0.71	0.03	0.69	0.03	1.87	0.07
Weed management								
Black polythene	9.24	0.95	12.28	0.67	18.61	0.77	20.15	1.30
Organic mulch	6.38	0.79	6.11	0.52	6.02	0.53	17.07	1.22
Hand weeding	5.41	0.73	5.05	0.56	4.61	0.45	13.67	1.13
No weeding	4.72	0.67	4.22	0.49	1.79	0.26	8.23	0.84
CD (0.05)	1.14	0.07	1.00	0.05	0.97	0.05	2.64	0.10

4.1.5. Soil microflora

Total population of bacteria, actinomycetes and fungi at sowing, 4 MAP and at harvest

Data on the population of soil microflora including bacteria, actinomycetes and fungi are presented in Table 14. Compared to initial population, counts of bacteria, actinomycetes and fungi total count was increased towards harvesting stage of crop. The initial populations of bacteria, actinomycetes and fungi were $14x10^6$cfu/g, $63.33x10^4$ cfu/g and $17x10^4$ cfu/g respectively.

At 4 MAP and at harvest, the highest bacterial population was noticed under open condition ($20.38x10^6$cfu g^{-1} and $16.92 x10^6$cfu g^{-1} respectively), FYM @ 10 t/ha ($19.75x10^6$ cfu g^{-1} and $16.46 x10^6$ cfu g^{-1} respectively) and organic mulch ($21.92x10^6$cfu g^{-1} and $19.29x10^6$cfu g^{-1} respectively).

Total population of actinomycetes were the highest under open condition at 4 MAP and at harvest ($68.33x10^4$ cfu g^{-1} and $72.75x10^4$ cfu g^{-1} respectively). FYM @ 10 t/ha recorded the highest population of actinomycetes both at 4 MAP and harvest ($65.50x10^4$ cfu g^{-1} and $68.75x10^4$ cfu g^{-1} respectively). Among weed management practices the highest population of actinomycetes were recorded in plots with organic mulch at 4 MAP and at harvest ($66.92x10^4$ cfu g^{-1} and $72.75x10^4$ cfu g^{-1} respectively).

The highest population of fungi were noticed under open condition during 4 MAP and harvest ($15.33x10^4$ cfu g^{-1} and $18.17x10^4$ cfu g^{-1}). FYM @ 10 t/ha recorded the highest fungi population at 4 MAP and harvest ($13.54x10^4$ cfu g^{-1} and $16.21x10^4$ cfu g^{-1}). Among weed management, highest fungi population were noticed in no weeding plot in both 4 MAP and harvest ($15.08x10^4$ cfu g^{-1} and $17.75x10^4$ cfu g^{-1} respectively).

Root colonization (%) of arbuscular mycorrhizal fungi

Data on the effect of treatments on per cent root colonization of arbuscular mycorrhizal fungi and soil microbial biomass carbon presented in Table 15. At 1 MAP, the highest per cent root colonization of AMF was recorded under open condition (6.25%). No root colonization was observed under shade. Among manuring, the highest colonization was observed in plots with FYM @ 10 t/ha (5%).

Among weed management methods, plots without weeding recorded the highest colonization of AMF (5.83%), whereas hand weeding plots did not show any colonization at 1 MAP.

At 4 MAP, the highest root colonization was observed in open condition (8.75%), FYM @ 10 t/ha (6.25%) and no weeding plots (7.50%). At harvest, also the same trend was followed. The highest root colonization was observed under open condition, plots with FYM @ 10 t/ha and no weeding plots (11.25%, 7.50% and 9.17% respectively).

Soil microbial biomass carbon

Soil microbial biomass carbon content increased from sowing to harvest (Table 15). Soil microbial biomass carbon estimated from initial soil was 95.33µg/g. At 4 MAP, the highest soil microbial biomass carbon was recorded in open condition (265.25µg g^{-1}), plots with FYM @ 10 t/ha (245.29 µg g^{-1}) and no weeding plots (309.08 µg g^{-1}). At harvest, among growing condition, the highest soil microbial biomass carbon was estimated from open condition (287.99 µg g^{-1}). FYM @ 10 t/ha plots recorded the highest soil microbial biomass carbon (274.94 µg g^{-1}). Among different weed management methods, plots with no weeding recorded higher soil microbial biomass carbon of 328.16 µg g^{-1} followed by organic mulch (290.47 µg g^{-1}) and the lowest was from hand weeding plot (161.19 µg g^{-1}).

Table 14. Effect of treatments on total population of bacteria, actinomycetes and fungi in the rhizosphere of Sida hemp at different growth stages

Treatments	Total population of bacteria ($x10^6$ cfu g^{-1})		Total population of actinomycetes ($x10^4$ cfu g^{-1})		Total population of fungi ($x10^4$ cfu g^{-1})	
	4 MAP	Harvest	4 MAP	Harvest	4 MAP	Harvest
Growing condition						
Open	1.29 (20.38)	1.22 (16.92)	1.82 (68.33)	1.85 (72.75)	1.16 (15.33)	1.25 (18.17)
50% Shade	1.22 (16.83)	1.17 (14.88)	1.70 (51.00)	1.74 (55.46)	0.99 (10.96)	1.09 (12.83)
CD (0.05)	0.05	0.03	0.04	0.04	0.09	0.05
Manuring						
No manure	1.22 (16.46)	1.16 (14.89)	1.72 (53.83)	1.77 (59.46)	0.89 (12.75)	1.12 (14.79)
FYM @ 10 t/ha	1.28 (19.75)	1.21 (16.46)	1.80 (65.50)	1.83 (68.75)	1.09 (13.54)	1.19 (16.21)
CD (0.05)	0.05	0.03	0.04	0.04	0.09	0.05
Weed management						
Black polythene	1.22 (17.08)	1.17 (14.83)	1.76 (59.42)	1.79 (62.33)	0.87 (12.00)	1.14 (14.33)
Organic mulch	1.33 (21.92)	1.27 (19.29)	1.82 (66.92)	1.85 (72.75)	1.02 (13.08)	1.21 (16.92)
Hand weeding	1.20 (16.17)	1.17 (14.83)	1.68 (49.58)	1.73 (54.50)	0.83 (11.42)	1.10 (13.00)
No weeding	1.25 (19.25)	1.22 (16.78)	1.79 (62.75)	1.82 (66.83)	1.17 (15.08)	1.24 (17.75)
CD (0.05)	0.07	0.04	0.05	0.05	0.14	0.07
At sowing	14.00		63.33		17.00	

** Logarithmic transformed values, Original values are in parentheses

Table 15. Effect of treatments on root colonization by arbuscular myccorrhizal fungi and soil microbial biomass carbon in the rhizosphere of Sida hemp at different growth stages

Treatments	Root colonization by arbuscular mycorrhizal fungi (%)			Soil microbial biomass carbon ($\mu g\ g^{-1}$) of soil	
	1 MAP	4 MAP	Harvest	4 MAP	Harvest
Growing condition					
Open	3.19 (6.25)	4.73 (8.75)	5.47 (11.25)	265.25	287.99
50% Shade	0.22 (0.00)	0.22 (0.00)	0.22 (0.00)	166.92	205.90
CD (0.05)	1.74	2.49	3.21	3.66	3.42
Manuring					
No manure	0.98 (1.25)	1.31 (2.50)	1.54 (3.75)	186.88	218.94
FYM @ 10 t/ha	2.34 (5.00)	3.19 (6.25)	4.03 (7.50)	245.29	274.94
CD (0.05)	1.74	2.49	3.21	3.66	3.42
Weed management					
Black polythene	1.75 (2.50)	1.64 (3.33)	2.04 (4.17)	181.50	207.93
Organic mulch	2.04 (4.17)	2.84 (5.83)	4.03 (7.50)	239.00	290.47
Hand weeding	0.22 (0.00)	0.25 (0.83)	0.62 (1.67)	134.75	161.19
No weeding	2.84 (5.83)	4.03 (7.50)	4.97 (9.17)	309.08	328.16
CD (0.05)	2.45	3.51	4.54	5.04	4.83
At sowing	-			95.33	

**Arc sin transformed values, Original values are in parentheses

4.1.6 Observation on weeds

Weed count at 1, 3, 5 MAP and at harvest

Data on the effect of treatments on weed count at different growth stages presented in Table 16. At 1 MAP, the highest density of grass weeds were observed in open condition (18.25 no.m^{-2}), FYM @ 10 t/ha (12.87 no.m^{-2}) and no weeding (23.92 no.m^{-2}). At 3 MAP, the highest weed density was recorded in open condition (27.42 no.m^{-2}) FYM @ 10 t/ha (22.21 no.m^{-2}) and no weeding (31.92 no.m^{-2}). At 5 MAP and at harvest also higher weed intensity was noticed in open condition (34.83 no.m^{-2}& 26.42 no.m^{-2}), FYM @ 10 t/ha (25.83 no.$m^{-2}$and 23.88 no.m^{-2}) and no weeding (41.92 no.m^{-2} and 42.25 no.m^{-2}). Same trend was followed in case of broad leaved weeds also. Throughout the growing periods, highest broad leaved weed counts were observed in open (18.79 no.m^{-2}, 40.13 no.m^{-2}, 47.71 no.m^{-2} and 31.71 no.m^{-2} respectively), FYM @ 10 t/ha (17.92 no.m^{-2}, 25.04 no.m^{-2}, 41.71 no.m^{-2} and 30.42 no.m^{-2} respectively) and no weeding (26.42 no.m^{-2}, 42.67 no.m^{-2}, 52.67 no.m^{-2} and 60.33no.m^{-2} respectively). At 1,3,5 MAP and at harvest the highest total weed count was observed in open (37.04 no.m^{-2}, 67.54 no.m^{-2}, 82.45 no.m^{-2} and 58.13 no.m^{-2} respectively), FYM @ 10 t/ha (33.50 no.m^{-2}, 56.46 no.m^{-2}, 71.83 no.m^{-2} and 54.29 no.m^{-2} respectively) and no weeding plots (50.33 no.m^{-2}, 74.58 no.m^{-2}, 94.58 no.m^{-2} and 102.58 no.m^{-2} respectively).

Weed dry weight at 1,3,5 MAP and at harvest

Effect of treatments on weed dry weight at different growth stages are furnished in Table 17. Dry weight of grasses were non significant with respect to growing condition at all growth stages. At 1 MAP, FYM @ 10 t/ha applied plots and no weeding plots recorded the highest weed dry weights (33.18 $gm^{-2}$and 49.78 gm^{-2}). At 3, 5 MAP and at harvest, the highest weed dry weight was observed in FYM @ 10 t/ha (42.39 gm^{-2}, 36.70 gm^{-2} and 30.10 gm^{-2}respectively) and no weeding plots (61.54 gm^{-2}, 54.63 gm^{-2} and 48.53 gm^{-2} respectively). Dry weight of broad leaved weeds did not show any significant variation with respect to growing condition. At all growth stages, FYM @ 10 t/ha (36.96 gm^{-2}, 46.33 gm^{-2}, 40.29 gm^{-2} and 35.75 gm^{-2}) and no weeding plots (52.46 gm^{-2}, 64.73 gm^{-2}, 58.26 gm^{-2} and 52.77 gm^{-2}) recorded weed dry weight. Total weed dry weight also followed the same trend. Effect of

growing condition on total weed dry weight was non significant. The highest weed dry weight was observed in FYM @ 10 t/ha (70.14 gm^{-2}, 88.71 gm^{-2}, 76.33 gm^{-2} and 65.73 gm^{-2}) and unweeded plots (102.24 gm^{-2}, 126.27 gm^{-2}, 112.89 $gm^{-2}$and 100.80 gm^{-2} respectively).

4.1.7 Correlation studies

Data on correlation between biometric characters and yield at harvest are depicted in Table 18. Plant height was negatively correlated with root:shoot ratio and yield(-0.474 and -0.312) where as, biomass yield per plant was strongly positively correlated with root:shoot ratio and yield (0.767 and 0.971). Root:shoot ratio was positively correlated with yield (0.757).

Correlation between microclimatic factors, yield and total alkaloid at vegetative and harvest stages are depicted in Table 19. At vegetative stage, soil temperature was negatively correlated with soil moisture (-0.391) and positively correlated with yield and total alkaloid (0.373 and 0.311 respectively). Soil moisture was negatively correlated with light intensity(-0.628) and light intensity was positively correlated with yield and total alkaloid (0.449 and 0.473 respectively). Yield and total alkaloid were positively correlated (0.337).

At harvest, soil temperature was negatively correlated with soil moisture (-0.357) and positively correlated with yield (0.596). Soil moisture was negatively correlated with soil temperature, light intensity and total alkaloid (-0.357, 0.533 and -0.332 respectively). Light intensity was positively correlated with yield and total alkaloid (0.452 and 0.473). Yield was positively correlated with total alkaloid (0.337).

Correlation between biometric characters and microclimatic factors at harvest was furnished in Table 20. Soil temperature was positively correlated with biomass yield per plant and root:shoot ratio (0.536 and 0.384 respectively). Soil moisture was negatively correlated with light intensity (-0.680) and positively correlated with plant height (0.416). Light intensity was negatively correlated with plant height and positively correlated with root:shoot ratio (-0.406 and 0.396 respectively).

Table 16. Effect of treatments on weed count at different growth stages

Treatments	Weed count(no.m^{-2})											
	Grasses				Broad leaved				Total weeds			
	1 MAP	3 MAP	5 MAP	Harvest	1 MAP	3 MAP	5 MAP	Harvest	1 MAP	3 MAP	5 MAP	Harvest
Growing condition												
Open	3.97 (18.25)	4.88 (27.42)	5.45 (34.83)	4.73 (26.42)	4.14 (18.79)	5.81 (40.13)	6.34 (47.71)	5.05 (31.71)	7.49 (37.04)	7.49 (67.54)	8.26 (82.45)	6.83 (58.13)
50% Shade	3.21 (10.21)	3.47 (13.17)	4.35 (21.13)	3.93 (16.83)	3.65 (14.00)	4.19 (19.17)	4.84 (26.54)	4.52 (23.08)	5.33 (24.21)	5.33 (32.33)	6.41 (47.67)	5.89 (39.92)
CD (0.05)	0.48	0.23	0.22	0.43	0.25	0.16	0.18	0.22	0.26	0.26	0.27	0.35
Manuring												
No manure	3.43 (11.08)	4.06 (18.38)	4.76 (18.92)	4.14 (19.38)	3.74 (14.88)	4.69 (24.21)	5.31 (32.54)	4.58 (24.38)	6.10 (27.75)	6.10 (43.42)	7.03 (58.38)	6.08 (43.75)
FYM @10 t/ha	3.75 (12.87)	4.29 (22.21)	5.04 (25.83)	4.52 (23.88)	4.06 (17.92)	5.31 (25.04)	5.87 (41.71)	4.99 (30.42)	6.72 (33.50)	6.72 (56.46)	7.65 (71.83)	6.65 (54.29)
CD (0.05)	0.10	0.11	0.22	0.15	0.25	0.16	0.18	0.22	0.26	0.26	0.27	0.35
Weed management												
Black polythene	0.92 (1.33)	0.88 (1.25)	0.76 (1.17)	0.95 (1.42)	1.03 (1.58)	0.92 (1.33)	0.88 (1.25)	0.92 (1.33)	1.88 (2.92)	1.88 (2.58)	1.84 (2.42)	1.93 (2.75)
Organic mulch	3.86 (14.17)	4.67 (21.83)	5.67 (31.83)	4.52 (19.75)	4.01 (15.17)	6.05 (36.67)	6.84 (46.67)	4.58 (20.17)	7.58 (29.33)	7.58 (58.50)	8.83 (78.50)	6.37 (39.92)
Hand weeding	4.22 (17.50)	4.99 (26.17)	6.05 (37.00)	4.82 (23.08)	4.81 (22.42)	6.07 (37.92)	6.87 (47.92)	5.34 (27.75)	7.81 (39.92)	7.81 (64.08)	9.10 (84.92)	7.16 (50.83)
No weeding	4.77 (23.92)	5.54 (31.92)	6.43 (41.92)	6.42 (42.25)	5.18 (26.42)	6.37 (42.67)	7.16 (52.67)	7.71 (60.33)	8.38 (50.33)	8.38 (74.58)	9.57 (94.58)	10.00 (102.58)
CD (0.05)	0.68	0.33	0.31	0.61	0.35	0.22	0.25	0.31	0.37	0.37	0.38	0.49

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

Table 17. Effect of treatments on weed dry weight at different growth stages

Treatments	Weed dry weight (g m^{-2})											
	Grasses				Broad leaved				Total weeds			
	1 MAP	3 MAP	5 MAP	Harvest	1 MAP	3 MAP	5 MAP	Harvest	1 MAP	3 MAP	5 MAP	Harvest
Growing condition												
Open	5.09 (30.49)	5.87 (39.81)	5.34 (33.94)	5.09 (27.6)	5.54 (33.63)	6.35 (43.58)	5.07 (37.18)	5.29 (32.39)	7.54 (64.12)	8.68 (83.39)	7.75 (70.76)	7.09 (59.77)
50% Shade	4.82 (28.28)	5.66 (37.56)	5.18 (32.15)	4.82 (25.89)	5.38 (31.74)	6.07 (41.01)	5.51 (35.28)	5.16 (30.78)	7.24 (60.02)	8.30 (78.57)	7.47 (66.99)	6.91 (56.67)
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Manuring												
No manure	4.59 (25.59)	5.66 (34.98)	4.94 (29.38)	4.59 (23.78)	5.09 (28.40)	5.94 (38.27)	5.29 (32.18)	4.87 (27.43)	6.89 (53.99)	8.10 (73.25)	7.25 (61.42)	6.54 (50.71)
FYM @ 10 t/ha	5.31 (33.18)	6.00 (42.39)	5.57 (36.70)	5.31 (30.10)	5.82 (36.96)	6.49 (46.33)	5.91 (40.29)	5.58 (35.75)	7.89 (70.14)	8.88 (88.71)	7.96 (76.33)	7.45 (65.73)
CD (0.05)	0.25	0.25	0.30	0.35	0.29	0.25	0.29	0.29	0.34	0.29	0.35	0.31
Weed management												
Black polythene	1.57 (2.79)	(3.29) 4.68	1.59 (2.86)	(1.57) 2.01	(2.54) 5.67	2.82 (7.32)	1.79 (2.46)	1.66 (1.87)	3.00 (8.46)	3.51 (12.01)	2.07 (3.71)	2.07 (3.44)
Organic mulch	4.75 (23.08)	(4.90) 34.85	5.24 (27.93)	(4.75) 17.90	(5.03) 24.86	6.14 (37.12)	5.58 (30.66)	5.00 (24.67)	6.93 (47.94)	8.49 (71.97)	7.66 (58.59)	6.54 (42.57)
Hand weeding	6.54 (41.89)	7.04 (53.67)	6.82 (46.75)	(6.45) 38.51	(6.96) 47.75	7.79 (60.01)	7.37 (53.55)	6.95 (47.56)	9.49 (89.94)	10.69 (113.68)	10.04 (100.29)	9.31 (86.07)
No weeding	7.04) (49.78)	7.82 (61.54)	7.38 (54.63)	(7.04) 48.53	(7.29) 52.46	8.09 (64.73)	7.68 (58.26)	7.28 (52.27)	10.14 (102.24)	11.27 (126.27)	10.66 (112.89)	10.07 (100.80)
CD (0.05)	0.35	1.44	0.43	0.40	0.41	0.35	0.42	0.41	0.48	0.42	0.50	0.44

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

Table 18. Correlation between biometric characters and yield at harvest

	Plant height	Biomass yield per plant	Root:shoot ratio	Yield
Plant height	1.000			
Biomass yield per plant	-0.179	1.000		
Root:shoot ratio	-0.474**	0.767**	1.000	
Yield	-0.312*	0.971**	0.757**	1.000

Table 19. Correlation between microclimate factors, yield and total alkaloid content at vegetative and harvesting stage

Vegetative stage					
	Soil temperature	Soil moisture	Light intensity	Yield	Total alkaloid
Soil temperature	1.000	-			
Soil moisture	-0.391**	1.000			
Light intensity	0.180	-0.628**	1.000		
Yield	0.373**	-0.041	0.449**	1.000	
Total alkaloid	0.311*	-0.070	0.473**	0.337**	1.000
Harvesting stage					
	Soil temperature	Soil moisture	Light intensity	Yield	Total alkaloid
Soil temperature	1.000				
Soil moisture	-0.357**	1.000			
Light intensity	0.254	-0.533**	1.000		
Yield	0.596**	0.161	0.452**	1.000	
Total alkaloid	0.271	-0.332*	0.473**	0.337**	1.000

Table 20. Correlation between biometric characters and microclimate at harvest

	Soil temperature	Soil moisture	Light intensity	Plant height	Biomass yield per plant	Root:shoot ratio
Soil temperature	1.000					
Soil moisture	-0.264	1.000				
Light intensity	0.174	-0.680**	1.000			
Plant height	-0.233	0.416**	-0.406**	1.000		
Biomass yield per plant	0.536**	0.179	0.299	-0.179	1.000	
Root:shoot ratio	0.384**	-0.108	0.396**	-0.474**	0.767**	1.000

4.2. Two factor interactions

4.2.1. Interaction between growing condition and manuring

4.2.1.a. Biometric observations

Plant height at 1, 3, 5 MAP and at harvest

Data on interaction between growing condition and manuring are furnished in Table 21. At 1 MAP, there was no significant interaction for plant height. However, interaction was significant for plant height at 3 MAP, 5 MAP and at harvest. At 3 MAP, FYM @ 10 t/ha under 50% shaded condition recorded the taller plants (94.52 cm). Plants grown without manures under open condition showed the lowest plant height (58.14cm).

Similar trend was followed at 5 MAP and at harvest. At 5 MAP and at harvest, the highest plant height of 103.55cm and 108.60cm respectively were seen in FYM @ 10 t/ha plots under shaded condition.

Biomass yield per plant at 1, 3 ,5 MAP and at harvest

At 1 MAP, there was no significant interaction for biomass yield per plant (Table 21). At 3 MAP, the highest biomass per plant was observed in FYM @ 10 t/ha plots in open condition (26.82 g) and the lowest was recorded by plants in no manure plots grown under shaded condition (14.98 g).

Similarly, at 5 MAP and at harvest the highest biomass yield per plant of 48.15 g and 65.99 g respectively were recorded by plants in FYM @ 10 t/ha plots in open condition.

Root yield per plant

The interaction of growing condition and manuring on root yield per plant is depicted in Table 22. At 1 MAP, the highest root yield per plant was recorded in FYM @ 10 t/ha plots in open condition (3.57 g). The lowest root yield per plant was recorded in plots with FYM @ 10 t/ha (3.42 g) and no manure (3.37 g) under 50% shade. At 3 MAP, the highest root yield per plant was recorded by plants grown with FYM @ 10 t/ha under open condition (4.49 g) and lowest was from no manure plots under 50% shade (3.47 g). At 5 MAP, the highest root yield per plant was recorded

in FYM @ 10 t/ha under open condition (5.74 g). No manure plot under open condition (4.75 g) was on par with FYM @ 10 t/ha (4.38 g) and no manure (4.09 g) under shaded condition. At harvest, the higher root yield per plant was obtained from FYM @ 10 t/ha (7.42 g) and no manure (6.26 g) under open condition. Plots with FYM @ 10 t/ha and no manure under 50% shade recorded lower root yield per plant (5.65g and 5.15g respectively).

Total root yield

There was significant interaction of growing condition and manuring on total root yield at harvest (Table 22).The highest root yield was in plots with FYM @ 10 t/ha under open condition (951.87 kg ha^{-1}). The lowest yield was obtained from no manure plots under shade (615.93 kg ha^{-1}).

Root:shoot ratio

There was no significant interaction of growing condition and manuring on root:shoot ratio at 1 MAP (Table 22). At 3 MAP, the highest root:shoot ratio was obtained from FYM @ 10 t/ha under open condition (0.28) and the lowest were recorded in no manure plot under shaded condition(0.21). At 5 MAP and at harvest the same trend was followed. The highest root:shoot ratio was recorded in FYM @ 10 t/ha under open condition (0.37 and 0.44) and lowest was recorded in no manure plot under 50% shade (0.28 and 0.36 respectively).

Table 21. Interaction effect of growing condition and manuring on plant height (cm) and biomass yield per plant (g) of Sida hemp at different growth stages

Treatments	Plant height (cm)								Biomass yield per plant (g)							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	8.77	11.49	58.14	88.86	72.12	96.83	83.38	103.54	6.47	5.93	21.35	14.98	36.64	25.55	51.83	37.94
FYM@10 t/ha	9.80	12.65	76.69	94.52	86.69	103.55	92.86	108.60	7.50	6.26	26.82	17.90	48.15	32.75	65.99	46.46
CD (0.05)	NS		1.67		1.98		2.58		NS		1.65		1.64		1.93	

Table 22. Interaction effect of growing condition and manuring on root yield per plant (g) and root:shoot ratioof Sida hemp at different growth stages

Treatments	Root yield per plant (g)								Total root yield (kg ha^{-1})		Root:shoot ratio							
	1 MAP		3 MAP		5 MAP		Harvest		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	3.44	3.37	3.89	3.47	4.75	4.09	6.26	5.15	812.80	615.93	0.14	0.12	0.25	0.21	0.34	0.28	0.39	0.36
FYM@10 t/ha	3.57	3.42	4.49	3.68	5.74	4.38	7.42	5.65	951.87	699.40	0.15	0.13	0.28	0.24	0.37	0.31	0.44	0.39
CD (0.05)	0.12		0.18		0.84		1.22		14.55		NS		0.04		0.02		0.02	

4.2.1.b. Micro climate studies

Soil temperature

Data on the interaction between growing condition and manuring on soil temperature are furnished on Table 23. Interaction between growing condition and manuring had significant effect on soil temperature. Higher temperature was recorded in plots with FYM @ 10 t/ha under open condition and lower temperature was recorded in plots without manure under 50% shade. The highest temperature recorded was 27.6°C at 16th week and the lowest temperature recorded was 24.3 °C at 12th week.

Soil moisture

Significant influence of growing condition and manuring on soil moisture content was noticed initially during week 1, and from 2nd to 13th week interaction was non significant (Table 24). From 18th to 25th week higher soil moisture content was noticed in treatments with FYM 10 t/ha under shaded condition and it was on par with manure application under open.

Light intensity

Data on the interaction between growing condition and manuring on light intensity are depicted in Table 25. Interaction between growing condition and manuring was found to be non significant throughout growing periods.

4.2.1.c. Soil analysis

Soil pH

Data on the interaction between growing condition and manuring on soil pH are depicted in Table 26. Interaction between growing condition and manuring was found to be non significant throughout growing periods.

Organic carbon

Interaction between growing condition and manuring did not show any significant effect on organic carbon content of soil after the experiment (Table 26).

Available nitrogen

The interaction effect of growing condition and manuring on the available N was non significant (Table 26).

Available phosphorus

The data pertaining to the interaction effect of growing condition and manuring on available soil phosphorus are given in Table 26.

Available potassium

The data on available K are given in Table 26. Significantly higher available K was observed under open condition with FYM (274.29 kg/ha).

4.2.1.d. Physiological, chemical and biochemical observations

Total chlorophyll content at 1, 3, 5 MAP and at harvest

Interaction between growing condition and manuring on total chlorophyll content and total alkaloid are depicted in Table 27. Interaction effect did not show any significant influence on total chlorophyll content.

Total alkaloid content

Interaction between growing condition and manuring on total alkaloid content was non significant (Table 27).

Crop growth rate

Interaction effect of growing condition and manuring on crop growth rate and relative growth rate are given in Table 28. There was no significant influence of growing condition and manuring on crop growth rate.

Relative growth rate

Interaction between growing condition and manuring on relative growth rate was found non significant (Table 28).

Table 23. Interaction effect of growing condition and manuring on soil temperature (^{0}C)

Treatments	Soil temperature (°C)																									
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9		Week10		Week11		Week12		Week13	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manure	26.9	24.7	27.1	26.2	26.7	26.3	26.3	25.3	25.9	25.6	26.3	25.4	26.2	25.5	25.7	25.2	25.3	25.1	25.4	25.2	25.9	25.6	25.1	24.6	26.6	25.8
FYM @ 10 t/ha	26.3	25.5	27.2	26.8	26.9	26.2	26.3	26.1	26.2	26.1	26.3	25.8	26.3	25.4	25.9	25.3	25.5	25.0	25.4	24.9	26.2	26.1	25.4	25.0	26.4	26.1
CD (0.05)	1.5		1.3		1.2		1.1		1.4		1.4		1.7		1.6		1.3		1.3		0.4		0.6		1.3	

Treatments	Soil temperature (°C)																									
	Week14		Week15		Week16		Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25			
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S		
No manure	26.6	25.8	26.9	26.4	27.3	27.0	26.1	26.5	25.8	26.7	27.2	25.9	26.9	25.8	26.9	24.7	26.8	24.9	26.6	25.8	26.9	25.8	26.7	26.5		
FYM @ 10 t/ha	26.5	26.2	27.0	26.8	27.6	27.1	26.7	26.9	26.6	26.4	26.3	25.5	26.6	26.4	26.3	25.5	26.2	25.5	26.5	26.2	26.6	26.4	26.8	26.1		
CD (0.05)	1.4		0.9		1.1		1.1		1.4		1.3		1.4		1.5		1.5		1.4		1.4		1.2			

*O - Open

*S - Shade

Table 24. Interaction effect of growing condition and manuring on soil moisture (%)

Treatments	Soil moisture (%)																							
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9		Week10		Week11		Week12		Week13	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manure	14.2	14.6	31.9	32.2	33.4	33.5	31.9	32.3	31.9	32.2	33.4	33.5	31.9	32.3	31.9	32.2	31.9	32.2	33.5	33.6	31.9	32.2	33.4	33.5	33.5	33.6
FYM @ 10 t/ha	14.4	15.1	32.1	32.3	33.3	33.7	32.1	32.4	32.1	32.3	33.3	33.7	32.1	32.4	32.1	32.3	32.1	32.3	33.1	34.0	32.1	32.3	33.3	33.7	33.1	34.0
CD (0.05)	0.9		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	

Treatments	Soil moisture (%)																							
	Week14		Week15		Week16		Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manure	13.5	15.7	13.6	14.1	13.2	15.6	14.0	15.8	14.1	15.3	13.5	15.7	13.6	14.1	13.1	14.6	13.5	14.9	13.2	14.1	13.6	14.8	13.1	14.6
FYM @ 10 t/ha	13.6	15.8	13.4	14.7	13.8	15.9	13.8	15.9	13.3	15.4	13.6	15.8	13.4	14.7	13.2	14.1	13.6	14.6	13.6	14.7	13.4	14.9	13.2	14.1
CD (0.05)	1.8		1.3		1.5		1.3		1.2		1.8		1.3		1.4		1.4		1.5		1.3		1.1	

*O - Open

*S – Shade

Table 25. Interaction effect of growing condition and manuring on light intensity (lux)

Treatments	Light intensity (lux)																	
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manure	19500.8	4214.5	19490.8	4209.2	19481.2	4201.2	19476.1	4186.1	14397.6	3103.7	1309.2	3006.2	10288.1	1981.2	9283.2	978.3	8787.8	480.8
FYM @ 10 t/ha	19513.3	4203.1	19508.3	4198.6	19492.3	4174.3	19446.2	4150.5	14367.3	3067.3	1286.1	2985.1	10263.1	1943.1	9263.6	942.1	8763.4	442.6
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS		NS	

Treatments	Light intensity (lux)																	
	Week10		Week11		Week12		Week13		Week14		Week15		Week16		Week17		Week18	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manure	10341.2	2041.2	11287.8	2980.8	14500.8	14513.3	19490.8	4209.2	19605.0	4273.5	19605.0	4273.5	19546.7	4236.9	19613.6	4292.4	19575.0	4263.4
FYM @ 10 t/ha	10318.3	1998.3	11263.4	2942.6	3714.9	3703.1	19508.3	4198.6	19562.5	4247.6	19562.5	4247.6	19512.5	4202.7	19578.3	4271.8	19531.7	4241.7
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS		NS	

*O - Open

*S - Shade

Treatments	Light intensity (lux)													
	Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manure	19614.6	4292.3	1957.1	4263.2	19605.0	4273.5	19614.1	4292.1	19655.6	4351.2	19595.1	4286.5	19614.2	4292.3
FYM @ 10 t/ha	19578.3	4272.1	19532.3	4242.1	19562.3	4247.3	19578.2	4272.1	19637.1	4337.6	19560.3	4266.1	19578.3	4272.1
CD (0.05)	NS		NS		NS		NS		NS		NS		NS	

*O - Open

*S – Shade

Table 26. Interaction effect of growing condition and manuring on pH, Organic carbon(%), Available N(Kg/ha),Available P (Kg/ha), Available K (Kg/ha) and Total Alkaloid (%)of sida hemp after harvest

Treatments	pH		Organic carbon (%)		Available N (Kg ha^{-1})		Available P (Kg ha^{-1})		Available K (Kg ha^{-1})	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	4.62	4.52	1.01	1.04	119.55	103.73	25.69	30.15	166.06	200.05
FYM@10 t/ha	4.47	4.59	1.04	1.11	135.89	129.74	28.88	33.26	274.29	232.64
CD (0.05)	NS		NS		NS		NS		1.52	

Table 27. Interaction effect of growing condition and manuring on chlorophyll content (mg g^{-1}) and total alkaloid (%) of Sida hemp at different growth stages

Treatments	Chlorophyll content (mg g^{-1})								Total alkaloid (%)	
	1 MAP		3 MAP		5 MAP		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	8.06	8.89	8.47	10.44	8.99	11.25	9.02	11.47	3.03	2.68
FYM@5t/ha	8.66	9.90	9.11	12.44	9.62	12.95	9.82	13.09	3.23	2.80
CD (0.05)	NS		NS		NS		NS		NS	

Table 28. Interaction effect of growing condition and manuring on CGR (g $m^{-2}day^{-1}$) and RGR (g $g^{-1}day^{-1}$) of Sida hemp at different growth stages

Treatments	CGR (g $m^{-2}day^{-1}$)								RGR (g $g^{-1}day^{-1}$)							
	0-1 MAP		1MAP-3 MAP		3MAP-5 MAP		5MAP-Harvest		0-1 MAP		1MAP-3MAP		3MAP-5MAP		5MAP-Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	6.47	5.78	7.44	4.61	7.65	5.28	15.19	12.39	0.79	0.75	0.56	0.47	0.53	0.42	1.15	1.01
FYM@5t/ha	7.24	6.26	9.79	5.83	10.67	7.43	17.83	13.71	0.84	0.77	0.59	0.52	0.57	0.52	1.24	1.09
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS	

4.2.1.e Soil microflora

Total population of bacteria, actinomycetes and fungi at sowing, 4 MAP and at harvest

Interaction effect of growing condition and manuring on total population of bacteria, actinomycetes and fungi depicted in Table 29. Total population of bacteria was higher in plots with FYM @ 10 t/ha under open condition ($22.08x10^6$cfu g^{-1}) and the lowest colonization was found in no manure plots under shade ($16.25x10^6$ cfu g^{-1}). At harvest, the highest population of bacteria was recorded in plots with FYM @ 10 t/ha under open condition ($18x10^6$cfu g^{-1}) and lower colonization were found in FYM @ 10 t/ha ($14.92x10^6$cfu g^{-1}) and no manure ($14.80x10^6$cfu g^{-1}) plots.

At 4 MAP and at harvest, total population of actinomycetes were higher in plots with FYM @ 10 t/ha ($77.83x10^4$ cfu g^{-1} and $81.75x10^4$ cfu g^{-1} respectively). No manure plot under shade recorded the lowest population of actinomycetes at 4 MAP ($48.83x10^4$ cfu g^{-1}) and at harvest ($55.17x10^4$ cfu g^{-1}).

At 4 MAP and at harvest, total population of fungi were higher in plots with FYM @ 10 t/ha ($15.92x10^4$ cfu g^{-1} and $17.83x10^4$ cfu g^{-1} respectively). No manure plots under shade recorded the lowest population of actinomycetes at 4 MAP ($10.75x10^4$ cfu g^{-1}) and at harvest ($11.75x10^4$ cfu g^{-1}). Same trend was followed in total population of soil microbes also. At 4 MAP and at harvest, total population of soil microbes were higher in plots with FYM @ 10 t/ha (115.83 cfu g^{-1} and 118.75 cfu g^{-1} respectively). No manure plot under shade recorded the lowest population of actinomycetes at 4 MAP (75.83 cfu g^{-1}) and at harvest (81.75 cfu g^{-1})

Root colonization (%) by arbuscular mycorrhizal fungi at 1, 4 MAP and at harvest

Data on the interaction effect of growing condition and manuring on percent root colonization of arbuscular mycorrhizal fungi and soil microbial biomass carbon are presented in Table 30. The highest root colonization was recorded in plots with FYM @ 10 t/ha under open condition at 1, 4 MAP and at harvest (10 %, 12.5% and 15% respectively). Plots under shade did not showed any colonization of AM fungi.

Soil microbial biomass carbon

At 4 MAP and at harvest, the highest soil microbial biomass carbon was recorded in FYM @ 10 t/ha plot under open condition (305.25µg g^{-1} and 331.49 µg g^{-1} respectively) and the lowest was estimated from no manure plot under 50% shade (148.50 µg g^{-1} and 193.41 µg g^{-1} respectively).

4.2.1.f Observations on weeds

Weed count at 1, 3, 5 MAP and at harvest

Interaction effect of growing condition and manuring on grasses count was non significant at 1 MAP (Table 31). At 3 MAP, 5 MAP and at harvest, FYM @ 10 t/ha plots under open condition showed the highest grass weed count (33.83 no m^{-2}, 41.33 no m^{-2} and 31.25 no m^{-2} respectively) and FYM @ 10 t/ha plots under shade showed the lowest weed count (10.58 no m^{-2}, 18.92 no $m^{-2}$and 16.50 no. m^{-2} respectively). Broad leaved weed count was also non significant at 1 MAP. During other growing stages, the highest weed count was observed in FYM @ 10 t/ha plots under open condition (50 no m^{-2}, 57.58 no m^{-2} and 37.08 no m^{-2} respectively). Total weed count was significant at all growing stages. The highest weed count was observed in FYM @ 10 t/ha plots under open condition (40.08 no m^{-2}, 83.33 no m^{-2}, 98.92 no $m^{-2}$and 68.33 no m^{-2} respectively). At 1 MAP to 5 MAP, there was an increasing trend in weed count but it decreased towards harvest.

Weed dry weight at 1,3,5 MAP and at harvest

There was no significant interaction of growing condition and manuring on weed dry weight at all growing stages (Table 32).

Table 29. Interaction effect of growing condition and manuring on total population of bacteria, actinomycetes and fungi in the rhizosphere of Sida hemp at different growth stages

Treatments	Total population of bacteria ($x10^6$ cfu g^{-1})				Total population of actinomycetes ($x10^4$ cfu g^{-1})				Total population of fungus ($x10^4$ cfu g^{-1})			
	4 MAP		Harvest		4 MAP		Harvest		4 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	1.27 (18.67)	1.21 (16.25)	1.19 (15.83)	1.17 (14.83)	1.76 (58.83)	1.68 (48.83)	1.79 (63.75)	1.74 (55.17)	1.14 (14.75)	0.97 (10.75)	1.24 (15.80)	1.07 (11.75)
FYM@10 t/ha	1.33 (22.08)	1.23 (17.42)	1.25 (18.00)	1.17 (14.92)	1.89 (77.83)	1.72 (53.17)	1.91 (81.75)	1.74 (55.17)	1.18 (15.92)	1.02 (11.17)	1.25 (17.83)	1.13 (13.92)
CD (0.05)	0.07		0.04		0.05		0.05		0.14		0.07	

** Logarithmic transformed values, original values are in parentheses

Table 30. Interaction effect of growing condition and manuring on root colonization by arbuscular mycorrhizal fungi and soil microbial biomass carbon in the rhizosphere of Sida hemp at different growth stages

Treatments	Root colonization by arbuscular mycorrhizal fungi (%)						Soil microbial biomass carbon (µg g^{-1}) of soil			
	1 MAP		4 MAP		Harvest		4 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	1.75 (2.50)	0.22 (0.00)	3.29 (5.00)	0.22 (0.00)	5.04 (7.50)	0.22 (0.00)	225.25	148.50	244.48	193.41
FYM@10 t/ha	6.50 (10.00)	0.22 (0.00)	7.88 (12.50)	0.22 (0.00)	10.05 (15.00)	0.22 (0.00)	305.25	185.33	331.49	218.39
CD (0.05)	2.45		3.51		4.54		5.04		4.88	

** Arc sin transformed values, original values are in parentheses

Table 31. Interaction effect of growing condition and manuring on weed count at different growth stages

Treatments	Weed count (no./m²)															
	Grasses								Broad leaved weeds							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% Shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	3.79 (16.42)	3.08 (9.33)	4.33 (21.00)	3.78 (15.75)	4.94 (28.33)	4.57 (23.33)	4.32 (21.58)	3.95 (17.17)	4.02 (17.58)	3.45 (12.17)	5.14 (30.25)	4.25 (19.83)	5.72 (37.83)	4.89 (27.25)	4.73 (26.33)	4.44 (22.42)
FYM@10 t/ha	4.16 (20.08)	3.34 (11.08)	5.42 (33.83)	3.16 (10.58)	5.95 (41.33)	4.14 (18.92)	5.14 (31.25)	3.89 (16.50)	4.27 (20.00)	3.85 (15.83)	6.49 (50.00)	4.13 (18.50)	6.96 (57.58)	4.79 (25.83)	5.38 (37.08)	4.61 (23.75)
CD (0.05)	NS		0.33		0.31		0.61		NS		0.22		0.25		0.31	

Treatments	Total weed count (no./m²)							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	6.62 (34.00)	5.58 (21.50)	6.62 (51.25)	5.58 (35.58)	7.46 (66.17)	6.59 (50.58)	6.30 (47.92)	5.86 (39.58)
FYM@10 t/ha	8.36 (40.08)	5.09 (26.92)	8.36 (83.33)	5.09 (29.08)	9.07 (98.92)	6.22 (44.75)	7.36 (68.33)	5.94 (40.25)
CD (0.05)	0.37		0.37		0.38		0.49	

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

Table 32. Interaction effect of growing condition and manuring on weed dry weight at different growth stages

Treatments	Weed dry weight (g m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	4.70 (26.49)	4.49 (24.69)	5.59 (35.93)	5.46 (34.04)	5.01 (30.14)	4.88 (28.62)	4.91 (24.03)	4.54 (22.73)	5.11 (28.95)	5.07 (27.85)	6.04 (39.24)	5.83 (37.29)	5.37 (32.89)	5.23 (31.46)	4.86 (27.85)	4.87 (27.01)
FYM@ 10 t/ha	5.48 (34.49)	5.15 (31.86)	6.15 (43.69)	5.85 (41.08)	5.66 (37.73)	5.48 (35.68)	4.74 (31.15)	5.11 (29.05)	5.96 (38.29)	5.68 (35.63)	6.66 (47.93)	6.31 (44.72)	6.04 (41.46)	5.79 (39.11)	5.71 (36.95)	5.44 (34.56)
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS	

Treatments	Total weed dry weight (g m^{-2})							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manure	6.98 (55.45)	6.80 (52.55)	8.24 (75.17)	7.96 (71.34)	7.34 (62.79)	7.17 (60.04)	6.58 (51.68)	6.51 (49.74)
FYM@10 t/ha	8.10 (72.79)	7.68 (67.49)	9.11 (91.61)	8.65 (85.81)	8.17 (78.72)	7.76 (73.93)	7.59 (67.85)	7.30 (63.61)
CD (0.05)	NS		NS		NS		NS	

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

4.2.2. Interaction between growing condition and weed management

4.2.2.a Biometric observations

Plant height at 1,3,5 MAP and at harvest

Interaction between growing condition and weed management on plant height and biomass yield per plant is furnished in Table 33. At 1MAP, there was no significant interaction for plant height. However, interaction was significant at 3 MAP, 5 MAP and at harvest. At 3 MAP, plants with black polythene mulch under 50% shaded condition recorded the highest plant height (121.05cm). Plants grown in plots without weeding under open condition produced the shortest plants (48.49cm). At 5 MAP, the tallest plants were seen in black polythene mulch under 50% shaded condition (131.58 cm). Plants in no weeding plots under open condition recorded the lowest plant height at 5 MAP (60.38cm) and was on par with plants in no weeding plots under shaded condition. At harvest, plants grown in black polythene sheet under 50% shaded condition produced taller plants (136.85cm) followed by plants with organic mulch (111.10cm) under 50% shaded condition which was on par with plant height of crops in hand weeding plots under 50% shade. The plants grown in no weeding plots under 50% shaded condition showed the lowest plant height of 66.47cm.

Biomass yield per plant at 1,3,5 MAP and at harvest

There was no significant variations among treatment combinations with respect to biomass yield per plant at 1 MAP (Table. 33). At 3 MAP, the highest biomass yield per plant was recorded in black polythene plots under open condition (43.02g), which was followed by plants under shaded condition in black polythene mulch (24.59 g). The next higher value was recorded by organic mulch (22.63 g) under open condition. The lowest biomass yield per plant was observed in no weeding plots under shaded condition (12.22 g).

At 5 MAP, the highest biomass yield per plant was observed in black polythene mulch under open condition (87.74 g). Biomass yield per plant recorded in hand weeding under 50% shade (20.12 g) was on par with no weeding under open

condition (18.05 g). The lowest biomass was recorded at no weeding plots under 50% shade (15.44 g). At harvest, the highest biomass yield per plant was observed in black polythene mulch under open condition (109.35 g). Hand weeding at open condition (43.41 g) was on par with plants with organic mulch under shaded condition (41.95 g). The lowest value recorded was 20.50 g in no weeding plots under shaded condition.

Root yield per plant at 1, 3, 5 MAP and at harvest

Data pertaining to interaction effect of growing condition and weed management on root yield per plant and root:shoot ratio are presented in Table 34. At 1 MAP, the data was non significant. At 3 MAP, the highest biomass yield per plant was recorded by plants in black polythene under open condition (4.89 g) followed by organic mulch under open condition (4.41 g). Root yield per plant in hand weeding under open condition (3.81 g) was on par with black polythene under shaded condition (3.49 g), no weeding under open condition and organic mulch under shaded condition (3.66 g). Under open condition lower root yield per plant was recorded in no weeding plot (3.66 g) which was on par with organic mulch (3.66 g) and hand weeding (3.49 g) under shaded condition. Root yield per plant at organic mulch under shade (3.66 g) was on par with hand weeding (3.49 g) and no weeding (3.39 g) under shade. Hand weeding under shade (3.49 g) was on par with no weeding (3.39 g) under shade.

At 5 MAP, the highest root yield per plant was recorded by black polythene under open condition (7.86 g) followed by organic mulch (5.39 g) under open condition which was on par with black polythene (2.15g) and organic mulch (1.08g) under shade. At harvest, black polythene mulch under open condition continued the trend of superiority (10.19 g). Organic mulch under open condition (7.12 g) was on par with black polythene mulch (6.41 g) and organic mulch under shade (5.64 g).

Total root yield at harvest

Highest root yield was recorded in black polythene under open condition (1329.20 kg ha^{-1}) and the lowest root yield was obtained from no weeding plots under 50% shade (550.27 kg ha^{-1}) (Table 34).

Root:shoot ratio at 1,3,5 MAP and at harvest

At 1MAP and 3 MAP, there was no significant interaction for root:shoot ratio (Table 34). At 5 MAP the highest root:shoot ratio was observed in plants grown under open condition with black polythene mulch (0.42) Organic mulching under open condition recorded the next best root:shoot ratio of 0.37 at this stage. The lowest root:shoot ratio of 0.24 was observed when plants were grown under 50 % shade without any weeding. At harvest, the highest root:shoot ratio was observed in black polythene sheet under open condition (0.48) followed by organic mulch under open condition (0.45) which was on par with hand weeding under open condition (0.43). No weeding under shade (0.34g) was on par with no weeding under open condition (0.32).

4.2.2.b Micro climate studies

Soil temperature

Interaction effect of growing condition and weed management was significant with respect to soil temperature (Table 35). The highest temperature was recorded at 2^{nd} week in black polythene plots under open condition (28.6^0C). The lowest temperature was recorded at 8^{th} week in no weeding plot under shade (24.2^0C).

Soil moisture

Interaction between growing condition and weed management on soil moisture was found significant except from 2^{nd} to 13^{th} week (Table 36).

Light intensity

Interaction effect of growing condition and weed management was significant with respect to light intensity (Table 37). The highest light intensity was recorded at 19^{th} week in hand weeding plots under open condition (19666.4 lux). The lowest light intensity was recorded at 9^{th} week in no weeding plot under shade (452.8 lux).

Table 33. Interaction effect of growing condition and weed management on plant height (cm) and biomass yield per plant (g) of Sida hemp at different growth stages

Treatments	Plant height (cm)								Biomass yield per plant (g)							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	10.53	14.46	84.44	121.05	94.49	131.58	99.55	136.85	10.19	9.11	43.02	24.59	87.74	54.56	109.35	72.98
Organic mulch	9.33	11.00	78.77	101.03	88.81	105.95	95.13	111.10	7.15	5.61	22.63	14.57	34.76	26.49	53.44	41.95
Hand weeding	9.97	12.55	57.97	93.55	73.94	100.82	86.40	109.87	5.76	5.06	16.59	14.41	29.31	20.12	43.41	33.36
No weeding	7.30	10.27	48.49	51.13	60.38	62.42	71.40	66.47	4.84	4.59	14.11	12.22	18.05	15.44	29.44	20.50
CD (0.05)	NS		2.36		2.79		3.65		NS		2.33		2.32		2.73	

Table 34. Interaction effect of growing condition and weed management on root yield per plant (g) and root:shoot ratio of Sida hemp at different growth stages

Treatments	Root yield per plant (g)								Total root yield(kg ha^{-1})		Root:shoot ratio							
	1 MAP		3 MAP		5 MAP		Harvest		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	3.78	3.60	4.89	3.81	7.86	5.28	10.19	6.41	1329.20	893.60	0.17	0.14	0.31	0.27	0.42	0.35	0.48	0.42
Organic mulch	3.49	3.38	4.41	3.66	5.39	4.22	7.12	5.64	815.21	606.93	0.16	0.14	0.28	0.24	0.37	0.31	0.45	0.38
Hand weeding	3.43	3.33	3.81	3.49	3.93	3.74	5.16	5.03	738.13	579.87	0.15	0.13	0.25	0.22	0.34	0.28	0.43	0.38
No weeding	3.31	3.26	3.66	3.39	3.81	3.71	4.89	4.52	646.80	550.27	0.13	0.12	0.21	0.19	0.27	0.24	0.32	0.34
CD (0.05)	NS		0.26		1.19		1.72		20.57		NS		NS		0.03		0.02	

Table 35. Interaction effect of growing condition and weed management on soil temperature (^{0}C)

Treatments	Soil temperature (°C)																							
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9		Week10		Week11		Week12		Week13	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	27.7	26.2	28.6	27.7	28.3	27.6	27.3	27.1	27.2	26.8	27.2	26.7	27.3	25.9	26.5	26.0	26.3	25.9	25.9	25.9	25.9	25.9	25.4	25.8	26.1	25.2
Organic mulch	26.0	24.9	26.8	26.5	26.2	26.1	25.9	24.9	25.5	25.6	25.8	25.3	25.9	26.2	25.5	25.4	24.3	25.2	24.4	25.5	24.3	25.3	24.3	25.2	25.7	25.4
Hand weeding	26.5	24.9	26.8	25.8	26.6	25.8	26.2	25.9	25.9	26.0	26.5	25.9	26.2	25.1	25.9	25.4	25.3	25.4	25.4	25.4	25.4	25.3	25.2	25.3	26.4	26.4
No weeding	26.0	24.4	26.4	25.9	26.5	25.4	25.9	24.8	25.5	24.9	25.7	24.5	25.5	24.6	25.5	24.2	24.8	24.3	24.9	24.5	24.8	24.4	24.7	24.6	25.9	24.9
CD (0.05)	1.01		1.24		1.14		1.45		2.01		1.33		1.54		2.29		1.89		1.89		0.61		0.83		1.8	

*O - Open

*S – Shade

Treatments	Soil temperature (°C)																					
	Week14		Week15		Week16		Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	28.1	27.2	28.1	27.8	28.5	28.1	28.1	27.8	28.2	27.4	28.2	27.1	28.2	27.4	27.7	26.2	27.7	26.2	28.1	27.2	28.3	27.4	27.8	28.1
Organic mulch	25.7	25.3	26.1	26.2	26.2	26.5	24.9	26.0	25.8	25.3	25.7	24.3	25.8	25.3	26.1	24.9	26.0	24.6	25.6	25.3	25.8	25.3	24.9	26.0
Hand weeding	26.1	26.5	25.8	26.7	26.9	26.5	26.0	26.6	26.4	26.5	27.4	26.6	26.4	26.5	26.5	24.9	26.8	25.5	26.1	26.5	26.4	26.5	26.0	26.6
No weeding	26.4	24.9	26.5	26.3	26.8	25.3	26.5	26.5	26.6	25.1	25.8	24.9	26.6	25.1	26.0	24.4	25.5	24.5	26.4	24.9	26.6	25.1	26.5	26.5
CD (0.05)	2.16		1.89		1.58		1.69		1.92		1.86		1.93		2.06		2.17		1.94		1.93		1.19	

*O - Open

*S - Shade

Table 36. Interaction effect of growing condition and weed management on soil moisture (%)

Treatments	Soil moisture (%)																									
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9		Week10		Week11		Week12		Week13	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	15.1	15.6	32.6	32.7	33.3	33.5	32.6	32.7	33.3	33.5	32.6	32.7	32.1	32.3	33.3	33.4	32.1	32.3	32.1	32.3	32.1	32.3	33.4	33.6	32.1	32.3
Organic mulch	14.4	14.6	32.2	32.3	33.3	33.3	32.2	32.3	33.3	33.3	32.2	32.3	32.0	32.3	33.3	33.2	32.0	32.3	32.0	32.3	32.0	32.3	33.4	33.4	32.0	32.3
Hand weeding	13.3	14.4	32.1	32.2	33.2	33.1	32.1	32.2	33.2	33.1	32.1	32.2	32.0	32.3	33.2	33.1	32.0	32.3	32.0	32.3	32.0	32.3	33.2	33.3	32.0	32.3
No weeding	14.3	14.8	32.3	32.4	33.4	33.4	32.3	32.4	33.4	33.4	32.3	32.4	32.1	32.4	33.4	33.4	32.1	32.4	32.1	32.4	32.1	32.4	33.4	33.5	32.1	32.4
CD (0.05)	2.5		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	

*O - Open

*S - Shade

Treatments	Soil moisture (%)																							
	Week14		Week15		Week16		Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	15.4	16.9	14.4	15.5	14.8	16.5	14.6	16.3	14.4	16.5	15.4	16.9	14.4	15.5	13.9	15.4	14.5	15.5	14.2	15.3	14.4	15.6	14.5	15.4
Organic mulch	14.2	15.9	13.3	14.5	12.9	15.6	13.6	15.6	13.9	15.1	14.2	15.9	13.3	14.5	13.4	14.5	13.4	14.9	13.6	14.4	13.1	14.2	13.8	14.0
Hand weeding	13.5	14.9	12.3	14.3	12.2	14.7	12.9	14.9	12.2	14.2	13.5	14.9	12.3	14.3	12.6	13.2	13.2	13.9	12.3	13.7	12.1	13.6	12.7	13.5
No weeding	14.2	15.5	13.9	15.2	14.2	16.3	14.4	16.6	14.3	15.7	14.2	15.5	13.9	15.2	12.7	14.2	13.1	14.4	13.4	14.4	13.2	14.9	14.1	14.6
CD (0.05)	2.6		1.9		2.2		1.3		1.5		2.6		1.9		2.1		1.9		2.1		1.8		1.6	

*O - Open

*S - Shade

Table 37. Interaction effect of growing condition and weed management on light intensity (lux)

Treatments	Light intensity (lux)																	
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	19465.0	4223.1	19453.3	4216.5	19433.3	4193.0	19420.4	4167.0	14341.3	3075.1	11261.9	2973.8	10240.7	1965.2	9238.1	964.6	8740.7	465.2
Organic mulch	19456.7	4164.8	19451.7	4158.4	19443.3	4144.5	19399.0	4150.5	14316.6	3074.3	11237.0	2980.1	10215.6	1955.4	9216.3	952.2	8715.6	455.4
Hand weeding	19550.0	4221.8	19450.0	4222.2	19521.7	4210.2	19507.2	4164.2	14442.5	3079.7	11352.1	2995.6	10324.5	1973.6	9320.9	976.3	8824.5	473.6
No weeding	19556.7	4226.4	19553.3	4218.4	19546.7	4203.7	19517.4	4189.9	14429.3	3112.9	11339.6	3025.9	10321.9	1952.8	9318.9	947.4	8821.9	452.8
CD (0.05)	43.9		45.1		31.9		8.8		8.9		9.1		52.1		51.7		52.1	

*O - Open

*S - Shade

Treatments	Light intensity (lux)															
	Week10		Week11		Week12		Week13		Week14		Week15		Week16		Week17	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	10290.5	2026.7	11240.7	2965.2	14465.0	3723.1	19453.3	4216.5	19590.0	4277.9	19590.0	4277.9	19500.0	4223.9	19600.6	4279.9
Organic mulch	10269.4	2013.4	11215.6	2955.2	14456.7	3664.8	19451.7	4158.4	19575.0	4258.4	19575.0	4258.4	19485.0	4204.8	19588.6	4279.9
Hand weeding	103.81.1	2029.9	11324.5	2973.6	14550.0	3721.8	19540.0	4222.2	19650.0	4277.5	19650.0	4277.5	19583.3	4223.5	19664.1	4297.5
No weeding	10378.3	2006.9	11321.9	2952.8	14556.7	3726.4	19553.3	4218.4	19520.0	4228.4	19520.0	4228.4	19550.0	4227.0	19530.7	4252.1
CD (0.05)	52.6		52.1		43.9		45.1		23.8		23.8		55.3		25.7	

*O – Open

*S - Shade

Treatments	Light intensity (lux)															
	Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
Black polythene	19570.0	4277.9	19600.2	4298.7	19570.0	4277.9	19590.0	4277.8	19600.6	4298.7	19651.9	4358.8	19590.8	4301.6	19600.6	4298.7
Organic mulch	19553.3	4257.8	19588.5	4279.9	19553.3	4257.9	19575.0	4258.4	19588.6	4279.9	19635.9	4343.2	19573.7	4279.6	19588.6	4279.9
Hand weeding	19610.0	4271.4	19664.4	4297.5	19610.0	4271.4	19650.0	4277.5	19664.1	4297.5	19712.7	4358.2	19637.2	4289.6	19664.1	4297.5
No weeding	19480.0	4202.9	19530.6	4252.2	19480.6	4202.9	19520.0	4228.5	19530.7	4252.1	19583.5	4318.2	19508.3	4232.1	19530.1	452.1
CD (0.05)	4.4		25.4		4.4		23.8		25.7		7.8		12.7		25.7	

*O - Open

*S - Shade

4.2.2.c Soil analysis

Soil pH

Interaction effect between growing condition and weed management on soil pH was non significant (Table 38).

Organic carbon

Interaction effect of growing condition and weed management could not bring any significant effect on organic carbon content (Table 38).

Available nitrogen

There was no significant influence of growing condition and weed management on available N (Table 38).

Available P

Interaction between growing condition and weed management on available P content was found non significant (Table 38).

Available K

Interaction between growing condition and weed management had significant influence on available K (Table 38). The highest available K was estimated from organic mulched plot under open condition (310.37 kg ha^{-1}) followed by no weeding under open condition (291.15 kg ha^{-1}). The lowest available K was estimated from hand weeding plot under open condition (120.29 kg ha^{-1}).

4.2.2.d. Physiological, chemical and biochemical observations

Chlorophyll content at 1, 3, 5 MAP and at harvest

Interaction between growing condition and weed management on total chlorophyll content and total alkaloid content are depicted in Table. 39 The interaction between growing condition and weed management had no significant effect on chlorophyll content.

Total alkaloid content

There was no significant influence of growing condition and weed management on total alkaloid content (Table 39).

Table 38. Interaction effect of growing condition and weed management on pH, organic carbon (%), available N (kg ha^{-1}), available P (kg ha^{-1}) and available K (kg ha^{-1}) of Sida hemp at harvest

Treatments	pH		Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene mulch	4.48	4.49	1.02	1.08	130.39	112.94	24.37	26.42	158.89	189.12
Organic mulch	4.59	4.49	1.09	1.14	166.92	147.66	34.94	36.49	310.37	275.43
Hand weeding	4.51	4.51	0.94	0.99	117.83	116.56	22.61	30.44	120.29	142.92
No weeding	4.59	4.62	1.04	1.08	95.75	89.79	27.24	33.48	291.15	257.91
CD (0.05)	NS		NS		NS		NS		2.15	

Table 39. Interaction effect of growing condition and weed management on chlorophyll content (mg g^{-1}) and total alkaloid (%) content of Sida hemp at different growth stages

Treatments	Chlorophyll content (mg g^{-1})								Total alkaloid (%)	
	1 MAP		3 MAP		5 MAP		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	8.89	10.67	9.49	12.71	10.11	13.15	10.23	13.13	3.19	2.85
Organic mulch	7.99	9.51	8.66	11.69	8.82	12.35	9.35	12.37	3.16	2.81
Hand weeding	8.69	9.54	8.88	11.31	9.19	11.65	9.13	11.97	3.13	2.79
No weeding	7.87	7.84	8.14	10.05	9.09	11.26	8.95	11.66	3.05	2.76
CD (0.05)	NS		NS		NS		NS		NS	

Crop growth rate (CGR)

Interaction between growing condition and weed management on CGR was found significant throughout all growth stages (Table 40). At 0-1 MAP, plants grown under open condition with black polythene mulching recorded higher CGR (9.68 g $m^{-2}day^{-1}$) which was on par with black polythene mulching under shaded condition (8.80 g $m^{-2}day^{-1}$). The lower CGR was observed under no weeding in shaded condition (4.59 g $m^{-2}day^{-1}$). At 1-3 MAP, the highest CGR was recorded in black polythene under open condition (16.41 g $m^{-2}day^{-1}$). The next higher CGR was recorded in black polythene under shaded condition (7.75 g $m^{-2}day^{-1}$) which was on par with organic mulch under open condition (7.74 g $m^{-2}day^{-1}$). Crop growth rate recorded in hand weeding plots under open condition (5.42 g $m^{-2}day^{-1}$)was on par with hand weeding under shade (4.68 g $m^{-2}day^{-1}$), no weeding under open condition (4.64 g $m^{-2}day^{-1}$) and organic mulch under shaded condition (4.48 g $m^{-2}day^{-1}$). Hand weeding under shaded condition (4.68 g $m^{-2}day^{-1}$) was on par with no weeding under open condition (4.64 g $m^{-2}day^{-1}$), organic mulch (4.48 g $m^{-2}day^{-1}$) and no weeding (3.82 g $m^{-2}day^{-1}$) under shaded condition. The lowest CGR recorded in open condition was in no weeding plot (4.64 g $m^{-2}day^{-1}$) which was on par with organic mulch under shaded condition (4.48 g $m^{-2}day^{-1}$). Under shaded condition, organic mulch was on par with no weeding (4.48 g $m^{-2}day^{-1}$ and 3.82 g $m^{-2}day^{-1}$ respectively).

At 3-5 MAP also, black polythene mulch under open condition continued the trend of superiority with respect to CGR which was followed by black polythene under 50% shaded condition. CGR recorded in hand weeding under open condition (6.36 g $m^{-2}day^{-1}$) was on par with organic mulch under open (6.07 g $m^{-2}day^{-1}$) and shaded condition (5.96 g $m^{-2}day^{-1}$). Organic mulch under open condition (6.07 g $m^{-2}day^{-1}$) was on par with organic mulch under shaded condition (5.96 g $m^{-2}day^{-1}$).

Hand weeding under shaded condition (2.85 g $m^{-2}day^{-1}$) was on par with no weeding under open (1.97 g $m^{-2}day^{-1}$) and shaded condition (1.61 g $m^{-2}day^{-1}$). At 5 MAP-harvest, also black polythene mulching under open condition showed higher values for CGR (21.88 g $m^{-2}day^{-1}$) followed by organic mulching under open condition (18.68 g $m^{-2}day^{-1}$) and black polythene mulching under shaded condition (18.43 g $m^{-2}day^{-1}$) which were on par.

Relative growth rate (RGR)

Interaction effect of growing condition and different weed management on RGR at different growth stages of Sida hemp is depicted in Table 40. At 0-1 MAP higher RGR was observed under open condition with black polythene mulching (0.98 g $g^{-1}day^{-1}$). No weeding under shaded condition resulted in the lowest RGR at this stage (0.66 g $g^{-1}day^{-1}$). At 1-3 MAP, the highest RGR was recorded in black polythene under open condition (0.75 g $g^{-1}day^{-1}$). The next highest RGR was recorded in black polythene under shade (0.59 g $g^{-1}day^{-1}$) which was on par with organic mulch under open condition (0.56 g $g^{-1}day^{-1}$). No weeding under open condition (0.48 g $g^{-1}day^{-1}$) was on par with hand weeding under shaded condition (0.48 g $g^{-1}day^{-1}$), organic mulch (0.47 g $g^{-1}day^{-1}$) and no weeding (0.44 g $g^{-1}day^{-1}$) under shade. Hand weeding under shade (0.48 g $g^{-1}day^{-1}$) was on par with organic mulch and no weeding under shade (0.47 g $g^{-1}day^{-1}$ and 0.44 g $g^{-1}day^{-1}$respectively). Organic mulch under shade was on par with no weeding under shade.

At 3-5 MAP, the highest RGR was recorded in black polythene under open condition (0.82 g $g^{-1}day^{-1}$) which was on par with black polythene under shaded condition (0.74 g $g^{-1}day^{-1}$). Hand weeding under open condition (0.55 g $g^{-1}day^{-1}$) was on par with organic mulch under shaded and open condition (0.54 g $g^{-1}day^{-1}$ and 0.53 g $g^{-1}day^{-1}$respectively). Hand weeding under shade (0.36 g $g^{-1}day^{-1}$) was on par with no weeding under open condition (0.29 g $g^{-1}day^{-1}$) and no weeding under shaded condition (0.24 g $g^{-1}day^{-1}$).

At 5 MAP to harvest also the highest RGR was recorded in black polythene mulched plots under open condition (1.34 g $g^{-1}day^{-1}$). The next higher value was

recorded in organic mulch under open condition which was on par with black polythene under shade (1.26 g $g^{-1}day^{-1}$), organic mulch under shade (1.18 g g^{-1} day^{-1}) and hand weeding under open condition (1.15 g $g^{-1}day^{-1}$). Black polythene under shade (1.26 g $g^{-1}day^{-1}$) was on par with organic mulch under shade (1.18 g $g^{-1}day^{-1}$) and hand weeding under open condition (1.15 g $g^{-1}day^{-1}$). Organic mulch under shade (1.18 g $g^{-1}day^{-1}$) was on par with hand weeding under open (1.15 g $g^{-1}day^{-1}$) and shaded condition (1.11 g $g^{-1}day^{-1}$). Hand weeding under open condition (1.15 g $g^{-1}day^{-1}$) was on par with hand weeding under shade (1.11 g $g^{-1}day^{-1}$) and no weeding under open condition (1.03 g $g^{-1}day^{-1}$). No weeding under open condition (1.03 g $g^{-1}day^{-1}$) is on par with no weeding under shaded condition (0.65 g $g^{-1}day^{-1}$).

Table 40. Interaction effect of growing condition and weed management on CGR (g $m^{-2}day^{-1}$) and RGR (g $g^{-1}day^{-1}$) of Sida hemp at different growth stages

Treatments	CGR (g $m^{-2}day^{-1}$)								RGR (g $g^{-1}day^{-1}$)							
	0-1 MAP		1MAP-3 MAP		3MAP-5 MAP		5MAP-Harvest		0-1 MAP		1MAP-3MAP		3MAP-5MAP		5MAP-Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% Shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	9.68	8.80	16.41	7.75	22.23	14.98	21.88	18.43	0.98	0.93	0.75	0.59	0.82	0.74	1.34	1.26
Organic mulch	7.15	5.61	7.74	4.48	6.07	5.96	18.68	15.46	0.84	0.74	0.56	0.47	0.53	0.54	1.27	1.18
Hand weeding	5.76	5.06	5.42	4.68	6.36	2.85	14.10	13.25	0.76	0.71	0.51	0.48	0.55	0.36	1.15	1.11
No weeding	4.84	4.59	4.64	3.82	1.97	1.61	11.39	5.07	0.68	0.66	0.48	0.44	0.29	0.24	1.03	0.65
CD (0.05)	2.45		1.43		1.37		1.99		0.24		0.17		0.17		0.14	

4.2.2.e Soil microflora

Total population of bacteria, actinomycetes and fungi at sowing, 4 MAP and at harvest

Interaction effect of growing condition and weed management on total population of bacteria, actinomycetes and fungi are depicted in Table 41. At 4 MAP and at harvest, total population of bacteria was higher in plots with organic mulch under open condition ($24.33x10^6$ cfu g^{-1} and $19.00 x10^6$ cfu g^{-1} respectively) and the lowest colonization was found in hand weeding plot under shade ($15.17 x10^6$ cfu g^{-1} and $14.17 x10^6$ cfu g^{-1} respectively).

At 4 MAP and at harvest, total population of actinomycetes were the highest in plots with organic mulch under open condition ($76.33 x10^4$ cfu g^{-1} and $81.17x10^4$ cfu g^{-1} respectively). Hand weeding plot under shade recorded the lowest population of actinomycetes at 4 MAP ($42.50x10^4$ cfu g^{-1}) and at harvest ($47.83x10^4$ cfu g^{-1}).

At 4 MAP and at harvest, total population of fungi were higher in no weeding plot under open condition ($18.50x10^4$ cfu g^{-1} and $20.50x10^4$ cfu g^{-1} respectively). Hand weeding plots under shade recorded the lowest population of fungi at 4 MAP ($9.83x10^4$ cfu g^{-1}) and at harvest ($10.67x10^4$ cfu g^{-1}).

At 4 MAP and at harvest, total population of soil microbes were higher in plots with organic mulch under open condition ($116.50 x10^4$cfu g^{-1} and 120.33 $x10^4$cfu g^{-1} respectively). Hand weeding plot under shade recorded the lowest population of actinomycetes at 4 MAP ($67.50 x10^4$cfu g^{-1}) and at harvest (72.67 $x10^4$cfu g^{-1}).

Root colonization (%) of arbuscular mycorrhizal fungi at 1,4 MAP and at harvest

Table 42 depicts the interaction effect of growing condition and weed management on percent root colonization of arbuscular mycorrhizal fungi and soil microbial biomass carbon. At 1 MAP, 4 MAP and at harvest, significantly higher root colonization was recorded in no weeding plots under open condition (11.67 %,

15.00% and 18.33% respectively). Plots under shade did not show any colonization of AM fungi.

Soil microbial biomass carbon

At 4 MAP and at harvest, the highest soil microbial biomass carbon was recorded in no weeding plot under open condition (363 µg g^{-1} and 375.91 µg g^{-1} respectively) and the lowest was estimated from hand weeding plot under 50% shade (88µg g^{-1} and 126.71 µg g^{-1} respectively).

4.2.2.f Observation on weeds

Weed count at 1, 3, 5 MAP and at harvest

Interaction effect of growing condition and weed management on grasses count was significant (Table 43). At all growing stages plots without weeding under open condition showed highest weed count (34.67 no m^{-2}, 44.17 no m^{-2}, 54.17 no m^{-2} and 56.00no m^{-2}respectively). Broad leaved weed count was non significant at 1 MAP. However, at all other growing stages, highest weed count was observed in no weeding plots under open condition (61.67 no m^{-2}, 71.67 no $m^{-2}$and 78.00 no m^{-2} respectively). Total weed count was significant at all growing stages. Highest weed count was observed in no weeding plot under open condition (66.50 no m^{-2}, 105.83 no m^{-2}, 125.83 no m^{-2} and 134 no m^{-2} respectively).

Weed dry weight at 1, 3, 5 MAP and at harvest

There was no significant interaction of growing condition and weed management on weed dry weight at all growing stages (Table. 44).

Table 41. Interaction effect of growing condition and weed management on total population of bacteria, actinomycetes and fungi in the rhizosphere of Sida hemp at different growth stages

Treatments	Total population of bacteria ($x10^6$ cfu g^{-1})				Total population of actinomycetes ($x10^4$ cfu g^{-1})				Total population of fungus ($x10^4$ cfu g^{-1})			
	4 MAP		Harvest		4 MAP		Harvest		4 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	1.27 (18.83)	1.18 (15.33)	1.19 (15.67)	1.17 (15.00)	1.82 (67.83)	1.70 (51.00)	1.85 (72.00)	1.72 (52.67)	1.13 (14.00)	0.97 (10.00)	1.22 (17.00)	1.06 (11.67)
Organic mulch	1.38 (24.33)	1.29 (19.50)	1.27 (19.00)	1.19 (15.50)	1.88 (76.33)	1.76 (57.50)	1.90 (81.17)	1.81 (64.33)	1.19 (15.83)	1.07 (12.33)	1.29 (19.83)	1.14 (14.00)
Hand weeding	1.23 (17.17)	1.18 (15.17)	1.18 (15.50)	1.15 (14.17)	1.74 (56.67)	1.62 (42.50)	1.78 (61.17)	1.68 (47.83)	1.06 (13.00)	0.97 (9.83)	1.18 (15.33)	1.03 (10.67)
No weeding	1.31 (21.17)	1.23 (17.33)	1.24 (17.50)	1.17 (14.83)	1.85 (72.50)	1.72 (53.00)	1.88 (76.67)	1.75 (57.00)	1.25 (18.50)	0.97 (11.67)	1.30 (20.50)	1.17 (15.00)
CD (0.05)	0.09		0.06		0.08		0.07		0.19		0.09	

** Logarithmic transformed values, original values are in parentheses

Table 42. Interaction effect of growing condition and weed management on root colonization by arbuscular myccorrhizal fungi and soil microbial biomass carbonin the rhizosphere of Sida hemp at different growth stages

Treatments	Root colonization by arbuscular mycorrhizal fungi (%)						Soil microbial biomass carbon ($\mu g\ g^{-1}$) of soil			
	1 MAP		4 MAP		Harvest		4 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% Shade	Open	50% shade	Open	50% shade
Black polythene	2.56 (5.00)	0.22 (0.00)	3.06 (6.67)	0.22 (0.00)	4.51 (8.33)	0.22 (0.00)	198.00	165.00	228.56	187.30
Organic mulch	4.51 (8.33)	0.22 (0.00)	5.84 (11.67)	0.22 (0.00)	7.21 (15.00)	0.22 (0.00)	318.50	159.50	351.77	229.18
Hand weeding	0.22 (0.00)	0.22 (0.00)	0.54 (1.67)	0.22 (0.00)	1.71 (3.33)	0.22 (0.00)	181.50	88.00	195.69	126.71
No weeding	5.84 (11.67)	0.22 (0.00)	7.21 (15.00)	0.22 (0.00)	9.62 (18.33)	0.22 (0.00)	363.00	255.17	375.91	280.41
CD (0.05)	3.47		4.97		6.41		7.13		6.84	

** Arc sin transformed values, original values are in parentheses

Table 43. Interaction effect of growing condition and weed management on weed count of Sida hemp at different growth stages

Treatments	Weed count (no.m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	1.41 (1.00)	1.63 (1.67)	1.52 (1.33)	1.47 (1.17)	1.39 (1.00)	1.52 (1.33)	1.57 (1.50)	1.52 (1.33)	1.62 (1.67)	1.57 (1.50)	1.41 (1.00)	1.62 (1.67)	1.52 (1.33)	1.47 (1.17)	1.52 (1.33)	1.52 (1.33)
Organic mulch	4.01 (15.50)	3.70 (12.83)	5.20 (27.00)	4.13 (16.67)	6.12 (37.00)	5.22 (26.67)	4.61 (20.67)	4.43 (18.83)	4.18 (16.50)	3.84 (13.83)	6.78 (45.67)	5.32 (27.67)	7.49 (55.67)	6.19 (37.68)	4.56 (20.00)	4.59 (20.33)
Hand weeding	4.68 (21.83)	3.76 (13.17)	6.12 (37.17)	3.86 (15.17)	6.89 (47.47)	5.19 (26.83)	5.25 (27.50)	4.39 (18.67)	5.08 (25.17)	4.53 (19.67)	7.22 (52.17)	4.92 (23.67)	7.89 (62.17)	5.86 (33.68)	5.31 (27.50)	5.38 (28.00)
No weeding	5.79 (34.67)	3.75 (13.17)	6.67 (44.17)	4.41 (19.67)	7.39 (54.17)	5.47 (29.67)	7.48 (56.00)	5.36 (28.50)	5.69 (31.83)	4.62 (21.00)	7.83 (61.67)	4.91 (23.67)	8.46 (71.67)	5.85 (33.68)	8.82 (78.00)	6.60 (42.67)
CD (0.05)	0.96		0.46		0.43		0.87		NS		0.32		0.36		0.43	

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

Treatments	Total Weed count(no.m^{-2})							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	1.82 (2.67)	1.95 (3.17)	1.82 (2.33)	1.95 (2.83)	1.81 (2.33)	1.87 (2.50)	1.95 (2.83)	1.91 (2.67)
Organic mulch	8.49 (32.00)	6.66 (26.67)	8.49 (72.67)	6.66 (44.33)	9.62 (92.67)	8.04 (64.33)	6.42 (40.67)	6.32 (39.17)
Hand weeding	9.41 (47.00)	6.20 (32.83)	9.41 (89.33)	6.20 (38.83)	10.43 (109.33)	10.43 (60.50)	7.43 (55.00)	6.88 (46.67)
No weeding	10.24 (66.50)	6.53 (34.17)	10.24 (105.83)	6.53 (43.33)	11.19 (125.83)	11.19 (63.33)	11.52 (134.00)	8.48 (71.17)
CD (0.05)	0.37		0.52		0.38		0.71	

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

Table 44. Interaction effect of growing condition and weed management on weed dry weight of Sida hemp at different growth stages

Treatments	Weed dry weight (g m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	1.84 (3.79)	1.31 (1.80)	3.02 (5.73)	3.57 (3.64)	1.65 (2.98)	1.53 (2.74)	1.79 (2.43)	1.59 (1.59)	2.69 (6.58)	2.39 (4.75)	3.21 (9.61)	2.43 (5.03)	2.01 (3.39)	1.56 (1.52)	1.74 (2.25)	1.57 (1.49)
Organic mulch	4.85 (24.19)	4.65 (21.96)	5.34 (35.97)	4.46 (33.73)	5.34 (29.05)	5.15 (26.82)	4.36 (18.48)	4.26 (17.33)	4.98 (24.69)	5.07 (25.02)	6.11 (36.96)	6.16 (37.28)	5.54 (30.49)	5.61 (30.82)	4.96 (24.51)	5.05 (24.83)
Hand weeding	(6.56) 43.22	6.35 (40.57)	7.23 (54.99)	6.86 (52.34)	6.92 (48.08)	6.72 (45.43)	6.38 (39.88)	6.16 (37.15)	7.13 (50.04)	6.79 (45.45)	7.95 (62.30)	7.64 (57.72)	7.53 (55.84)	7.21 (51.25)	7.12 (49.85)	6.78 (45.26)
No weeding	(7.11) 50.79	6.96 (48.77)	7.91 (62.55)	7.23 (60.54)	7.45 (55.64)	7.31 (53.62)	7.09 (49.56)	6.95 (47.49)	7.34 (53.18)	7.25 (51.74)	8.14 (65.45)	8.09 (64.01)	7.73 (58.98)	7.64 (57.54)	7.33 (52.99)	7.24 (51.55)
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS	

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

Treatments	Total weed dry weight (g m^{-2})							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
Black polythene	3.27 (10.37)	2.73 (6.56)	3.96 (15.34)	3.06 (8.67)	2.33 (4.94)	1.82 (2.47)	2.12 (3.79)	2.01 (3.09)
Organic mulch	6.98 (48.89)	6.88 (46.98)	8.54 (72.93)	8.45 (71.01)	7.71 (59.55)	7.61 (57.63)	6.56 (42.98)	6.53 (42.16)
Hand weeding	9.69 (93.26)	9.30 (86.03)	10.86 (117.29)	10.52 (110.06)	10.23 (103.91)	9.86 (96.68)	9.51 (89.73)	9.10 (82.41)
No weeding	10.22 (103.97)	10.05 (100.51)	11.34 (128.00)	11.19 (124.54)	10.74 (114.62)	10.57 (111.16)	10.16 (102.56)	9.98 (99.05)
CD (0.05)	NS		NS		NS		NS	

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

4.2.3. Interaction between manuring and weed management

4.2.3.a Biometric observations

Plant height at 1, 3, 5 MAP and at harvest

Data on interaction between manuring and weed management on plant height and biomass yield per plant are depicted in Table 45. Interaction was found to be significant at all stages of observation. At 1 MAP, plants grown under black polythene mulching manured with FYM @ 10 t/ha recorded the tallest plants (13.44 cm). Lower plant height at this stage was observed in plants grown without weeding and manuring (8.55 cm) and it was on par with No weeding along with FYM @ 10 t/ha (9.02 cm). At 3 MAP, the tallest plants were noticed under black polythene mulching with manuring (108.82 cm). No weeding and no manuring resulted in lowering of plant height of Sida hemp at 3 MAP also. At 5 MAP, the tallest plants were observed in black polythene mulch with FYM @ 10 t/ha (131.58 cm). No weeding with FYM @ 10 t/ha recorded lower plant height (62.42 cm) which was on par with no weeding in no manure plots (60.38 cm). At harvest also, the taller plants were observed in black polythene with FYM @ 10 t/ha (136.85 cm) followed by organic mulch with FYM @ 10 t/ha (111.10 cm) which was on par with hand weeding with FYM @ 10 t/ha (109.87cm). The lowest plant height was recorded in no weeding no manure plot (66.47cm).

Biomass yield per plant at 1, 3, 5 MAP and at harvest

Data on interaction between manuring and weed management is given in Table 45. At 1 MAP, the biomass yield per plant was higher and on par in treatments black polythene mulching with manure (10.18 g) and black polythene mulching without manure (9.13 g). At 3 MAP, the highest biomass yield per plant was recorded in black polythene with FYM @ 10 t/ha (38.90 g) followed by black polythene without manure (28.70 g) and organic mulch with FYM @ 10 t/ha (20.03 g). Crop with organic mulch and no manure (17.17 g) was on par to hand weeding with FYM @ 10 t/ha (16.59 g). Hand weeding with FYM @ 10 t/ha (16.59 g) was on par to hand weeding without manure (14.42 g). Biomass yield per plant in hand weeding without manure (14.42 g) was on par with no weeding with and without

manure (13.92 g and 12.41 g respectively). The lower biomass yield per plant was recorded in no weeding plot with and without manure (10.79g and 9.28g respectively).

At 5 MAP, the highest biomass yield per plant was recorded in black polythene with FYM @ 10 t/ha (84.11 g) followed by black polythene without manure (57.92 g). Biomass yield per plant in organic mulch plot without manure (28.82 g) was on par to hand weeding with FYM @ 10 t/ha (27.06 g). The lowest biomass yield per plant was recorded in no manure no weeding plot (15.28 g). At harvest, the highest biomass yield was obtained from crops planted in black polythene mulch with FYM @ 10 t/ha (105.01 g) and a minimum of 21.53 g was recorded in no manure no weeding plots.

Root yield per plant at 1, 3, 5 MAP and at harvest

Interaction between manuring and weed management was found to be significant at all stages of observation (Table 46). At 1 MAP, root yield per plant was higher in plots with FYM 10 t/ha and black polythene sheet (3.76 g). It was on par with plots without manure but mulched with black polythene (3.62 g). At 3 MAP, higher root yield per plant was obtained from black polythene with FYM @ 10 t/ha (4.68 g) and was on par with organic mulch with FYM @ 10 t/ha (4.32 g) and black polythene without manure (4.03 g). At 5 MAP, the highest root yield per plant was observed under black polythene mulching with manure (7.55 g). The lowest root weight at this stage was observed in plots with no manure and no weeding (3.72 g). At harvest also the highest root yield was noticed in black polythene mulching with application of FYM @ 10 t/ha (9.43 g). Black polythene mulching under no manure situation, organic mulching with manure and without manure, hand weeding with and without manure were on par with respect to root yield per plant at harvest stage of Sida hemp (7.17 g, 6.87 g, 5.88 g, 5.11 g and 5.08 g respectively). Lower root yield was observed in plots without weeding and FYM 10 t/ha (1.39 g).

Total root yield

Interaction between manuring and weed management was found to be significant on total root yield (Table 46). The highest total root yield was obtained from black polythene mulch with FYM @ 10 t/ha (1223.87 kg ha^{-1}) and the lowest yield was recorded from no weeding plot without manure (559.07 kg ha^{-1}).

Root:shoot ratio at 1,3,5 MAP and at harvest

Non significant interaction was observed between manuring and different weed management methods on root:shoot ratio at 1 MAP (Table 46). At 3 MAP, the highest root:shoot ratio was noticed in treatment with black polythene mulching and FYM 10 t/ha (0.31). The lower values were observed in no weeding without manure (0.19) and no weeding with manure (0.21) which was on par. At 5 MAP, the root:shoot ratio was on par in treatments black polythene with manure (0.39), black polythene without manure (0.37), organic mulching with manure (0.37), hand weeding with manure (0.33) and organic mulch without manure (0.32). At harvest stage, the highest root:shoot ratio of 0.46 was observed in treatment with black polythene mulching and manuring. The lowest root:shoot ratio was noticed in plots without weeding and manuring (0.31).

Table 45. Interaction effect of manuring and weed management on plant height (cm) and biomass yield per plant (g) of Sida hemp at different growth stages

Treatments	Plant height (cm)								Biomass yield per plant (g)							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene	11.23	13.44	96.68	108.82	94.49	131.58	99.55	136.85	9.13	10.18	28.70	38.90	57.92	84.11	77.32	105.01
Organic mulch	9.58	10.75	83.88	95.92	88.81	105.95	95.13	111.10	6.08	6.69	17.17	20.03	28.82	32.43	45.03	50.37
Hand weeding	10.37	12.15	69.86	81.66	73.94	100.82	86.40	109.87	4.98	5.84	14.42	16.59	22.36	27.06	35.68	41.09
No weeding	8.55	9.02	43.59	56.04	60.38	62.42	66.47	71.40	4.61	4.84	12.41	13.92	15.28	18.21	21.53	28.42
CD (0.05)	2.01		3.48		2.79		3.65		2.01		2.33		2.32		2.73	

Table 46. Interaction effect of manuring and weed managementon root yield per plant (g) and root:shoot ratio of Sida hemp at different growth stages

Treatments	Root yield per plant (g)								Total root yield(kg ha^{-1})		Root:shoot ratio							
	1 MAP		3 MAP		5 MAP		Harvest		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene	3.62	3.76	4.03	4.68	5.59	7.55	7.17	9.43	998.93	1223.87	0.15	0.15	0.27	0.31	0.37	0.39	0.43	0.46
Organic mulch	3.41	3.47	3.70	4.32	4.58	5.03	5.88	6.87	670.133	752.00	0.14	0.14	0.25	0.27	0.32	0.37	0.39	0.43
Hand weeding	3.36	3.41	3.58	3.72	3.79	3.86	5.08	5.11	629.33	688.67	0.13	0.14	0.22	0.25	0.29	0.33	0.38	0.42
No weeding	3.24	3.33	3.42	3.63	3.72	3.82	4.65	4.76	559.07	638.00	0.12	0.13	0.19	0.21	0.24	0.28	0.31	0.36
CD (0.05)	0.24		0.97		1.87		2.13		20.57		NS		0.02		0.09		0.03	

4.2.3.b. Micro climate studies

Soil temperature

There was significant influence of manuring and weed management on soil temperature (Table 47). The highest temperature was recorded at 16th week in black polythene mulch with FYM @ 10 t/ha (28.5°C) and lowest temperature was recorded at 11th week in no manure no weeding plot (24.3°C).

Soil moisture

Interaction between manuring and weed management on soil moisture was found significant except from 2nd week to 13th week (Table 48).

Light intensity

Interaction between manuring and weed management on light intensity was found to be non significant (Table 49).

Table 47. Interaction effect of manuring and weed management on soil temperature

Treatments	Soil temperature (°C)																							
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9		Week10		Week11		Week12		Week13	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	26.4	27.5	28.0	28.3	27.6	27.9	27.0	27.4	26..9	27.2	26.6	27.3	26.4	26.8	26.2	26.4	25.9	26.3	25.9	25.9	25.9	26.0	25.3	25.9	27.3	27.9
Organic mulch	25.7	25.2	26.7	26.6	26.6	25.8	25.3	25.5	25..3	25.9	25.6	25.6	25.6	26.5	25.5	25.4	24.8	24.8	24.9	24.9	24.8	24.8	24.9	24.7	25.9	25.1
Hand weeding	25.9	25.5	26.1	26.5	26.0	26.4	25.5	26.6	25.8	26.2	26.3	26.1	25.9	25.3	25.5	25.9	25.4	25.3	25.4	25.4	25.4	25.4	25.3	25.3	26.3	26.5
No weeding	25.2	25.2	25.7	26.6	25.7	26.2	25.3	25.4	25.0	25.4	24.9	25.1	24.9	25.3	24.9	24.9	24.7	24.4	24.9	24.4	24.3	24.8	24.9	24.5	25.1	25.6
CD (0.05)	2.1		1.8		1.6		1.5		1.9		1.9		2.3		2.3		1.8		1.9		0.6		0.8		1.8	

*N - No manure

*F- FYM @ 10 t/ha

Treatments	Soil temperature (°C)																					
	Week14		Week15		Week16		Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	27.5	27.8	27.9	28.4	28.2	28.5	27.6	28.3	27.7	28.0	27.0	28.3	27.7	28.0	26.4	27.5	26.9	27.1	27.2	27.8	27.7	28.0	27.6	28.3
Organic mulch	25.8	25.2	25.9	26.3	26.5	26.1	25.3	25.7	25.9	25.1	25.9	24.1	25.9	25.1	25.7	25.2	25.4	25.3	25.8	25.2	25.9	25.1	25.3	25.7
Hand weeding	26.4	26.3	26.4	26.0	27.1	26.4	26.8	25.8	26.4	26.4	26.9	26.9	26.4	26.4	25.9	25.5	25.9	26.3	26.4	26.2	26.4	26.4	26.8	25.8
No weeding	25.2	26.2	26.3	26.6	26.5	26.4	26.1	26.9	25.4	26.4	25.2	25.5	25.4	26.4	25.2	25.2	25.2	24.8	25.2	26.2	25.4	26.4	26.1	26.9
CD (0.05)	1.9		1.3		1.6		1.7		1.9		1.9		1.9		2.1		2.2		1.9		1.9		1.7	

*N - No manure

*F- FYM @ 10 t/ha

Table 48. Interaction effect of manuring and weed management on soil moisture

Treatments	Soil moisture (%)																									
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9		Week10		Week11		Week12		Week13	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	14.9	15.8	33.0	32.5	33.3	33.5	33.0	32.5	33.3	33.5	33.0	32.5	33.3	33.5	33.0	32.5	33.3	33.5	33.0	32.5	33.3	33.5	33.0	32.5	33.3	33.5
Organic mulch	14.5	14.5	33.0	32.7	33.2	33.3	33.0	32.7	33.2	33.3	33.0	32.7	33.2	33.3	33.0	32.7	33.2	33.3	33.0	32.7	33.2	33.3	33.0	32.7	33.2	33.3
Hand weeding	13.8	13.8	32.7	32.7	32.9	33.0	32.7	32.7	32.9	33.0	32.7	32.7	32.9	33.0	32.7	32.7	32.9	33.0	32.7	32.7	32.9	33.0	32.7	32.7	32.9	33.0
No weeding	14.3	14.7	32.8	32.8	33.1	33.2	32.8	32.8	33.1	33.2	32.8	32.8	33.1	33.2	32.8	32.8	33.1	33.2	32.8	32.8	33.1	33.2	32.8	32.8	33.1	33.2
CD (0.05)	2.5		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS		NS	

*N - No manure

*F- FYM @ 10 t/ha

Treatments	Soil miosture (%)																							
	Week14		Week15		Week16		Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	16.4	15.8	15.1	14.9	15.5	15.8	15.3	15.6	16.2	14.6	16.4	15.8	15.1	14.9	14.9	14.5	14.9	15.0	14.6	14.9	14.3	15.7	14.8	15.0
Organic mulch	14.7	15.5	14.1	13.6	14.0	14.5	14.9	14.4	14.7	14.3	14.7	15.5	14.1	13.6	13.9	14.0	14.4	13.9	13.5	14.6	13.7	13.7	13.5	14.4
Hand weeding	14.6	13.8	12.9	13.6	12.9	14.0	14.0	13.9	13.0	13.4	14.6	13.8	12.9	13.6	12.6	13.3	13.1	14.1	12.7	13.2	12.9	12.8	12.7	13.5
No weeding	14.6	15.1	14.6	14.6	15.2	15.4	15.5	15.5	14.9	15.1	14.6	15.1	14.6	14.6	13.9	12.9	14.4	13.1	13.9	13.9	14.1	13.9	14.1	14.6
CD (0.05)	2.6		1.9		2.1		1.8		1.5		2.6		1.9		2.1		1.9		2.1		1.8		1.5	

*N - No manure

*F- FYM @ 10 t/ha

Table 49. Interaction effect of manuring and weed management on light intensity (lux)

Treatments	Light intensity (lux)																	
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8		Week9	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	11811.6	11876.6	11799.4	11870.4	11789.4	11836.9	11795.4	11792.0	8710.5	8705.9	7119.1	7122.6	6093.8	6112.1	5093.6	5109.1	4293.8	4612.0
Organic mulch	11791.3	11830.2	11785.7	11824.3	11775.1	11812.7	11752.9	11796.6	8672.8	8718.2	7080.2	7136.9	6056.3	6114.7	5053.4	5115.0	4556.3	4614.7
Hand weeding	11916.1	11855.7	11912.5	11849.8	11898.9	11832.9	11867.8	11803.6	8799.8	8722.4	7205.8	7142.1	6181.7	6116.3	5177.9	5119.3	4681.7	4616.7
No weeding	11912.7	11870.4	11902.3	11869.3	11901.1	11849.2	11907.8	11799.5	8819.5	8722.6	7225.9	7139.7	6205.5	6069.1	5198.4	5067.9	4705.5	4569.1
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS		NS	

*N - No manure

*F- FYM @ 10 t/ha

Treatments	Light intensity (lux)															
	Week10		Week11		Week12		Week13		Week14		Week15		Week16		Week17	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	6151.6	6165.6	7093.8	7112.0	9061.6	9126.3	11799.6	11870.4	11916.4	11951.5	11916.4	11951.5	11855.2	11868.7	11934.7	11964.6
Organic mulch	6113.1	6169.7	7056.3	7114.7	9041.3	9080.1	11785.7	11824.3	11936.6	11896.8	11936.6	11896.8	11839.2	11849.7	11949.7	11918.8
Hand weeding	6238.3	6172.7	7181.8	7116.3	9166.1	9105.7	11912.4	11849.6	12036.3	11891.8	12036.6	11891.8	11945.7	11861.1	12048.4	11913.2
No weeding	6261.5	6123.7	7205.5	7069.1	9162.7	9120.4	11902.5	11869.2	11867.8	11880.6	11867.8	11880.6	11926.4	11850.6	11879.1	11903.7
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS	

*N - No manure

*F- FYM @ 10 t/ha

Treatments	Light intensity (lux)															
	Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	N	F	N	F	N	F	N	F	N	F	N	F	N	F	N	F
Black polythene	11916.5	11931.2	11934.6	11964.5	11916.5	11931.5	11916.4	11951.3	11934.7	11964.6	11992.2	12018.7	11934.9	11957.6	11934.7	11964.6
Organic mulch	11915.9	11895.2	11949.3	11918.8	11915.9	11895.2	11936.6	11896.8	11949.7	11918.8	11993.6	11985.8	11934.9	11918.1	11949.7	11918.8
Hand weeding	12016.3	11865.1	12048.5	11913.2	12016.3	11865.1	12036.8	11891.1	12048.4	11913.2	12093.1	11977.9	12034.9	11892.3	12083.4	11913.2
No weeding	11828.0	11854.9	11879.1	11936.1	11828.3	11854.3	11867.2	11880.6	11879.1	11903.7	11933.4	11986.9	11856.7	11884.5	11879.6	11903.7
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS	

4.2.3.c Soil analysis

Soil pH

Interaction effect of manuring and weed management on pH was given in Table 50. Interaction between manuring and weed management practices were non significant with respect to pH.

Organic carbon

The interaction between manuring and weed management on organic carbon was non significant (Table 50).

Available nitrogen

A non significant interaction was observed between manuring and different weed management methods on available nitrogen (Table 50).

Available phosphorus

The interaction between manuring and weed management on available phosphorus was non significant (Table 50).

Available potassium

Significant interactions were observed between manuring and weed management practices with respect to available potassium content of soil after harvest of crop (Table 50). The highest amount of available potassium was estimated from plots with organic mulching and FYM @ 10 t/ha (338.73 kg ha^{-1}). The lower potassium contents were noticed in plots hand weeding along with no manure (121.11 kg ha^{-1}) and hand weeding with FYM 10 t/ha (132.09 kg ha^{-1}).

Table 50. Interaction effect of manuring and weed management on pH, Organic carbon(%), Available N (kg ha^{-1}), Available P (kg ha^{-1}) and Available K (kg ha^{-1})

Treatments	pH		Organic carbon (%)		Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene mulch	4.55	4.42	0.99	1.11	109.40	133.93	22.96	27.83	142.74	206.28
Organic mulch	4.60	4.49	1.11	1.13	138.84	175.74	33.86	37.58	247.07	338.73
Hand weeding	4.61	4.35	0.96	0.98	111.34	123.04	25.65	27.40	121.11	132.09
No weeding	4.58	4..48	1.02	1.10	86.99	98.56	29.22	31.49	202.32	206.73
CD (0.05)	NS		NS		NS		NS		20.15	

4.2.3.d Physiological, chemical and biochemical observations

Chlorophyll content at 1, 3, 5 MAP and at harvest

Interaction of manuring and weed management on chlorophyll content and total alkaloid is depicted in Table 51. The combined effect of manuring and weed management on chlorophyll content was found non significant.

Total alkaloid content

There was no significant influence of manuring and different weed management methods on total alkaloid content (Table 51)

Crop growth rate (CGR)

Interaction effect of manuring and weed management on CGR and RGR is given in Table 52. At 0-1 MAP, higher CGR was noticed in plots with black polythene sheet and FYM 10 t/ha (9.65 g $m^{-2}day^{-1}$) and in black polythene sheet without manure (8.82 g $m^{-2}day^{-1}$). CGR in plots with hand weeding with and without manure (5.84 g $m^{-2}day^{-1}$ and 4.98 g $m^{-2}day^{-1}$ respectively) and no weeded plots with and without manure (4.82 g $m^{-2}day^{-1}$ and 4.61 g $m^{-2}day^{-1}$ respectively) were on par and recorded lower values. At 1-3 MAP, the highest CGR was recorded in black polythene mulch under FYM @ 10 t/ha (14.63g $m^{-2}day^{-1}$) followed by black polythene mulch without manure (9.94 g $m^{-2}day^{-1}$). Crop growth rate recorded in FYM @ 10 t/ha along with organic mulch plot (6.68 g $m^{-2}day^{-1}$) was on par with organic mulch plot without manure (5.55 g $m^{-2}day^{-1}$) and FYM @ 10 t/ha plot with hand weeding (5.38 g $m^{-2}day^{-1}$). No manure plot with organic mulch was on par with hand weeding plot with FYM @ 10 t/ha (5.38 g $m^{-2}day^{-1}$) and without manure (4.72 g $m^{-2}day^{-1}$) and no weeding plot with FYM @ 10 t/ha (4.56 g $m^{-2}day^{-1}$). The lower CGR was obtained from no weeding plots with FYM @ 10 t/ha (4.56 g $m^{-2}day^{-1}$) and without manure (3.89 g $m^{-2}day^{-1}$). At 3-5 MAP, the highest CGR was obtained from black polythene plot with FYM @ 10 t/ha (22.60 g $m^{-2}day^{-1}$) and lower values from no weeding plots with FYM @ 10 t/ha (2.14 g $m^{-2}day^{-1}$) and without manure (1.44 g $m^{-2}day^{-1}$). At 5MAP to harvest, black polythene mulching along with FYM 10 t/ha

and black polythene mulching without FYM recorded higher CGR values of 20.91 g $m^{-2}day^{-1}$ and 19.40 g $m^{-2}day^{-1}$ respectively. Lowest CGR value was observed in plots with no weeding and no manure (6.25 g $m^{-2}day^{-1}$).

Relative growth rate (RGR)

Interaction effect of manuring and weed management on relative growth rate is presented in Table 52. At 0-1 MAP, RGR value of 0.98g $g^{-1}day^{-1}$was noticed under black polythene mulching with manuring. The lowest RGR value was in plots without weeding and manuring (0.66g $g^{-1}day^{-1}$). Same trends of higher and lower values of RGR were noticed at 1-3 MAP, 3-5 MAP and at 5MAP to harvest. RGR values in plots with black polythene mulching and manuring during 1-3 MAP, 3-5 MAP and at 5MAP to harvest were 0.71 g $g^{-1}day^{-1}$, 0.82 g $g^{-1}day^{-1}$ and 1.32 g g^{-1} day^{-1} respectively. RGR lower values of 0.44 g $g^{-1}day^{-1}$, 0.22 g $g^{-1}day^{-1}$ and 0.73 g $g^{-1}day^{-1}$ were noticed in plots without weeding and manuring.

Table 51. Interaction effect of manuring and weed management on chlorophyll content (mg g^{-1}) and total alkaloid (%) of Sida hemp at different growth stages

Treatments	Chlorophyll content (mg g^{-1})								Total alkaloid (%)	
	1 MAP		3 MAP		5 MAP		Harvest		Harvest	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene	9.47	10.09	10.65	11.54	11.27	11.99	11.28	12.08	0.97	1.08
Organic mulch	8.51	8.99	9.48	10.87	9.77	11.40	10.22	11.49	0.94	1.03
Hand weeding	8.40	9.82	9.45	10.74	9.67	11.17	9.94	11.16	0.93	1.00
No weeding	7.49	8.22	8.25	9.94	9.76	10.59	9.53	11.07	0.85	0.96
CD (0.05)	NS		NS		NS		NS		NS	

Table 52. Interaction effect of manuring and weed management on CGR (g $m^{-2}day^{-1}$) and RGR (g $g^{-1}day^{-1}$) of Sida hemp at different growth stages

Treatments	CGR (g $m^{-2}day^{-1}$)								RGR (g $g^{-1}day^{-1}$)							
	0-1 MAP		1MAP-3 MAP		3MAP-5 MAP		5MAP-Harvest		0-1 MAP		1MAP-3MAP		3MAP-5MAP		5MAP-Harvest	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene	8.82	9.65	9.94	14.63	14.61	22.60	19.40	20.91	0.93	0.98	0.63	0.71	0.73	0.82	1.28	1.32
Organic mulch	6.07	6.69	5.55	6.68	5.83	6.20	16.21	17.93	0.77	0.81	0.51	0.53	0.53	0.54	1.20	1.24
Hand weeding	4.98	5.84	4.72	5.38	3.97	5.24	13.31	14.03	0.69	0.76	0.48	0.51	0.41	0.49	1.12	1.14
No weeding	4.61	4.82	3.89	4.56	1.44	2.14	6.25	10.21	0.66	0.68	0.44	0.47	0.22	0.31	0.73	0.95
CD (0.05)	2.10		1.43		1.37		2.57		0.08		0.03		0.04		0.02	

4.2.3.e Soil microflora

Total population of bacteria, actinomycetes and fungi at sowing, 4MAP and at harvest

Interaction effect of manuring and weed management on total population of bacteria, actinomycetes and fungi was depicted in Table 53.At 4 MAP and at harvest, total population of bacteria was higher in plots with organic mulch with FYM @ 10 t/ha ($23.67x10^6$ cfu g^{-1} and $18.00\ x10^6$ cfu g^{-1} respectively) and the lowest colonization was found in hand weeding plot without manure ($16.00\ x10^6$ cfu g^{-1} and $14.00\ x10^6$ cfu g^{-1} respectively).

At 4 MAP and at harvest, total population of actinomycetes were highest in plots with organic mulch with FYM @ 10 t/ha ($72.67\ x10^4$ cfu g^{-1} and $77.50\ x10^4$ cfu g^{-1} respectively). Hand weeding plot without manure recorded the lowest population of actinomycetes at 4 MAP ($43.50x10^4$ cfu g^{-1}) and at harvest ($50.17\ x10^4$ cfu g^{-1}).

At 4 MAP and at harvest, total population of fungi were higher in no weeding plot with FYM @ 10 t/ha ($15.50\ x10^4$ cfu g^{-1} and $20.00\ x10^4$ cfu g^{-1} respectively). Hand weeding plot without manure recorded the lowest population of fungi at 4 MAP ($11.17\ x10^4$ cfu g^{-1}) and at harvest ($12.67\ x10^4$ cfu g^{-1}).

Root colonization (%) by arbuscular mycorrhizal fungi at 1, 4 MAP and at harvest

Data on the interaction effect of manuring and weed management on percent root colonization of arbuscular myccorrhizal fungi and soil microbial biomass carbon presented in Table 54. At 1 MAP, 4 MAP and at harvest, significantly higher root colonization was recorded in no weeding plots with FYM @ 10 t/ha (8.34 %, 11.67% and 13.34% respectively). Plots under shade did not show any colonization of AM fungi.

Soil microbial biomass carbon

At 4 MAP and at harvest, the highest soil microbial biomass carbon was recorded in no weeding plot with FYM @ 10 t/ha (354.17µg g^{-1} and 377.75 µg g^{-1} respectively) and the lowest was estimated from hand weeding plot without manure (121 µg g^{-1} and 144.58 µg g^{-1} respectively).

4.2.3.f Observation on weeds

Weed count at 1, 3, 5 MAP and at harvest

Interaction effect of manuring and weed management on grasses count was non significant at 1 MAP (Table 55). At 3 and 5 MAP, no weeding plots with FYM @ 10 t/has showed highest weed count (33.17 no $m^{-2}$and 43.17 no m^{-2}respectively). The interaction was non significant at harvest. Broad leaved weed count was non significant at 1 MAP. However, at all other growing stages, highest weed count was observed in no weeding plots with FYM @ 10 t/ha (49.17 no m^{-2}, 59.17 no m^{-2} and 68.33 no m^{-2} respectively). Total weed count was significant at 1 and 3 MAP and non significant at 5 MAP and at harvest. Highest weed count was observed in no weeding plot with FYM @ 10 t/ha (55.83 no m^{-2}, 82.33 no m^{-2}, 102.33 no m^{-2} and 116.33 no m^{-2} respectively).

Weed dry weight at 1, 3, 5 MAP and at harvest

Interaction effect of manuring and weed management on grasses dry weight was significant at all stages whereas, interaction effect on broad leaved weeds and total weeds were non significant (Table 56).

Table 53. Interaction effect of manuring and weed management on total population of bacteria, actinomycetes and fungi in the rhizosphere of Sida hemp at different growth stages

Treatments	Total population of bacteria ($x10^6$ cfu g^{-1})				Total population of actinomycetes ($x10^4$ cfu g^{-1})				Total population of fungus ($x10^4$ cfu g^{-1})			
	4 MAP		Harvest		4 MAP		Harvest		4 MAP		Harvest	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene	1.20 (16.00)	1.25 (18.17)	1.17 (14.83)	1.19 (15.83)	1.73 (53.67)	1.80 (65.17)	1.76 (57.67)	1.81 (67.00)	1.03 (11.67)	1.07 (12.33)	1.13 (14.17)	1.15 (14.50)
Organic mulch	1.30 (20.17)	1.37 (23.67)	1.22 (16.50)	1.25 (18.00)	1.78 (61.17)	1.85 (72.67)	1.83 (68.00)	1.88 (77.50)	1.12 (13.50)	1.14 (14.67)	1.19 (16.17)	1.23 (17.67)
Hand weeding	1.19 (16.00)	1.21 (16.33)	1.15 (14.00)	1.19 (15.67)	1.63 (43.50)	1.73 (55.67)	1.69 (50.17)	1.76 (58.83)	0.99 (11.17)	1.04 (11.67)	1.09 (12.67)	1.12 (13.33)
No weeding	1.24 (17.67)	1.31 (20.83)	1.20 (16.00)	1.21 (16.33)	1.75 (57.00)	1.83 (68.50)	1.79 (62.00)	1.84 (71.67)	1.07 (14.67)	1.15 (15.50)	1.18 (15.50)	1.29 (20.00)
CD (0.05)	0.09		0.06		0.08		0.07		0.19		0.09	

** Logarithmic transformed values, original values are in parentheses

Table 54. Interaction effect of manuring and weed management on root colonization by arbuscular mycorrhizal fungi and soil microbial biomass carbon in the rhizosphere of Sida hemp at different growth stages

Treatments	Root colonization by arbuscular mycorrhizal fungi (%)						Soil microbial biomass carbon ($\mu g\ g^{-1}$) of soil			
	1 MAP		4 MAP		Harvest		4 MAP		Harvest	
	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha	No manure	FYM @ 10 t/ha
Black polythene	0.22 (0.00)	2.47 (5.00)	0.42 (1.67)	2.47 (5.00)	6.15 (3.34)	2.47 (5.00)	159.50	203.50	186.80	229.06
Organic mulch	0.42 (1.67)	3.04 (6.67)	1.57 (3.34)	4.34 (8.34)	2.47 (5.00)	4.87 (10.00)	203.00	275.00	265.81	315.14
Hand weeding	0.22 (0.00)	0.22 (0.00)	0.42 (1.67)	0.22 (0.00)	0.42 (1.67)	0.42 (1.67)	121.00	148.50	144.58	177.82
No weeding	1.57 (3.34)	4.34 (8.34)	1.57 (3.34)	5.84 (11.67)	2.47 (5.00)	7.04 (13.34)	264.00	354.17	278.58	377.75
CD (0.05)	3.47		4.97		6.41		7.13		6.84	

** Arc sin transformed values, original values are in parentheses

Table 55. Interaction effect of manuring and weed management on weed count of Sida hemp at different growth stages

Treatments	Weed count (no. m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha
Black polythene	1.47 (1.17)	1.57 (1.50)	1.47 (1.17)	1.52 (1.33)	1.39 (1.00)	1.52 (1.33)	1.47 (1.17)	1.63 (1.67)	1.56 (1.50)	1.62 (1.67)	1.47 (1.17)	1.57 (1.50)	1.47 (1.17)	1.52 (1.33)	1.52 (1.33)	1.52 (1.33)
Organic mulch	3.67 (12.50)	4.05 (15.83)	4.17 (17.00)	5.17 (26.67)	5.25 (27.00)	6.08 (36.67)	4.32 (17.67)	4.72 (21.83)	3.88 (14.17)	4.14 (16.17)	5.57 (30.67)	6.53 (42.67)	6.42 (40.67)	7.27 (52.67)	4.48 (19.33)	4.67 (21.00)
Hand weeding	4.11 (16.50)	4.33 (18.50)	5.01 (24.67)	4.97 (27.67)	5.94 (34.67)	6.15 (39.33)	4.74 (22.17)	4.90 (24.00)	4.60 (20.33)	5.01 (24.50)	5.70 (32.17)	6.44 (43.67)	6.53 (42.17)	7.22 (53.67)	5.05 (24.50)	5.63 (31.00)
No weeding	4.49 (21.33)	5.05 (26.50)	5.59 (30.67)	5.49 (33.17)	6.43 (40.67)	6.43 (43.17)	6.02 (36.50)	6.82 (48.00)	4.89 (23.50)	5.46 (29.33)	6.03 (36.17)	6.71 (49.17)	6.82 (46.17)	7.49 (59.17)	7.28 (52.33)	8.14 (68.33)
CD (0.05)	NS		0.46		0.43		NS		NS		0.32		0.36		0.43	

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

Treatments	Total weeds count (no. m^{-2})							
	1 MAP		3 MAP		5 MAP		Harvest	
	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha
Black polythene	1.82 (2.67)	1.95 (3.17)	1.82 (2.33)	1.95 (2.83)	1.77 (2.17)	1.91 (2.67)	1.87 (2.50)	1.99 (3.00)
Organic mulch	6.89 (26.67)	8.26 (32.00)	6.89 (47.67)	8.26 (69.33)	8.24 (67.67)	9.42 (89.33)	6.16 (37.00)	6.58 (42.83)
Hand weeding	7.53 (36.83)	8.08 (43.00)	7.53 (56.83)	8.08 (71.33)	8.77 (76.83)	9.43 (93.00)	6.87 (46.67)	7.44 (55.00)
No weeding	8.16 (44.83)	8.60 (55.83)	8.16 (66.83)	8.60 (82.33)	9.32 (86.83)	9.81 (102.33)	9.43 (88.83)	10.57 (116.33)
CD (0.05)	0.52		0.52		NS		NS	

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

Table 56. Interaction effect of manuring and weed management on weed dry weight of Sida hemp at different growth stages

Treatments	Weed dry weight (g m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha
Black polythene	1.29 (1.86)	1.85 (3.74)	2.89 (4.10)	3.70 (5.26)	1.41 (2.44)	1.77 (3.28)	1.68 (2.07)	1.69 (1.96)	2.33 (4.57)	2.76 (6.76)	2.80 (7.23)	1.72 (7.42)	1.72 (2.26)	1.86 (2.65)	1.48 (1.25)	1.82 (2.49)
Organic mulch	4.44 (20.03)	5.06 (26.13)	5.01 (31.80)	4.79 (37.89)	4.96 (24.88)	5.53 (30.98)	3.99 (15.08)	4.63 (20.73)	4.59 (20.51)	5.46 (29.20)	5.79 (32.79)	5.19 (41.47)	5.19 (26.31)	5.96 (35.00)	4.57 (20.32)	5.43 (29.01)
Hand weeding	6.01 (36.13)	6.90 (47.66)	6.76 (47.90)	7.32 (59.83)	6.40 (40.99)	7.24 (52.52)	5.85 (33.24)	6.69 (43.78)	6.54 (41.84)	7.39 (53.65)	7.42 (54.11)	6.97 (65.92)	6.97 (47.64)	7.77 (59.45)	6.52 (41.65)	7.37 (53.46)
No weeding	6.65 (44.36)	7.43 (55.19)	7.45 (56.13)	8.19 (66.96)	7.01 (49.22)	7.75 (60.04)	6.64 (43.12)	7.41 (53.94)	6.89 (46.69)	7.69 (58.24)	7.74 (58.95)	7.30 (70.51)	7.30 (52.49)	8.06 (64.04)	6.88 (46.49)	7.68 (58.05)
CD (0.05)	0.49		2.04		0.60		0.25		NS		NS		NS		NS	

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

Treatments	Total weeds dry weight (g m^{-2})							
	1 MAP		3 MAP		5 MAP		Harvest	
	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha	No manure	FYM @10 t/ha
Black polythene	(2.68) 6.43	(3.33) 10.49	(3.42) 11.34	(3.60) 12.68	(2.33) 4.13	(1.82) 3.28	(1.94) 2.92	(2.19) 3.97
Organic mulch	(6.41) 40.55	(7.44) 55.33	(8.08) 64.58	(8.91) 79.36	(7.71) 51.19	(7.61) 65.98	(6.02) 35.40	(7.07) 49.74
Hand weeding	(8.88) 77.98	(10.11) 101.31	(10.14) 102.01	(11.23) 125.34	(10.23) 88.63	(9.86) 111.96	(8.71) 74.89	(9.90) 97.24
No weeding	(9.59) 91.05	(10.69) 113.43	(10.77) 115.08	(11.76) 137.46	(10.74) 101.70	(10.57) 124.08	(9.52) 89.62	(10.63) 111.99
CD (0.05)	NS		NS		NS		NS	

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

4.3. Three factor interactions

4.3.1. Interaction between growing condition, manuring and weed management

4.3.1.a Biometric observations

Plant height at 1, 3, 5 MAP and at harvest

Interaction effect of growing condition, manuring and weed management on plant height was non significant at 1 MAP (Table 57). At 3 MAP, the tallest plants were noticed in plots with black polythene and FYM @ 10 t/ha under 50% shade (123.33cm). The shortest plants was in no manuring no weeding plots under open condition (39.47cm). At 5 MAP also, similar trend was noticed. The highest plant height of 135.07cm was recorded in black polythene plot with FYM @ 10 t/ha under 50% shade and the lowest plant height was recorded in no manuring no weeding plot under open condition (53.40 cm). At harvest, taller plants were recorded in black polythene with FYM @ 10 t/ha under shade (139.20cm) was on par with no manuring black polythene plot under 50% shade (134.50cm). The lower plant height was recorded in no weeding plots under open condition with manure (68.43 cm) and without manure (64.50 cm).

Biomass yield per plant at 1, 3, 5 MAP and at harvest

Interaction effect of growing condition, manuring and weed management on biomass yield per plant was non significant at 1 and 3 MAP (Table 57). At 5 MAP, the highest biomass yield per plant was recorded in black polythene mulch with FYM @ 10 t/ha under open condition (103.48 g). The lower biomass yield per plant was recorded in no weeding plot with FYM @ 10 t/ha under 50% shade, no weeding no manure plot under open and 50% shade (16.93 g, 16.61 g and 13.94 g respectively). At harvest, the highest biomass yield per plant was recorded in black polythene plot with FYM @ 10 t/ha (126.56 g) in open condition and the lowest was recorded in no manuring no weeding plot under 50% shade (17.58 g).

Table 57. Interaction effect of growing condition, manuring and weed management on plant height (cm) and biomass yield per plant (g) of Sida hemp at different growth stages

Treatments	Plant height (cm)								Biomass yield per plant (g)							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	9.47	13.63	74.58	118.78	84.35	128.10	91.10	134.50	9.65	8.61	36.77	20.63	71.46	44.38	92.15	62.49
No manuring x Organic mulch	8.40	10.77	68.23	99.53	78.39	101.37	86.50	106.53	6.65	5.50	21.54	12.80	32.11	25.53	49.48	40.57
No manuring x Hand weeding	9.07	11.67	50.29	89.43	72.35	97.23	85.27	108.63	4.92	5.04	14.46	14.38	26.37	18.35	40.23	31.12
No manuring x No weeding	8.13	9.90	39.47	47.71	53.40	60.63	64.50	70.67	4.66	4.57	12.63	12.18	16.61	13.94	25.48	17.58
FYM @ 10 t/ha x Black polythene	11.60	15.28	94.30	123.33	104.63	135.07	108.00	139.20	10.75	9.60	49.26	28.55	103.48	64.73	126.56	83.47
FYM @ 10 t/ha x Organic mulch	10.27	11.23	89.30	102.53	99.23	110.53	103.77	115.67	7.65	5.72	23.72	16.35	37.41	27.46	57.38	43.33
FYM @ 10 t/ha x Hand weeding	10.87	13.43	65.65	97.67	75.53	104.40	87.53	111.10	6.60	5.08	18.73	14.44	32.24	21.88	46.59	35.60
FYM @ 10 t/ha x No weeding	6.47	10.63	57.53	54.54	67.36	64.20	68.43	72.13	5.01	4.63	15.59	12.26	19.48	16.93	33.41	23.43
CD (0.05)	NS		3.34		3.95		5.16		NS		NS		3.28		3.87	

Root yield per plant at 1, 3 ,5 MAP and at harvest

Interaction effect of growing condition, manuring and weed management on root yield per plant was significant (Table 58). At1 MAP, the higher root yield per plant was recorded in plots with FYM @ 10 t/ha and black polythene mulch under open condition (3.88g) and was on par with no manuring plots with black polythene mulch under open condition (3.67 g) and with FYM @ 10 t/ha and black polythene mulch under 50% shade (3.64 g). Lower root yield per plant was obtained from no manuring no weeding plot under open and 50% shaded condition (3.24 g). At 3 MAP, the highest root yield per plant was recorded in black polythene mulched plot with FYM @10 t/ha (5.49 g) and the lowest was from no manuring no weeding plot under shaded condition (3.29 g). At 5 MAP, the highest root yield per plant was obtained from black polythene mulched plot with FYM @10 t/ha under open condition (9.44 g) and the lowest yield was obtained from no manure no weeding plot under 50% shade (3.67 g). At harvest also black polythene mulched plot with FYM @10 t/ha under open condition followed the superiority trend in root yield per plant (11.81 g) and lower yield was obtained from no manure no weeding plot under 50% shade (4.47g).

Root:shoot ratio at 1,3,5 MAP and at harvest

At 1MAP, the higher root:shoot ratio was obtained from FYM @ 10 t/ha with black polythene mulch under open condition (0.17) which was on par with no manuring black polythene mulch under open condition (0.16), no manuring organic mulch under open condition (0.16), hand weeding with FYM @ 10 t/ha under open condition (0.16) and organic mulch with FYM @ 10 t/ha under open condition (0.15) (Table 58). At 3 MAP, higher root:shoot ratio was obtained from black polythene mulch with FYM @ 10 t/ha under open condition (0.33) and was on par with black polythene mulch without manuring under open condition (0.29), black polythene mulch with FYM @ 10 t/ha under shade (0.28), no manuring with organic mulch under open condition (0.27), hand weeding with FYM @ 10 t/ha under open condition (0.26). The lowest biomass yield per plant was obtained from no manuring no weeding plot under 50% shade (0.18).

At 5 MAP, higher root:shoot ratio was recorded in black polythene mulch with FYM @ 10 t/ha under open condition (0.43) and was on par with organic mulch with FYM @ 10 t/ha under open condition (0.40) and black polythene mulch without manure under open condition (0.40). The lower root:shoot ratio was obtained from no weeding plot without manure under open condition (0.26), hand weeding plot without manure under shade (0.26) and no manure no weeding plot under 50% shade (0.22). At harvest, the higher root:shoot ratio was obtained from black polythene and organic mulch plot with FYM @ 10 t/ha under open condition, black polythene mulch without manure under open condition (0.49, 0.46 and 0.46 respectively). Lower root:shoot ratio was obtained from no manuring no weeding plot under open and 50% shade (0.29 and 0.32 respectively).

Total root yield

Interaction effect of growing condition, manuring and weed management on total root yield was significant (Table 59). The highest total root yield was obtained from black polythene mulched plots with FYM @ 10 t/ha under open condition (1466.00 kg ha^{-1}). The lowest root yield was recorded in no weeding plots without manure under 50% shade (513.47 kg ha^{-1}).

Table 58. Interaction effect of growing condition, manuring and weed management on root yield per plant (g) and root:shoot ratio of Sida hemp at different growth stages

Treatments	Root yield per plant (g)								Root:shoot ratio							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	3.67	3.56	4.31	3.75	6.29	4.91	8.57	5.78	0.16	0.14	0.29	0.25	0.40	0.33	0.46	0.40
No manuring x Organic mulch	3.44	3.38	3.94	3.46	5.10	4.06	6.42	5.35	0.16	0.13	0.27	0.23	0.35	0.29	0.43	0.36
No manuring x Hand weeding	3.42	3.30	3.76	3.39	3.87	3.73	5.22	5.01	0.13	0.12	0.24	0.19	0.33	0.26	0.40	0.37
No manuring x No weeding	3.24	3.24	3.55	3.29	3.76	3.67	4.84	4.47	0.12	0.11	0.20	0.18	0.26	0.22	0.29	0.32
FYM @ 10 t/ha x Black polythene	3.88	3.64	5.49	3.87	9.44	5.66	11.81	7.05	0.17	0.13	0.33	0.28	0.43	0.36	0.49	0.43
FYM @ 10 t/ha x Organic mulch	3.55	3.39	4.88	3.76	5.69	4.37	7.82	5.92	0.15	0.14	0.29	0.25	0.40	0.33	0.46	0.40
FYM @ 10 t/ha x Hand weeding	3.48	3.36	3.86	3.59	3.98	3.75	5.11	5.04	0.16	0.13	0.26	0.23	0.36	0.30	0.45	0.39
FYM @ 10 t/ha x No weeding	3.38	3.27	3.77	3.49	3.85	3.75	4.94	4.57	0.13	0.12	0.22	0.20	0.29	0.26	0.35	0.36
CD (0.05)	0.25		0.37		1.68		2.44		0.03		0.07		0.04		0.03	

Table 59. Interaction effect of growing condition, manuring and weed management on total root yield of Sida hemp at harvest

Treatments	Total root yield (kg ha^{-1})	
	Harvest	
	Open	50% shade
No manuring x Black polythene	1192.40	805.47
No manuring x Organic mulch	745.20	595.07
No manuring x Hand weeding	708.93	549.73
No manuring x No weeding	604.67	513.47
FYM @ 10 t/ha x Black polythene	1466.00	981.73
FYM @ 10 t/ha x Organic mulch	885.20	618.80
FYM @ 10 t/ha x Hand weeding	767.33	610.00
FYM @ 10 t/ha x No weeding	688.93	587.07
CD (0.05)	29.09	

4.3.1.b Microclimate studies

Soil temperature at 10 cm depth

The interaction effect of growing condition, manuring and weed management on soil temperature was significant (Table 60). The highest temperature was recorded at 15th week in black polythene mulch with FYM @ 10 t/ha under open condition (29.1 ^{0}C). Lower temperature was recorded in 1st and 21st week in no manuring no weeding plot under 50% shade (23.7 ^{0}C).

Soil moisture at 10 cm depth

The interaction effect of growing condition, manuring and weed management on soil moisture was significant except from 2nd week to 13th week (Table 61).

Light intensity

The interaction effect of growing condition, manuring and weed management on light intensity was significant (Table 62). The highest light intensity was recorded at 23rd week in no manure, hand weeding plot under open condition (19792.9 lux). Lower light intensity was recorded in 9th week in no weeding plot with FYM @ 10 t/ha under 50% shade (355.9 lux).

Table 60.Interaction effect of growing condition, manuring and weed management on soil temperature (^{0}C)

Treatments	Soil temperature (°C)															
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	27.0	25.7	28.6	27.4	27.8	27.4	27.3	26.8	27.3	26.5	27.1	26.1	27.3	26.3	26.6	25.7
No manuring x Organic mulch	26.6	24.8	26.8	26.6	26.3	26.9	26.3	24.4	25.3	25.2	25.8	25.4	25.7	25.5	25.5	25.5
No manuring x Hand weeding	27.1	24.8	26.7	25.6	26.6	25.5	25.9	25.1	25.9	25.7	26.9	25.7	26.4	25.6	25.5	25.5
No manuring x No weeding	26.7	23.7	26.2	25.3	26.2	25.2	25.7	24.8	25.1	24.9	25.5	24.5	25.3	24.5	25.4	24.3
FYM @ 10 t/ha x Black polythene	28.3	26.7	28.6	28.0	28.0	27.8	27.3	27.4	27.1	27.2	27.3	27.4	27.3	25.5	26.5	26.4
FYM @ 10 t/ha x Organic mulch	25.5	25.0	26.7	26.4	26.1	25.4	25.5	25.4	25.7	25.9	25.9	25.2	26.2	26.7	25.5	25.3
FYM @ 10 t/ha x Hand weeding	25.9	25.0	26.9	26.1	26.7	26.1	26.4	26.9	26.0	26.3	26.1	26.1	26.1	24.5	26.4	25.3
FYM @ 10 t/ha x No weeding	25.3	25.1	26.6	26.6	26.8	25.7	26.0	24.8	25.9	24.9	25.8	24.4	25.8	24.8	25.6	24.3
CD (0.05)	2.9		2.6		2.3		2.1		2.7		2.8		3.3		3.2	

*O - Open

*S - Shade

Treatments	Soil temperature (°C)															
	Week 9		Week 10		Week 11		Week 12		Week 13		Week 14		Week 15		Week 16	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	26.5	25.3	26.4	25.6	26.3	25.5	25.2	25.4	27.5	27.1	27.7	27.4	27.2	28.6	28.7	28.4
No manuring x Organic mulch	24.3	25.3	24.4	25.5	24.4	25.3	24.4	25.3	26.2	25.7	26.0	25.6	25.7	26.2	26.6	26.5
No manuring x Hand weeding	25.3	25.6	25.4	25.4	25.4	25.4	25.3	25.3	26.7	26.0	26.6	26.2	26.1	26.8	26.6	27.6
No manuring x No weeding	25.2	24.3	25.5	24.5	25.3	24.4	25.3	24.4	26.0	24.2	26.1	24.2	26.8	25.8	26.2	26.6
FYM @ 10 t/ha x Black polythene	26.2	26.5	25.4	26.4	25.6	26.4	25.5	26.2	28.6	27.2	28.5	27.1	29.1	27.7	27.7	28.7
FYM @ 10 t/ha x Organic mulch	24.3	25.2	24.3	25.5	24.3	25.4	24.2	25.2	25.2	25.1	25.3	25.1	26.5	26.2	25.8	26.5
FYM @ 10 t/ha x Hand weeding	25.3	25.2	25.4	25.4	25.4	25.3	25.2	25.3	26.2	26.7	25.6	26.9	25.5	26.7	27.3	25.4
FYM @ 10 t/ha x No weeding	24.5	24.3	24.3	24.4	24.2	24.4	24.1	24.8	25.7	25.5	26.7	25.8	26.2	26.9	25.4	27.4
CD (0.05)	2.6		2.7		0.9		1.2		2.6		2.7		1.8		2.2	

*O - Open

*S - 50% Shade

Treatments	Soil temperature (°C)																	
	Week 17		Week 18		Week 19		Week 20		Week 21		Week 22		Week 23		Week 24		Week 25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	28.1	28.4	27.9	27.4	29.2	27.4	27.9	27.4	27.0	25.7	27.9	25.8	27.7	27.4	27.9	27.4	28.1	28.4
No manuring x Organic mulch	25.1	25.5	26.3	25.5	26.6	25.2	26.3	25.5	26.6	24.8	26.5	24.2	26.0	25.6	26.3	25.5	25.1	25.5
No manuring x Hand weeding	25.9	27.7	26.8	26.0	27.3	26.6	26.8	26.0	27.1	24.8	26.9	24.9	26.6	26.2	26.8	26.0	25.9	27.7
No manuring x No weeding	27.0	25.2	26.5	24.2	25.7	24.7	26.5	24.2	26.7	23.7	25.9	24.5	26.1	24.2	26.5	24.2	27.0	25.2
FYM @ 10 t/ha x Black polythene	27.5	27.8	28.6	27.4	27.3	26.8	28.6	27.4	28.3	26.7	27.5	26.6	28.6	27.1	28.6	27.4	27.5	27.8
FYM @ 10 t/ha x Organic mulch	24.9	26.5	25.3	25.1	24.7	23.4	25.2	25.1	25.5	25.0	25.5	25.0	25.3	25.1	25.2	25.1	24.9	26.5
FYM @ 10 t/ha x Hand weeding	26.1	25.5	25.9	26.9	27.4	26.5	25.9	26.9	25.9	25.0	26.6	26.0	25.6	26.9	25.9	26.9	26.1	25.5
FYM @ 10 t/ha x No weeding	25.9	27.8	26.7	25.9	25.9	25.2	26.7	25.9	25.3	25.1	25.2	24.4	26.7	25.8	26.7	25.9	25.9	27.8
CD (0.05)	2.4		2.7		2.6		2.7		2.9		3.1		2.8		2.7		2.4	

*O - Open

*S - 50% Shade

Table 61. Interaction effect of growing condition, manuring and weed management on soil moisture (%)

Treatments	Soil moisture (%)															
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	14.5	15.3	32.7	32.8	32.8	32.8	32.7	32.8	32.8	32.8	32.7	32.8	32.8	32.8	32.7	32.8
No manuring x Organic mulch	14.5	14.5	32.6	32.8	32.8	32.9	32.6	32.8	32.8	32.9	32.6	32.8	32.8	32.9	32.6	32.8
No manuring x Hand weeding	13.3	14.4	32.2	32.4	32.4	32.5	32.2	32.4	32.4	32.5	32.2	32.4	32.4	32.5	32.2	32.4
No manuring x No weeding	14.3	14.3	32.6	32.6	32.6	32.7	32.6	32.6	32.6	32.7	32.6	32.6	32.6	32.7	32.6	32.6
FYM @ 10 t/ha x Black polythene	15.6	15.9	32.7	32.8	32.8	32.9	32.7	32.8	32.8	32.9	32.7	32.8	32.8	32.9	32.7	32.8
FYM @ 10 t/ha x Organic mulch	14.4	14.7	32.7	32.8	32.8	32.8	32.7	32.8	32.8	32.8	32.7	32.8	32.8	32.8	32.7	32.8
FYM @ 10 t/ha x Hand weeding	13.3	14.4	32.3	32.4	32.4	32.4	32.3	32.4	32.4	32.4	32.3	32.4	32.4	32.4	32.3	32.4
FYM @ 10 t/ha x No weeding	14.2	15.3	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7
CD (0.05)	3.5		NS		NS		NS		NS		NS		NS		NS	

*O - Open *S - 50% Shade

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Treatments	Soil moisture (%)															
	Week 9		Week 10		Week 11		Week 12		Week 13		Week 14		Week 15		Week 16	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	32.8	32.8	33.4	33.5	32.8	32.8	33.4	33.5	32.8	32.8	14.4	15.5	14.2	14.9	15.5	17.4
No manuring x Organic mulch	32.8	32.9	33.2	33.4	32.8	32.9	33.2	33.4	32.8	32.9	13.4	15.4	13.4	13.6	13.9	15.4
No manuring x Hand weeding	32.4	32.5	33.0	33.1	32.4	32.5	33.0	33.1	32.4	32.5	12.4	13.7	11.9	13.4	14.3	14.9
No manuring x No weeding	32.6	32.7	33.3	33.4	32.6	32.7	33.3	33.4	32.6	32.7	13.8	15.0	13.2	14.5	14.1	15.2
FYM @ 10 t/ha x Black polythene	32.8	32.9	32.9	32.9	32.8	32.9	32.9	32.9	32.8	32.9	14.5	15.5	14.2	15.5	15.3	16.4
FYM @ 10 t/ha x Organic mulch	32.8	32.8	32.8	32.9	32.8	32.8	32.8	32.9	32.8	32.8	13.4	14.5	13.9	15.3	14.6	16.4
FYM @ 10 t/ha x Hand weeding	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	32.4	14.0	14.3	12.5	13.9	12.8	14.8
FYM @ 10 t/ha x No weeding	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	32.7	12.4	13.9	13.6	14.2	14.4	15.7
CD (0.05)	NS		NS		NS		NS		NS		3.8		2.7		3.1	

*O - Open

*S - 50% Shade

Treatments	Soil moisture(%)																	
	Week 17		Week 18		Week 19		Week 20		Week 21		Week 22		Week 23		Week 24		Week 25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	14.5	15.6	14.2	15.6	14.4	15.5	14.2	14.9	14.3	14.3	14.3	15.2	14.4	15.0	14.5	15.6	14.2	15.6
No manuring x Organic mulch	13.5	14.6	13.3	14.6	13.4	15.4	13.4	13.6	13.2	14.1	13.4	13.6	13.4	13.6	13.5	14.6	13.3	14.6
No manuring x Hand weeding	12.0	13.9	11.9	13.3	12.4	13.7	11.9	13.4	11.9	13.9	11.9	13.4	12.0	13.3	12.0	13.9	11.9	13.3
No manuring x No weeding	14.2	15.1	12.9	14.9	13.8	15.0	13.2	14.5	13.3	14.9	13.7	14.5	13.6	14.1	14.2	15.1	12.9	14.9
FYM @ 10 t/ha x Black polythene	14.2	15.5	13.8	15.2	14.5	15.5	14.2	15.5	14.4	16.9	14.5	15.5	14.7	15.6	14.2	15.5	13.8	15.2
FYM @ 10 t/ha x Organic mulch	12.9	14.3	13.6	14.4	13.4	14.5	13.9	15.3	13.0	14.3	14.3	14.5	14.4	14.8	12.9	14.3	13.6	14.4
FYM @ 10 t/ha x Hand weeding	12.7	14.5	13.2	13.4	14.0	14.3	12.5	13.9	12.3	13.3	13.4	13.5	13.9	13.1	12.7	14.5	13.2	13.4
FYM @ 10 t/ha x No weeding	13.8	15.4	12.4	13.4	12.4	13.9	13.6	14.2	13.1	14.7	14.4	14.7	14.6	14.7	13.8	15.4	12.4	13.4
CD (0.05)	2.6		2.2		3.8		2.7		2.9		2.7		2.9		2.6		2.2	

*O - Open

*S - 50% Shade

Table 62. Interaction effect of growing condition, manuring and weed management on light intensity (lux)

Treatments	Light intensity (lux)															
	Week1		Week2		Week3		Week4		Week5		Week6		Week7		Week8	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	19390.0	4233.2	19373.3	4225.4	19360.0	4218.8	19380.0	4210.7	14300.7	3120.2	11221.4	3016.9	10200.0	1987.7	9194.0	993.2
No manuring x Organic mulch	19460.0	4122.6	19456.7	4114.6	19433.3	4116.8	19376.7	4129.1	14290.7	3054.8	11211.4	2949.1	10190.0	1922.6	9190.7	916.1
No manuring x Hand weeding	19580.0	4252.3	19566.7	4258.1	19556.7	4241.2	19573.7	4162.9	14523.1	3076.5	11429.1	2981.9	10400.0	1963.5	9393.7	1041.3
No manuring x No weeding	19573.3	4252.0	19566.7	4238.3	19573.3	4167.2	19574.4	4241.2	14475.8	3163.3	11375.9	3075.9	10361.0	2049.6	9355.5	1041.3
FYM @ 10 t/ha x Black polythene	19540.0	4213.1	19533.3	4207.5	19506.7	4172.1	19460.7	4171.8	14381.8	3030.0	11302.5	2942.9	10281.4	1942.5	9282.2	936.0
FYM @ 10 t/ha x Organic mulch	19454.3	4207.0	19446.7	4202.0	19453.3	4179.2	19421.4	4166.4	14342.5	3093.5	11262.6	3011.1	10248.9	1988.2	9241.8	988.2
FYM @ 10 t/ha x Hand weeding	19520.0	4191.4	19513.3	4186.2	19486.7	4178.5	19440.8	4171.8	14361.9	3082.8	11275.0	3009.7	10282.3	1983.7	9248.2	990.3
FYM @ 10 t/ha x No weeding	19540.0	4200.7	19540.0	4198.5	19520.0	4172.6	19460.4	4138.5	14382.8	3062.5	11303.2	2976.1	10245.6	1855.9	9282.2	853.5
CD (0.05)	62.1		63.8		45.1		12.4		12.7		12.9		73.7		73.2	

*O - Open

*S - 50% Shade

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Treatments	Light intensity (lux)															
	Week9		Week10		Week11		Week12		Week13		Week14		Week15		Week16	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	8700.0	487.7	10246.7	2056.6	11200.0	2987.6	14390.0	3733.2	19373.3	4225.4	19580.0	4252.7	19580.0	4252.7	19466.7	4243.8
No manuring x Organic mulch	8690.0	422.6	10243.3	1982.8	11190.0	2922.6	14460.0	3622.6	19456.6	4114.8	19590.0	4283.2	19590.0	4322.2	19483.3	4196.4
No manuring x Hand weeding	8900.0	463.5	10453.7	2022.9	11400.0	2963.5	14580.0	3752.2	19566.7	4258.1	19750.0	4322.6	19750.0	4235.6	19653.7	4234.8
No manuring x No weeding	8861.4	549.6	10421.7	2101.3	11361.0	3049.6	14573.3	3752.0	19566.7	4207.5	19500.0	4235.6	19500.0	4303.1	19580.0	4272.8
FYM @ 10 t/ha x Black polythene	8741.4	442.9	10334.4	1996.7	11281.4	2942.7	14540.0	3713.1	19533.3	4202.0	19600.0	4303.1	19560.0	4233.6	19533.3	4204.2
FYM @ 10 t/ha x Organic mulch	8781.2	488.2	10295.4	2043.9	11241.2	2988.8	14453.3	3707.1	19446.3	4186.2	19560.0	4233.3	19550.0	4232.3	19486.7	4213.2
FYM @ 10 t/ha x Hand weeding	8748.9	483.7	10308.5	2036.9	11248.9	2983.8	14520.0	3691.4	19513.3	4198.5	19550.0	4232.3	19540.0	4221.2	19510.0	4212.2
FYM @ 10 t/ha x No weeding	8782.3	355.9	10334.5	1912.6	11282.3	2855.9	14540.0	3700.7	19540.0	4207.5	19540.0	4221.2	19560.0	4232.3	19520.0	4181.2
CD (0.05)	73.7		74.4		73.6		62.2		63.8		33.7		33.7		78.2	

*O – Open

*S - 50% Shade

Treatments	Light intensity (lux)																	
	Week17		Week18		Week19		Week20		Week21		Week22		Week23		Week24		Week25	
	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S	O	S
No manuring x Black polythene	19600.0	4269.4	19580.0	4253.0	19600.0	4269.3	19580.0	4253.0	19580.0	4252.7	19600.0	4269.4	19660.0	4324.3	19600.0	4269.9	19600.0	4269.4
No manuring x Organic mulch	19596.7	4302.7	19550.0	4322.5	19596.6	4302.7	19550.0	4281.9	19590.0	4283.2	19596.7	4302.7	19623.3	4363.9	19566.7	4303.1	19596.7	4302.7
No manuring x Hand weeding	19757.4	4339.4	19710.0	4196.1	19757.4	4339.4	19710.1	4302.9	19750.0	4235.6	19757.4	4339.4	19792.9	4393.2	19730.7	4339.3	19757.4	4339.4
No manuring x No weeding	19500.3	4257.9	19460.0	4302.9	19500.3	4257.9	19460.0	4233.7	19500.0	4322.6	19500.3	4257.9	19543.8	4322.2	19482.1	4231.4	19500.3	4257.9
FYM @ 10 t/ha x Black polythene	19601.1	4328.0	19560.0	4233.7	19601.1	4328.0	19560.0	4220.3	19600.0	4235.6	19601.1	4328.2	19643.9	4393.9	19581.7	4333.5	19601.1	4328.0
FYM @ 10 t/ha x Organic mulch	19580.5	4257.2	19556.7	4281.9	19580.4	4257.1	19510.2	4302.1	19560.0	4303.1	19580.5	4257.2	19648.6	4323.1	19580.8	4255.5	19580.5	4257.2
FYM @ 10 t/ha x Hand weeding	19570.7	4255.7	19513.0	4220.3	19561.0	4255.6	19556.2	4209.7	19550	4233.6	19570.7	4255.7	19632.5	4323.3	19543.7	4240.7	19561.0	4255.7
FYM @ 10 t/ha x No weeding	19561.0	4246.3	19500.0	4209.7	19570.7	4246.3	19510.2	4220.3	19540	4232.3	19561.0	4246.3	19623.2	4314.8	19534.4	4234.5	19570.7	4246.3
CD (0.05)	36.4		6.3		36.4		6.3		33.7		36.4		11.1		18.0		36.4	

*O - Open

*S - 50% Shade

4.3.1.c Soil analysis

Soil pH

Interaction effect of growing condition, manuring and weed management on pH is given in Table 63. Interaction between growing condition, manuring and weed management practices were non significant with respect to pH.

Organic carbon

The interaction between growing condition, manuring and weed management on organic carbon was non significant (Table 63).

Available nitrogen

A non significant interaction was observed between growing condition, manuring and weed management on available nitrogen (Table 63).

Available phosphorus

The interaction between growing condition, manuring and weed management on available phosphorus was non significant (Table 63).

Available potassium

Significant interaction was observed between growing condition, manuring and weed management practices with respect to available potassium content of soil after harvest of the crop (Table 63). The highest amount of available potassium was estimated from plots with organic mulching and FYM @ 10 t/ha under open condition (391.09 kg/ha). The lower potassium contents were noticed in black polythene mulch plots along with no manure under open condition (121.14 kg/ha), hand weeding with FYM @ 10 t/ha under open condition (120.94 kg/ha) and hand weeding without manure under open condition (119.64 kg/ha).

Table 63. Interaction effect of growing condition, manuring and weed management on pH, organic carbon (%), available N (kg/ha), available P (kg/ha) and available K (kg/ha) of Sida hemp at harvest

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 manuring x Black polythene	4.63	4.47	1.01	0.98	124.50	94.31	21.61	24.31	121.14	162.33
No manuring x Organic mulch	4.59	4.39	1.09	1.13	152.25	125.42	33.26	34.45	229.65	264.48
No manuring x Hand weeding	4.69	4.64	0.94	0.97	110.21	112.47	21.87	29.43	119.64	142.57
No manuring x No weeding	4.56	4.59	0.98	1.05	91.24	82.73	26.04	32.40	193.82	230.83
FYM @ 10 t/ha x Black polythene	4.32	4.51	1.03	1.18	136.29	131.57	27.13	28.53	196.65	215.92
FYM @ 10 t/ha x Organic mulch	4.60	4.61	1.11	1.15	181.59	169.89	36.62	38.53	391.09	286.38
FYM @ 10 t/ha x Hand weeding	4.32	4.37	0.94	1.01	125.44	120.64	23.36	31.45	120.94	143.26
FYM @ 10 t/ha x No weeding	4.62	4.65	1.09	1.11	100.26	96.86	28.43	34.55	388.47	284.99
CD (0.05)	NS		NS		NS		NS		3.05	

4.3.1.d Physiological, chemical and biochemical observations

Chlorophyll content at 1, 3, 5 MAP and at harvest

A non significant interaction was observed between growing condition, manuring and weed management on chlorophyll content (Table 64).

Total alkaloid content at harvest

The interaction between growing condition, manuring and weed management on total alkaloid content of roots at harvest was significant (Table 64). Higher total alkaloid content of 3.31 % was recorded from plants grown with FYM @10 t/ha and black polythene mulching under open condition. However, it was on par with all other treatment combinations of manure and weed management methods under open condition.

Crop growth rate (CGR)

Interaction effect of growing condition, manuring and weed management on CGR and RGR is given in Table 65. At 0-1 and 1-3 MAP, CGR was found no significant. At 3-5 MAP, the highest CGR was obtained from black polythene plot with FYM @ 10 t/ha under open condition (27.11 g $m^{-2}day^{-1}$) and lowest CGR was obtained from no weeding plots without manure under shade (0.88 g $m^{-2}day^{-1}$). At 5MAP to harvest, higher CGR value was recorded in black polythene plot with FYM @ 10 t/ha under open condition (24.07 g $m^{-2}day^{-1}$), black polythene plot without manure under open condition (20.69 g $m^{-2}day^{-1}$) and organic mulch plot with FYM @ 10 t/ha under open condition (19.99g $m^{-2}day^{-1}$).

Relative growth rate (RGR)

Interaction effect of growing condition, manuring and weed management on relative growth rate is presented in Table 65. At 0-1 and 1-3 MAP, RGR was non significant. At 3-5 MAP, the highest RGR was obtained from black polythene plot with FYM @ 10 t/ha under open condition (0.87g $g^{-1}day^{-1}$). The lowest RGR was recorded in no weeding plots without manure under shade (0.15 g $g^{-1}day^{-1}$). 5 MAP to harvest, higher RGR was recorded in black polythene mulch with FYM @ 10 t/ha under open condition (1.50 g $g^{-1}day^{-1}$) and black polythene mulch without manure under open condition (1.31 g $g^{-1}day^{-1}$).

Table 64. Interaction effect of growing condition, manuring and weed management on chlorophyll content (mg g^{-1}) and total alkaloid (%) of Sida hemp at different growth stages

Treatments	Chlorophyll content (mg g^{-1})								Total alkaloid (%)	
	1 MAP		3 MAP		5 MAP		Harvest		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	8.60	10.34	9.12	12.18	10.07	12.47	10.05	12.51	3.08	2.86
No manuring x Organic mulch	7.49	9.52	7.98	10.97	8.23	11.32	9.09	11.35	3.07	2.79
No manuring x Hand weeding	8.32	8.47	8.54	10.35	8.59	10.74	8.48	11.39	3.04	2.81
No manuring x No weeding	7.81	7.17	8.23	8.26	9.05	10.47	8.44	10.63	2.94	2.75
FYM @ 10 t/ha x Black polythene	9.16	11.00	9.85	13.23	10.15	13.83	10.40	13.75	3.31	2.84
FYM @ 10 t/ha x Organic mulch	8.49	9.49	9.33	12.40	9.42	13.38	9.61	13.38	3.24	2.82
FYM @ 10 t/ha x Hand weeding	9.05	10.59	9.22	12.27	9.78	12.56	9.78	12.55	3.23	2.78
FYM @ 10 t/ha x No weeding	7.92	8.51	8.04	11.85	9.13	12.04	9.47	12.69	3.16	2.76
CD (0.05)	NS		NS		NS		NS		0.40	

Table 65. Interaction effect of growing condition, manuring and weed management on CGR (g $m^{-2}day^{-1}$) and RGR (g $g^{-1}day^{-1}$) of Sida hemp at different growth stages

Treatments	CGR (g $m^{-2}day^{-1}$)								RGR (g $g^{-1}day^{-1}$)							
	0-1 MAP		1MAP-3 MAP		3MAP-5 MAP		5MAP-Harvest		0-1 MAP		1MAP-3MAP		3MAP-5MAP		5MAP-Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	9.65	8.00	13.57	6.01	17.34	11.88	20.69	18.11	0.98	0.88	0.71	0.54	0.77	0.69	1.31	1.25
No manuring x Organic mulch	6.65	5.50	7.44	3.65	5.29	6.37	17.37	15.05	0.81	0.73	0.58	0.43	0.50	0.55	1.24	1.17
No manuring x Hand weeding	4.92	5.04	4.77	4.67	5.96	1.99	13.86	12.77	0.69	0.70	0.49	0.48	0.54	0.28	1.13	1.09
No manuring x No weeding	4.66	4.57	3.98	3.81	1.99	0.88	8.87	3.63	0.67	0.66	0.45	0.43	0.29	0.15	0.92	0.53
FYM @ 10 t/ha x Black polythene	9.71	9.60	19.25	9.48	27.11	18.09	24.07	18.74	0.98	0.97	0.79	0.63	0.87	0.77	1.50	1.27
FYM @ 10 t/ha x Organic mulch	7.65	5.72	8.03	5.32	6.85	5.56	19.99	15.87	0.87	0.75	0.54	0.51	0.56	0.52	1.29	1.19
FYM @ 10 t/ha x Hand weeding	6.60	5.08	6.07	4.68	6.76	3.72	14.34	13.72	0.82	0.71	0.54	0.48	0.56	0.43	1.16	1.13
FYM @ 10 t/ha x No weeding	5.01	4.63	5.29	3.82	1.95	2.34	13.92	6.49	0.69	0.66	0.51	0.44	0.28	0.33	1.13	0.77
CD (0.05)	NS		NS		1.94		5.28		NS		NS		0.09		0.20	

4.3.1.e Soil microflora

Total population of bacteria, actinomycetes and fungi at sowing, 4MAP and at harvest

Interaction effect of growing condition, manuring and weed management on total population of bacteria, actinomycetes and fungi is depicted in Table 66. At 4 MAP and at harvest, total population of bacteria was higher in plots with organic mulch with FYM @ 10 t/ha under open condition (27.0 $x10^6$ cfu g^{-1} and 20.3 $x10^6$ cfu g^{-1} respectively) and the lower colonization were found in hand weeding plot without manure under shade, black polythene mulch without manure under shade (15.0 $x10^6$ cfu g^{-1} and 13.7 $x10^6$ cfu g^{-1} respectively).At 4 MAP and at harvest, total population of actinomycetes were highest in plots with organic mulch with FYM @ 10 t/ha under open condition (86.3$x10^4$ cfu g^{-1} and 91.3 $x10^4$ cfu g^{-1} respectively). Hand weeding plot without manure under shade recorded the lowest population of actinomycetes at 4 MAP (40.0$x10^4$ cfu g^{-1}) and at harvest (47.7 $x10^4$ cfu g^{-1}).At 4 MAP and at harvest, total population of fungi were higher in no weeding plot with FYM @ 10 t/ha under open condition (19.0 $x10^4$ cfu g^{-1} and 1.36 $x10^4$ cfu g^{-1} respectively). Hand weeding plot without manure recorded the lowest population of fungi at 4 MAP (8.3 $x10^4$ cfu g^{-1}) and at harvest (10.0$x10^4$ cfu g^{-1}).

Root colonization (%) by arbuscular mycorrhizal fungi at 1,4 MAP and at harvest

Data on interaction effect of growing condition, manuring and weed management on percent root colonization of arbuscular myccorrhizal fungi and soil microbial biomass carbon are presented in Table 67. The highest root colonization was recorded in no weeding plots with FYM @ 10 t/ha under open condition at 1, 4 MAP and at harvest (16.67 %, 23.33% and 26.67% respectively). Under shaded condition, colonization of AM fungi was not observed.

Soil microbial biomass carbon

At 4 MAP and at harvest, the highest soil microbial biomass carbon was recorded in no weeding plot with FYM @ 10 t/ha under open condition (418.00µg g^{-1} and 436.38 µg g^{-1} respectively) and the lowest was estimated from hand weeding plot without manure (77.00 µg g^{-1} and121.23 µg g^{-1} respectively).

Table 66. Interaction effect of growing condition, manuring and weed management on total population of bacteria, actinomycetes and fungi in the rhizosphere of Sida hemp at different growth stages

Treatments	Total population of bacteria(x10^6 cfu g^{-1})				Total population of actinomycetes(x10^4 cfu g^{-1})				Total population of fungus(x10^4 cfu g^{-1})			
	4 MAP		Harvest		4 MAP		Harvest		4 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	1.23 (17.0)	1.17 (15.0)	1.18 (15.0)	1.14 (13.7)	1.77 (58.7)	1.69 (48.7)	1.79 (63.3)	1.72 (52.0)	1.13 (14.0)	0.93 (9.3)	1.24 (18.0)	1.01 (10.3)
No manuring x Organic mulch	1.33 (21.7)	1.27 (18.7)	1.25 (17.7)	1.18 (15.3)	1.82 (66.3)	1.74 (56.0)	1.84 (71.0)	1.81 (65.0)	1.17 (15.0)	1.07 (12.0)	1.28 (19.7)	1.10 (12.7)
No manuring x Hand weeding	1.23 (17.0)	1.17 (15.0)	1.14 (13.7)	1.16 (14.3)	1.67 (47.0)	1.59 (40.0)	1.72 (52.7)	1.67 (47.7)	1.00 (12.0)	0.90 (8.3)	1.19 (15.7)	1.00 (10.0)
No manuring x No weeding	1.27 (19.0)	1.21 (16.3)	1.23 (17.0)	1.18 (15.0)	1.79 (63.3)	1.70 (50.7)	1.83 (68.0)	1.75 (56.0)	1.25 (18.0)	0.98 (11.3)	1.25 (18.0)	1.11 (13.0)
FYM @ 10 t/ha x Black polythene	1.30 (20.7)	1.19 (15.7)	1.21 (16.3)	1.18 (15.3)	1.88 (77.0)	1.72 (53.3)	1.91 (80.7)	1.72 (53.3)	1.12 (14.0)	1.00 (10.7)	1.19 (16.0)	1.11 (13.0)
FYM @ 10 t/ha x Organic mulch	1.43 (27.0)	1.31 (20.3)	1.29 (20.3)	1.19 (15.7)	1.93 (86.3)	1.77 (59.0)	1.96 (91.3)	1.80 (63.7)	1.21 (16.7)	1.08 (12.7)	1.30 (20.0)	1.17 (15.3)
FYM @ 10 t/ha x Hand weeding	1.23 (17.3)	1.18 (15.3)	1.23 (17.3)	1.15 (14.0)	1.82 (66.3)	1.65 (45.0)	1.84 (69.7)	1.68 (48.0)	1.12 (14.0)	0.96 (9.3)	1.17 (15.0)	1.01 (10.3)
FYM @ 10 t/ha x No weeding	1.36 (23.3)	1.25 (18.3)	1.25 (18.0)	1.17 (14.7)	1.91 (81.7)	1.74 (53.3)	1.93 (85.3)	1.76 (58.0)	1.25 (19.0)	1.04 (12.0)	1.36 (23.0)	1.22 (17.0)
CD (0.05)	0.14		0.09		0.11		0.10		0.28		0.14	

** Logarithmic transformed values, original values are in parentheses

Table 67. Interaction effect of growing condition, manuring and weed management on root colonization by arbuscular mycorrhizal fungi and soil microbial biomass carbon in the rhizosphere of Sida hemp at different growth stages

Treatments	Root colonization by arbuscular mycorrhizal fungi (%)						Soil microbial biomass carbon ($\mu g\ g^{-1}$) of soil			
	1 MAP		4 MAP		Harvest		4 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	0.22 (0.00)	0.22 (0.00)	1.45 (3.33)	0.22 (0.00)	3.54 (6.67)	0.22 (0.00)	176.00	143.00	190.22	183.38
No manuring x Organic mulch	1.45 (3.33)	0.22 (0.00)	3.54 (6.67)	0.22 (0.00)	4.88 (10.00)	0.22 (0.00)	252.00	154.00	304.31	227.31
No manuring x Hand weeding	0.22 (0.00)	0.22 (0.00)	1.45 (3.33)	0.22 (0.00)	1.45 (3.33)	0.22 (0.00)	165.00	77.00	167.92	121.23
No manuring x No weeding	3.54 (6.67)	0.22 (0.00)	3.54 (6.67)	0.22 (0.00)	4.88 (10.00)	0.22 (0.00)	308.00	220.00	315.44	241.71
FYM @ 10 t/ha x Black polythene	4.88 (10.00)	0.22 (0.00)	4.88 (10.00)	0.22 (0.00)	4.88 (10.00)	0.22 (0.00)	220.00	187.00	266.90	191.22
FYM @ 10 t/ha x Organic mulch	7.05 (13.33)	0.22 (0.00)	8.71 (16.67)	0.22 (0.00)	10.07 (20.00)	0.22 (0.00)	385.00	165.00	399.22	231.05
FYM @ 10 t/ha x Hand weeding	0.22 (0.00)	0.22 (0.00)	0.22 (0.00)	0.22 (0.00)	1.45 (3.33)	0.22 (0.00)	198.00	99.00	223.46	132.18
FYM @ 10 t/ha x No weeding	8.71 (16.67)	0.22 (0.00)	11.84 (23.33)	0.22 (0.00)	13.37 (26.67)	0.22 (0.00)	418.00	290.33	436.38	319.11
CD (0.05)	4.91		7.01		9.01		10.08		9.67	

** Arc sin transformed values, original values are in parentheses

4.3.1.f Observation on weeds

Weed count at 1, 3, 5 MAP and at harvest

Interaction effect of growing condition, manuring and weed management on weed count at different growth stages are depicted in Table 68. At 1 MAP, the interaction was non significant for grasses. At 3, 5 MAP and at harvest, higher weed count was recorded in no weeding plots with FYM @ 10 t/ha under open condition (53.67 no.m^{-2}, 63.71 no.m^{-2} and 68.71 no.m^{-2} respectively). Broad leaved weeds count was non significant at 1 MAP. However in all other growing stages broad leaved weed count was significant with higher density in no weeding plot with FYM @ 10 t/ha under open condition (78.67 no.m^{-2}, 88.70no.m^{-2} and 96.66 no.m^{-2}). At 1, 3, 5 MAP and at harvest the highest total weed count was observed in no weeding plots with FYM @ 10 t/ha under open condition (72 no.m^{-2}, 132.3 no.m^{-2}, 152.3 no.m^{-2} and 165.3 no.m^{-2} respectively).

Weed dry weight at 1, 3, 5 MAP and at harvest

Interaction effect of growing condition, manuring and weed management on weed count at different growth stages were non significant (Table 69).

Weed control efficiency (WCE)

Weed control efficiency ranged from 10.2% to 93.7% at 1 MAP. Higher weed control efficiency was recorded in no manure plot with black polythene mulch under shade (93.7 %) (Table 70). Black polythene mulch with FYM @ 10 t/ha under shade and black polythene mulch without manure under open condition also showed more than 90 per cent weed control efficiency. Lower weed control efficiency was recorded in hand weeding plot with FYM @ 10 t/ha under open condition (10.2 %). At 3 MAP, weed control efficiency ranged from 8.3 % to 93.6 %. Higher WCE was recorded in black polythene mulch with FYM @ 10 t/ha under shade (93.6 %) and lower WCE was recorded in hand weeding plot without manure under open condition (8.3 %). At 5 MAP, weed control efficiency was ranged from 9.3 % to 98.9 %. Higher WCE was recorded in black polythene mulch with FYM @ 10 t/ha under shade (98.9 %) and lower WCE was recorded in hand weeding plot with FYM @ 10 t/ha under open condition (9.3 %). Weed control efficiency ranged from 12.4 % to 97.1 % at harvest. Higher WCE was recorded in black polythene mulch with FYM @ 10 t/ha under shade (97.1 %) and lower WCE was recorded in hand weeding plot without manure under open condition (12.4 %).

Weed index

Maximum weed index was recorded in no weeding plots with FYM under open condition (53%) and minimum weed index was recorded in organic mulch plots without manure under shade (26.1 %) (Table 70).

4.3.1.g Economics

The data on economics (Rs ha^{-1}) of cultivation of Sida hemp under different growing condition, manuring and weed management is furnished in Table 71. Highest cost of cultivation was observed with black polythene mulch with FYM @ 10 t/ha in open condition and in 50% shade, black polythene mulch with FYM @10 t/ha (Rs. 72250) and the lowest cost of cultivation was observed in no weeding without manure in open condition (Rs. 35,000). A higher B:C ratio of 1.73 was obtained from black polythene mulch with manure under open condition. Hand weeding with and without manure under shaded condition recorded lower B:C ratio (0.82).

Table 68. Interaction effect of growing condition, manuring and weed management on weed count at different growth stages

Treatments	Weed count (no. m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	1.41 (1.00)	1.52 (1.33)	1.52 (1.33)	1.41 (1.00)	1.28 (0.67)	1.52 (1.33)	1.41 (1.00)	1.52 (1.33)	1.52 (1.33)	1.61 (1.67)	1.41 (1.00)	1.52 (1.33)	1.52 (1.33)	1 41 (1.00)	1.52 (1.33)	1.52 (1.33)
No manuring x Organic mulch	3.74 (13.00)	3.59 (12.00)	4.45 (19.33)	3.88 (14.67)	5.48 (29.33)	5.03 (24.67)	4.24 (17.00)	4.39 (18.33)	4.15 (16.33)	3.61 (12.00)	6.12 (36.67)	5.03 (24.67)	6.89 (46.67)	5.95 (34.67)	4.67 (21.00)	4.29 (17.67)
No manuring x Hand weeding	4.49 (20.00)	3.74 (13.00)	5.42 (28.67)	4.61 (20.67)	6.28 (38.67)	5.60 (30.67)	5.01 (25.00)	4.47 (19.33)	4.93 (23.33)	4.28 (17.33)	6.28 (38.67)	5.13 (25.67)	7.03 (48.67)	6.03 (35.67)	4.97 (23.67)	4.96 (25.33)
No manuring x No weeding	5.52 (31.67)	3.46 (11.00)	5.95 (34.67)	5.23 (26.67)	6.74 (44.67)	6.12 (36.66)	6.62 (43.33)	5.43 (29.67)	5.48 (29.33)	4.31 (17.67)	6.74 (44.67)	5.32 (27.67)	7.45 (54.67)	6.19 (37.67)	7.76 (59.33)	5.13 (45.33)
FYM @ 10 t/ha x Black polythene	1.41 (1.00)	1.73 (2.00)	1.52 (1.33)	1.52 (1.33)	1.52 (1.33)	1.52 (1.33)	1.73 (2.00)	1.52 (1.33)	1.72 (2.00)	1.52 (1.33)	1.41 (1.00)	1.72 (2.00)	1.52 (1.33)	1.52 (1.33)	1.52 (1.33)	6.79 (1.33)
FYM @ 10 t/ha x Organic mulch	4.29 (18.00)	3.81 (13.67)	5.95 (34.67)	4.38 (18.67)	6.74 (44.67)	5.42 (28.67)	4.98 (24.33)	4.47 (19.33)	4.20 (16.67)	4.08 (15.67)	7.45 (54.67)	5.60 (30.67)	8.09 (64.67)	6.44 (40.67)	4.49 (19.00)	1.52 (23.00)
FYM @ 10 t/ha x Hand weeding	4.87 (23.67)	3.78 (13.33)	6.82 (45.67)	3.12 (9.67)	7.52 (55.67)	4.78 (23.00)	5.49 (30.00)	4.32 (18.00)	5.24 (27.00)	4.79 (22.00)	8.16 (65.67)	47.17 (21.67)	8.75 (75.67)	5.69 (31.67)	5.65 (31.33)	4.89 (30.67)
FYM @ 10 t/ha x No weeding	6.06 (37.67)	4.04 (15.33)	7.38 (53.67)	3.60 (12.67)	8.03 (63.71)	4.82 (22.67)	8.34 (68.71)	5.29 (27.33)	5.90 (34.33)	5.02 (24.33)	8.92 (78.67)	4.49 (19.67)	9.46 (88.70)	55.10 (29.67)	9.88 (96.66)	5.62 (40.00)
CD (0.05)	NS		0.65		0.61		0.32		NS		0.45		0.51		6.57	

Treatments	Total weed count (no. m^{-2})							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	1.8 (2.3)	1.8 (3.0)	1.8 (2.3)	1.8 (2.3)	1.7 (2.0)	1.8 (2.3)	1.8 (2.3)	1.9 (2.7)
No manuring x Organic mulch	7.5 (29.3)	6.3 (24.0)	7.5 (56.0)	6.3 (39.33)	8.7 (76.0)	7.2 (59.3)	6.2 (38.0)	6.1 (36.0)
No manuring x Hand weeding	8.2 (43.3)	6.8 (30.3)	8.2 (67.3)	6.8 (46.3)	9.4 (87.3)	8.2 (66.3)	6.9 (48.67)	6.8 (44.7)
No manuring x No weeding	8.9 (61.0)	7.4 (28.7)	8.9 (79.3)	7.4 (54.3)	9.9 (99.3)	8.7 (74.3)	10.2 (102.7)	8.7 (75.0)
FYM @ 10 t/ha x Black polythene	1.8 (3.0)	2.1 (3.3)	1.8 (2.3)	2.1 (3.3)	1.9 (2.7)	1.9 (2.7)	2.1 (3.3)	1.9 (2.7)
FYM @ 10 t/ha x Organic mulch	9.5 (34.7)	7.0 (29.3)	9.4 (89.3)	7.0 (49.33)	10.5 (109.3)	8.4 (69.3)	6.6 (43.3)	6.6 (42.3)
FYM @ 10 t/ha x Hand weeding	10.6 (50.7)	5.6 (35.3)	10.5 (111.3)	5.6 (31.3)	11.5 (131.3)	7.4 (52.3)	7.9 (61.3)	7.0 (48.7)
FYM @ 10 t/ha x No weeding	11.5 (72.0)	5.7 (39.7)	11.5 (132.3)	5.7 (32.3)	12.4 (152.3)	7.3 (52.3)	12.9 (165.3)	8.2 (67.3)
CD (0.05)	0.7		0.74		0.8		0.9	

Table 69. Interaction effect of growing condition, manuring and weed management on weed dry weight at different growth stages

Treatments	Weed dry weight (g m^{-2})															
	Grasses								Broad leaved							
	1 MAP		3 MAP		5 MAP		Harvest		1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	1.47 (2.41)	1.12 (1.30)	2.13 (4.83)	3.64 (3.37)	1.45 (2.41)	1.36 (2.46)	1.79 (2.66)	1.56 (1.47)	2.37 (4.83)	2.30 (9.16)	3.12 (3.19)	2.49 (1.34)	1.93 (3 19)	1.51 (1.34)	1.39 (0.99)	1.57 (1.51)
No manuring x Organic mulch	4.49 (20.78)	4.38 (19.29)	5.66 (32.55)	4.35 (31.05)	5.01 (25.63)	4.89 (24.14)	3.96 (14.91)	4.03 (15.25)	4.37 (18.63)	4.83 (30.90)	5.62 (24.43)	5.96 (28.19)	4.99 (24.23)	5.39 (28.19)	4.34 (18.44)	4.80 (22.20)
No manuring x Hand weeding	6.12 (37.43)	5.90 (34.83)	7.01 (49.20)	6.52 (46.60)	6.50 (42.29)	6.29 (39.69)	5.96 (34.51)	5.74 (31.97)	6.80 (45.29)	6.28 (57.56)	7.65 (51.09)	7.18 (44.19)	7.22 (51.09)	6.72 (44.19)	6.79 (45.11)	6.26 (38.19)
No manuring x No weeding	6.73 (45.37)	6.58 (43.35)	7.56 (57.14)	7.34 (55.12)	7.08 (50.23)	6.94 (48.21)	6.71 (44.02)	6.57 (42.20)	6.91 (47.05)	6.87 (59.32)	7.76 (52.85)	7.72 (52.12)	7.32 (52.85)	7.29 (52.12)	6.90 (46.86)	6.86 (46.13)
FYM @ 10 t/ha x Black polythene	2.20 (5.17)	1.50 (2.30)	3.89 (6.62)	3.50 (3.90)	1.84 (3.54)	1.69 (3.01)	1.78 (2.21)	1.62 (1.71)	3.03 (8.33)	2.48 (10.07)	3.29 (3.60)	2.37 (1.70)	2.09 (3.60)	1.62 (1.70)	2.08 (3.51)	1.57 (1.49)
FYM @ 10 t/ha x Organic mulch	5.21 (27.62)	4.92 (24.64)	5.02 (39.38)	4.57 (36.41)	5.66 (32.47)	5.39 (29.49)	4.77 (22.04)	4.48 (19.41)	5.59 (30.76)	5.32 (43.02)	6.59 (36.56)	6.36 (33.44)	6.09 (36.56)	5.83 (33.44)	5.57 (30.57)	5.29 (27.45)
FYM @ 10 t/ha x Hand weeding	6.99 (49.01)	6.80 (46.31)	7.44 (60.78)	7.21 (58.08)	7.34 (53.86)	7.15 (51.17)	6.79 (45.24)	6.58 (42.32)	7.46 (54.78)	7.31 (67.04)	8.24 (60.56)	8.10 (58.32)	7.84 (60.58)	7.69 (58.32)	7.45 (54.59)	7.29 (52.33)
FYM @ 10 t/ha x No weeding	7.49 (56.19)	7.36 (54.18)	8.26 (67.96)	8.12 (65.95)	7.81 (61.05)	7.68 (59.04)	7.49 (55.10)	7.33 (52.78)	7.76 (59.31)	7.62 (71.58)	8.52 (65.11)	8.39 (62.96)	8.03 (65.11)	7.99 (62.96)	7.75 (59.12)	7.61 (56.97)
CD (0.05)	NS		NS		NS		NS		NS		NS		NS		NS	

Treatments	Weed dry weight (g m^{-2})							
	Total weeds							
	1 MAP		3 MAP		5 MAP		Harvest	
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	2.79 (7.24)	2.56 (5.61)	3.78 (13.99)	3.06 (8.67)	2.33 (4.63)	2.13 (3.64)	1.89 (2.86)	1.97 (2.98)
No manuring x Organic mulch	6.31 (39.41)	6.51 (41.68)	7.99 (63.45)	8.15 (65.71)	7.11 (50.07)	7.28 (52.33)	5.84 (33.35)	6.19 (37.45)
No manuring x Hand weeding	9.15 (82.73)	8.61 (73.22)	10.38 (106.76)	9.91 (97.25)	9.72 (93.38)	9.21 (83.87)	8.98 (79.62)	8.43 (70.17)
No manuring x No weeding	9.67 (92.43)	9.51 (89.67)	10.84 (116.46)	10.70 (113.70)	10.19 (103.08)	10.06 (100.32)	9.58 (90.89)	9.45 (88.35)
FYM @ 10 t/ha x Black polythene	3.75 (13.50)	2.91 (7.49)	4.15 (16.69)	3.06 (8.66)	2.34 (5.25)	1.51 (1.31)	2.34 (4.73)	2.05 (3.20)
FYM @ 10 t/ha x Organic mulch	7.64 (58.37)	7.24 (52.28)	9.08 (82.41)	8.74 (76.32)	8.31 (69.03)	7.95 (62.94)	7.27 (52.61)	6.87 (46.86)
FYM @ 10 t/ha x Hand weeding	10.23 (103.79)	9.99 (98.83)	11.34 (127.82)	11.12 (122.87)	10.74 (114.44)	10.51 (109.49)	10.04 (99.83)	9.77 (94.65)
FYM @ 10 t/ha x No weeding	10.79 (115.51)	10.59 (111.35)	11.85 (139.54)	11.68 (135.38)	11.27 (126.16)	11.09 (122.00)	10.73 (114.23)	10.52 (109.75)
CD (0.05)	NS		NS		NS		NS	

Table 70. Interaction effect of growing condition, manuring and weed management on weed control efficiency and weed index at different growth stages

Treatments	WCE (%)								WI (%)	
	1 MAP		3 MAP		5 MAP		Harvest			
	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade	Open	50% shade
No manuring x Black polythene	92.2	93.7	87.9	92.4	95.5	96.4	96.8	96.6	-	-
No manuring x Organic mulch	57.4	53.5	45.5	42.2	51.4	47.8	63.3	57.6	37.5	26.1
No manuring x Hand weeding	10.5	18.4	8.3	14.5	9.4	16.4	12.4	20.6	40.6	31.8
No manuring x No weeding	-	-	-	-	-	-	-	-	49.3	36.3
FYM @ 10 t/ha x Black polythene	88.3	93.3	88.0	93.6	95.8	98.9	95.9	97.1	-	-
FYM @ 10 t/ha x Organic mulch	49.5	53.0	40.9	43.6	45.3	48.4	53.9	57.3	47.7	36.9
FYM @ 10 t/ha x Hand weeding	10.2	11.2	8.4	9.2	9.3	10.3	12.6	13.8	39.6	37.9
FYM @ 10 t/ha x No weeding	-	-	-	-	-	-	-	-	53.0	40.2

Table 71. Interaction effect of growing condition, manuring and weed management on Benefit : Cost ratio

Treatments	Cost of cultivation (Rs/ha)	Gross income (Rs/ha)	Net income (Rs/ha	B:C ratio
A1B1C1	66250	101354.00	35104.00	1.53
A1B1C2	43688	63342.00	19654.00	1.45
A1B1C3	57250	60259.33	3009.33	1.05
A1B1C4	35000	51396.67	16396.67	1.47
A1B2C1	72250	124610.00	52360.00	1.73
A1B2C2	49688	65223.33	15535.33	1.31
A1B2C3	63250	75242.00	11992.00	1.19
A1B2C4	41000	58559.33	17559.33	1.43
A2B1C1	66250	68464.67	2214.67	1.03
A2B1C2	43688	50580.67	6892.67	1.16
A2B1C3	57250	46727.33	-10522.67	0.82
A2B1C4	35000	43644.67	8644.67	1.25
A2B2C1	72250	83447.33	11197.33	1.15
A2B2C2	49688	52598.00	2910.00	1.06
A2B2C3	63250	51850.00	-11400.00	0.82
A2B2C4	41000	49900.67	8900.67	1.22

A1 – Open
A2 – 50% shade
B1 – No manure
B2 – FYM @ 10 t/ha
C1 – Black polythene sheet
C2 – Organic mulch
C3 – Hand weeding
C4 – No weeding

- Labour charges (Rs.600/day)
- Cost of polythene sheet – Rs.7/m^{-2}
- Cost of FYM – Rs. 1200/tonne
- Cost of organic mulch – Rs.6/Kg

Discussion

5. DISCUSSION

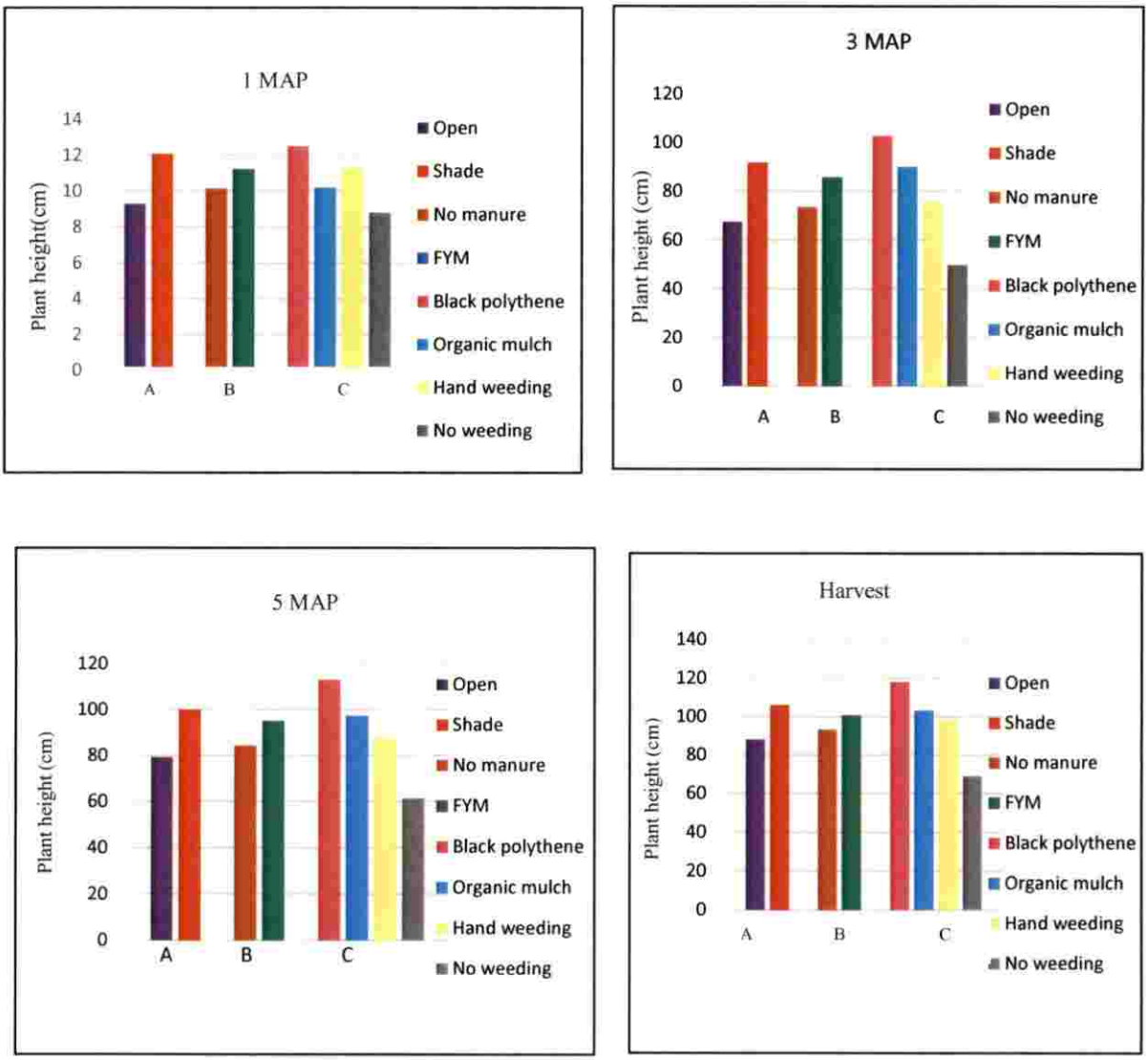
The experiment entitled "Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management" was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during 2018. The direct effects of treatments obtained from the experiment are discussed below based on available literature.

5.1 Effect of growing condition, manuring and weed management on growth and yieldof Sida hemp

5.1.1 Plant height

In general, the plant height increased from first month and continued its increasing trend till harvest (Table 4, Fig. 4). Taller plants were observed under 50 per cent shaded condition throughout the growth stages (12.07cm, 91.69cm, 100.19cm and 106.07cm respectively at 1, 3, 5 MAP and at harvest). Compared to open condition, under shade, light intensity was lower whereas, soil moisture was higher (Table10, Table 9).Soil moisture showed a positive correlation and light intensity showed a negative correlation with plant height(Table 20). According to Abdel-Mawgoud (1995), plants grown under shade try to increase capturing of intercepted light by increasing interception area which leads to increased plant height. Latha and Radhakrishnan (2015), also observed increase in height of *Sida cordifolia* L. under shaded condition.

Increased plant height was observed with FYM @ 10 t/ha throughout the growth stages (Table 4, Fig. 4). FYM application has been reported to improve crop growth by supplying plant nutrients including micronutrients as well as improving soil physical, chemical and biological properties (Dejene and Lemlem, 2012). Plants under black polythene mulch recorded taller plants during all stages of observation. Mulching with paddy straw was the next best treatment with respect to plant height. In Solanum, increase in plant height due to mulching with black polythene was reported by Kaur (2015). According to Pramanik (1999), plant height and crop growth were increased under paddy straw mulching. Increase in plant height in treatments with mulching can be related to favourable micro climatic parameters observed under mulched soil as compared to bare soil.



A-Growing condition B-Manuring C-Weed management

Fig. 4. Effect of growing condition, manuring and weed management on plant height at different growth stages of Sida hemp

5.1.2 Biomass yield per plant

In general, the biomass yield per plant increased from 1 MAP to harvest (Table 5 and Fig. 5). Higher biomass per yield was recorded in crops grown under open condition at 1, 3, 5 MAP and at harvest (6.99g, 24.09g, 42.39g and 58.91g respectively). Under open condition, soil temperature was high as compared to shade. Biomass yield per plant had showed a positive correlation with soil temperature (Table 20). Preference of open condition for better growth and performance of *Sida cordifolia* was reported by Latha and Radhakrishnan (2015). Significant variation was observed for biomass yield per plant with manuring. The highest biomass yield per plant was obtained in FYM @ 10 t/ha plots at all growth stages (Fig. 5). Improved biomass yield and crop growth of different crops with addition of FYM was reported by Dejene and Lemlem (2012).

Weed management significantly influenced the biomass yield per plant of *Sida alnifolia*. Black polythene mulching recorded the highest per plant biomass yield of 9.65 g, 33.80 g, 71.01g and 91.17 g at 1 MAP, 3 MAP, 5 MAP and at harvest respectively (Table 5 and Fig. 5). Significant increase in biomass yield of chilli with black polythene mulching was reported by Ashrafuzzaman *et al.* (2011). High soil moisture retention, optimum soil temperature and reduced weed density (Table 8, 9 and 16) might have contributed to the increased biomass yield per plant under black polythene mulch.

5.1.3 Root:shoot ratio

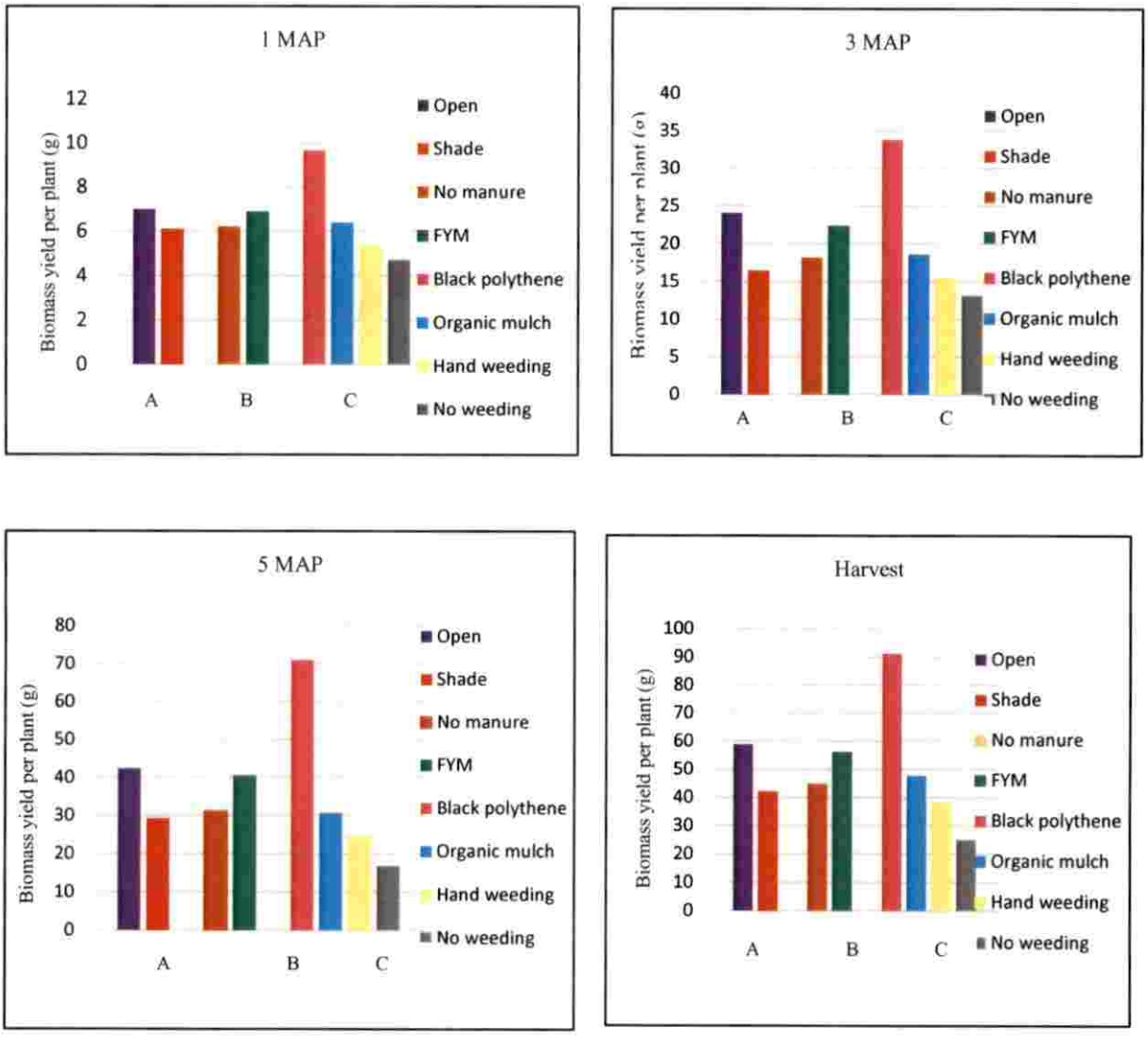
Growing condition, manuring and weed management significantly influenced the root:shoot ratio of *Sida alnifolia* (Table 7 and Fig. 6). Lower root:shoot ratio was observed under shaded condition throughout growth period. This can be correlated with higher plant height and lower biomass yield per plant under shade (Table 4 and 5). Under open condition, soil temperature and light intensity was higher. Root:shoot ratio showed a positive correlation with soil temperature and light intensity (Table 20). In wheat, a negative correlation of root: shoot ratio with plant height was reported by Mc Caig and Morgan (1993). Higher root:shoot ratio was recorded in FYM applied plots at 1 MAP, 3 MAP, 5 MAP and harvest (0.14, 0.26, 0.34 and 0.42 respectively). According to Ibrahim *et al.* (2010), FYM provides a better environment for root development by improving the soil structure and this could be

the reason for the increase in root volume and root yield with FYM application. Among different weed management, black polythene mulching recorded higher root:shoot ratio. This might be due to better microclimate under black polythene mulch.

5.1.4 Total root yield

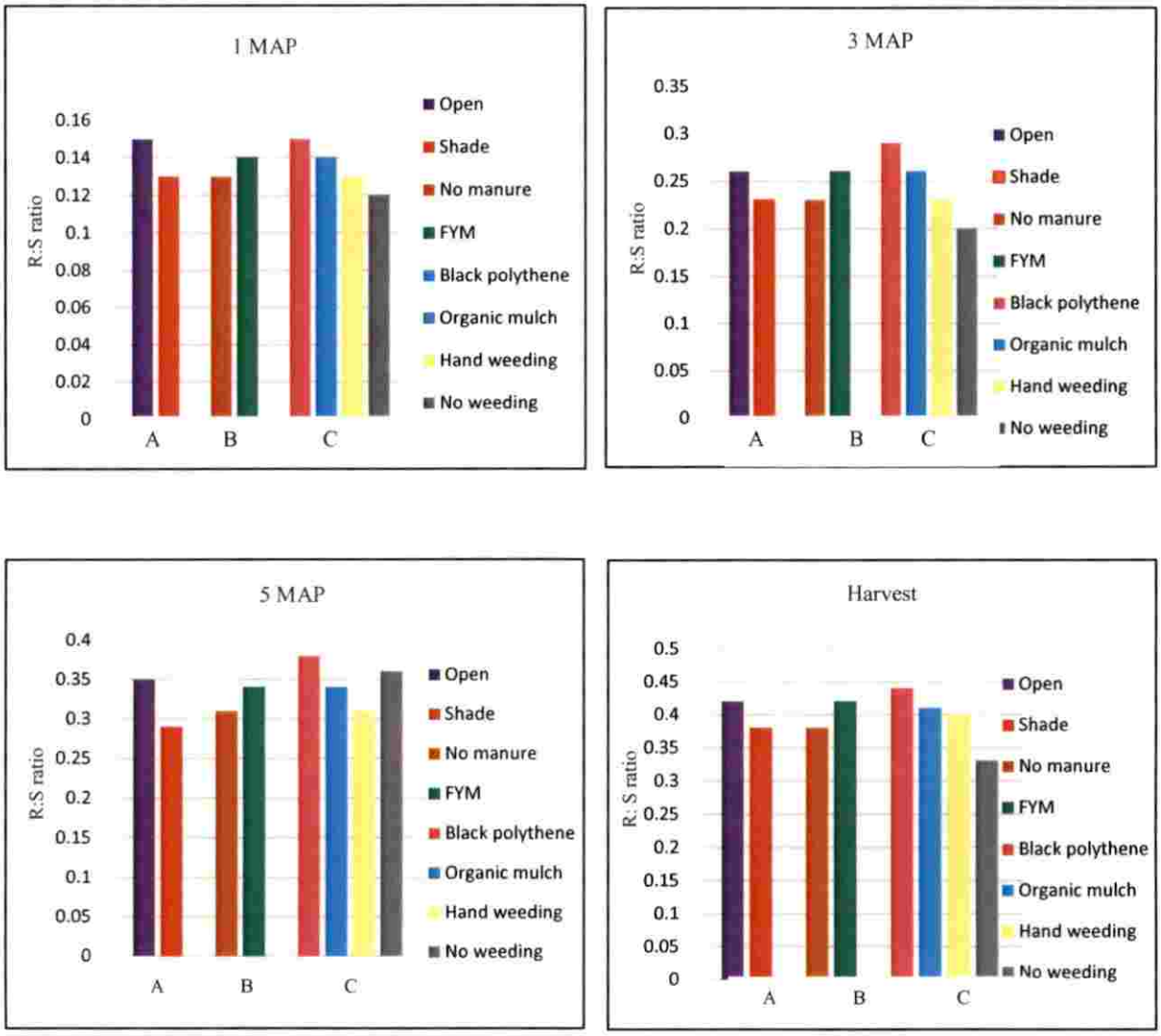
Growing condition, manuring and weed management significantly influenced the total root yield of *Sida alnifolia* (Table 6 and Fig. 7). The highest yield of 882.33 kg/ha was recorded in crops grown under open condition. The yield under shaded condition was only 657.67 kg/ha. A strong positive correlation was observed between biomass yield per plant, root shoot ratio and root yield (Table 18). Biomass yield and root shoot ratio were higher under open condition. Microclimatic factors like soil temperature and light intensity were better under open condition. Both at vegetative and harvesting stage, yield showed a positive correlation with these two (Table 19). According to Latha and Radhakrishnan (2015), the yield and yield attributing characters like number of roots, root yield per plant and root length were considerably higher under open condition. Lower root yield under shade might be due to more vegetative growth as indicated by taller plants and poor allocation of assimilates to root portion. Manuring and black polythene mulching continued their beneficial effect with respect to total root yield also. Improved biomass production, better root shoot ratio and favourable micro climatic parameters experienced in these plots with manuring and mulching with black polythene sheet might have contributed to enhanced root yield. According to Stone and Ekwue (1995) manure application improves soil physical properties which in turn improve crop growth and yield.

Interaction effect of growing condition, manuring and weed management was significant with respect to total yield (Table 56 and Fig. 8). The highest total yield was recorded in treatment combination, black polythene mulching with FYM under open condition followed by black polythene mulching without manure under open condition (Table 6). Under best treatment combination of manuring and weed management (FYM @ 10 t/ha x black polythene), by altering only growing condition, a yield increase of 500kg could be observed. This indicates the sun loving nature of *Sida alnifolia*. Growing condition, nutrient availability, optimum macro and micro meteorological conditions and reduced weed infestation in this combination might have contributed to higher root yield.



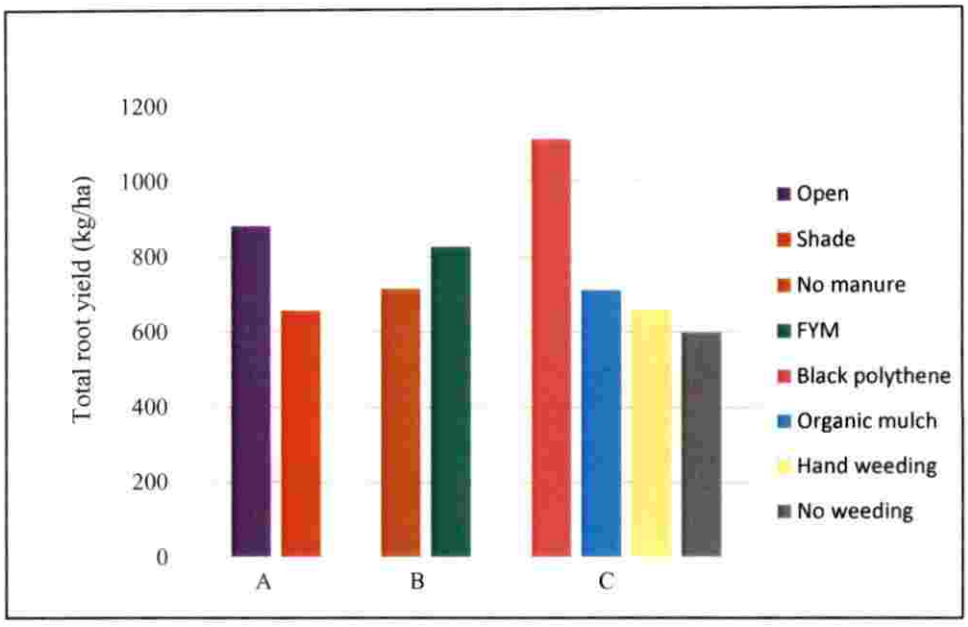
A-Growing condition B-Manuring C-Weed management

Fig. 5. Effect of growing condition, manuring and weed management on biomass yield per plant at different growth stages of Sida hemp



A-Growing condition B-Manuring C-Weed management

Fig. 6. Effect of growing condition, manuring and weed management on root:shoot ratio at different growth stages of Sida hemp



A-Growing condition B-Manuring C-Weed management

Fig. 7.Effect of growing condition, manuring and weed management on total root yield atharvest

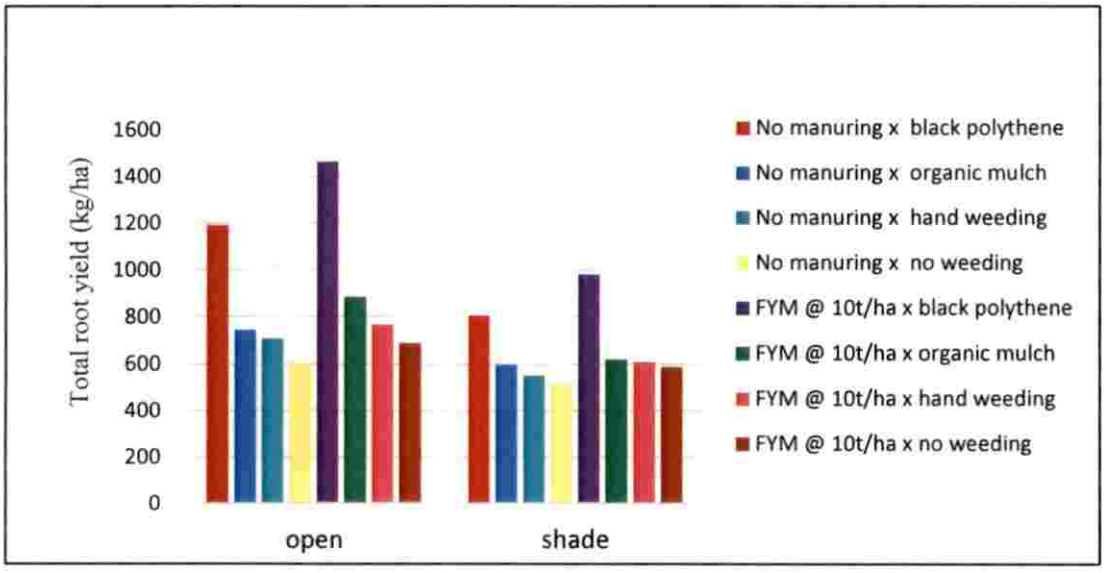


Fig. 8. Interaction effect of growing condition, manuring and weed management on total root yield at harvest

5.2 Effect of growing condition, manuring and weed management on soil chemical properties

Soil pH, organic carbon, available N, P and K were analysed before and after the experiment (Table 11). As compared to pre experiment soil, soil pH decreased after the experiment. Organic carbon, available N, P and K were recorded maximum in organic mulched plots (1.11%, 157.29 kg/ha, 35.72 kg/ha and 292.89 kg/ha respectively) (Fig. 9). Solaiappan and Dason (1995) reported improvement in soil N,P,K and organic carbon status by the addition of paddy straw. Plots with FYM were also recorded higher organic carbon, available N, P and K as compared to initial nutrient status.

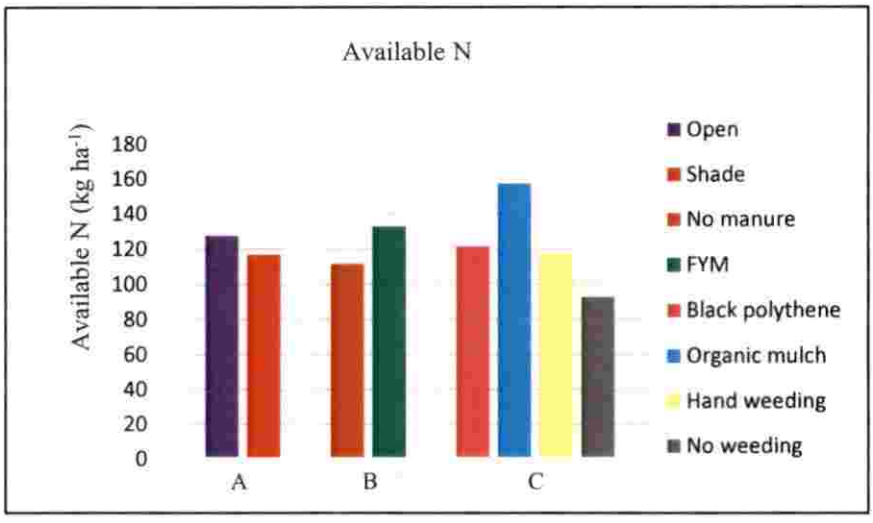
5.3 Effect of growing condition, manuring and weed management on micro climatic parameters

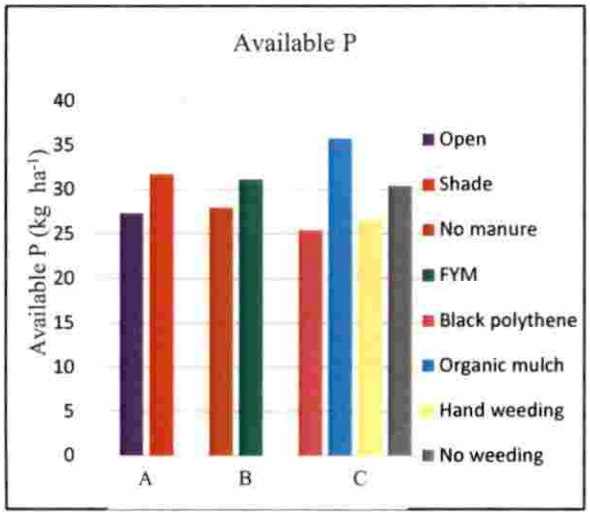
5.3.1 Soil temperature

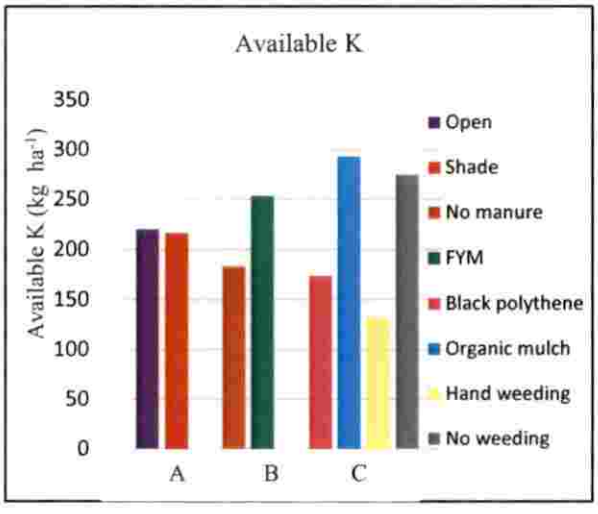
Throughout the growing period higher temperature was observed in open condition as compared to shaded condition (Fig. 10). As per Abu-Hamdah (2003), the soil temperature differs according to the amount of solar radiation from the sun that reached on the soil surface and amount that was absorbed by the soil. Geiger *et al.* (2003) also reported increase in soil temperature with increased solar radiation that reached the soil surface. Significant influence of manuring on soil temperature could not be observed in this experiment. Among different weed management practices, black polythene mulched soil recorded higher temperature (Fig. 11). The rise in soil temperature may due to solar energy trapped inside the mulch material through green house effect (Hu *et al.*, 1995).

5.3.2 Soil moisture

Plots under shade recorded higher soil moisture content at 15 cm depth except from 2nd week to 13th week (Fig. 12). This exception was due to monsoon rains received during this period. Under shade condition the light intensity was low. Soil moisture showed a negative correlation with light intensity (Table 20). Dodd *et al.* (2005) also observed higher soil moisture under shaded condition. Soil moisture content was unaffected by manuring. Weed management significantly influenced the soil moisture content at 15 cm depth. Black polythene mulching recorded higher moisture content as compared to other weed management practices except from 2nd week to 13th week (Fig. 13). According to Sandal and Acharya (1997), mulching with black polythene sheet conserved soil moisture by reducing rate of evaporation.







A-Growing condition B-Manuring C-Weed management

Fig. 9. Effect of growing condition, manuring and weed management on available N, P and K at harvest

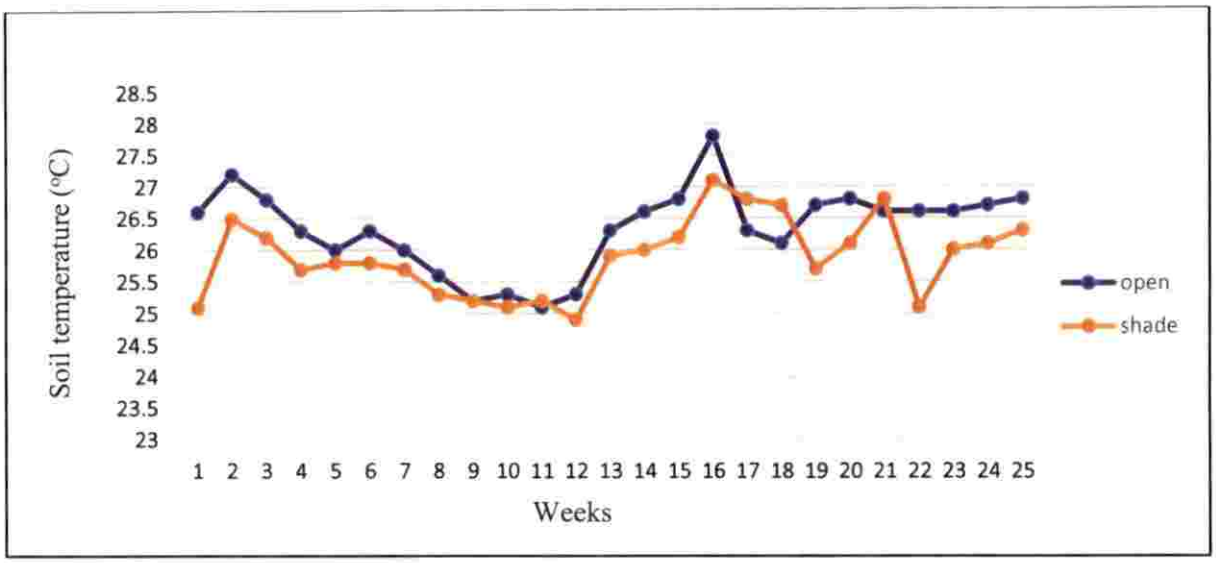


Fig. 10. Effect of growing condition on soil temperature (°C) at 10 cm depth

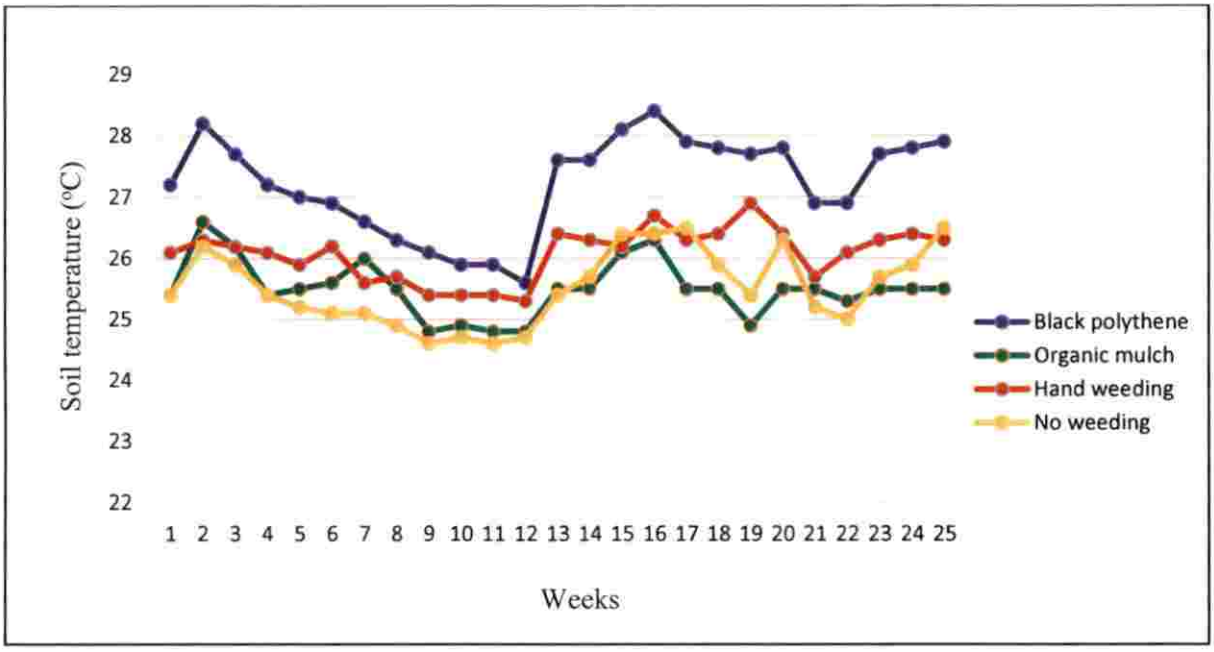


Fig. 11. Effect of weed management on soil temperature (°C) at 10 cm depth

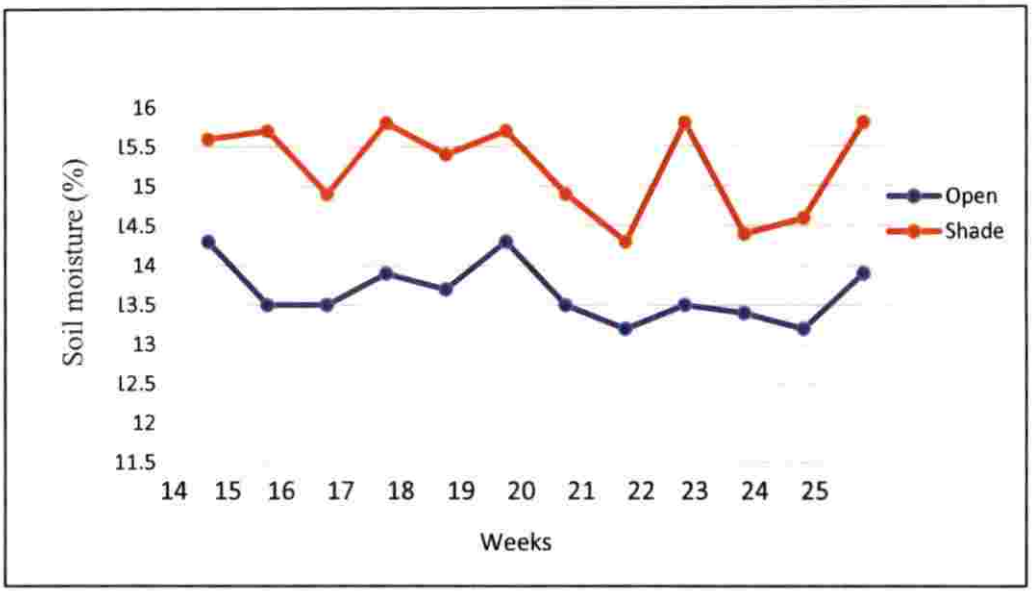


Fig. 12. Effect of growing condition on soil moisture (%) at 0-15cm depth

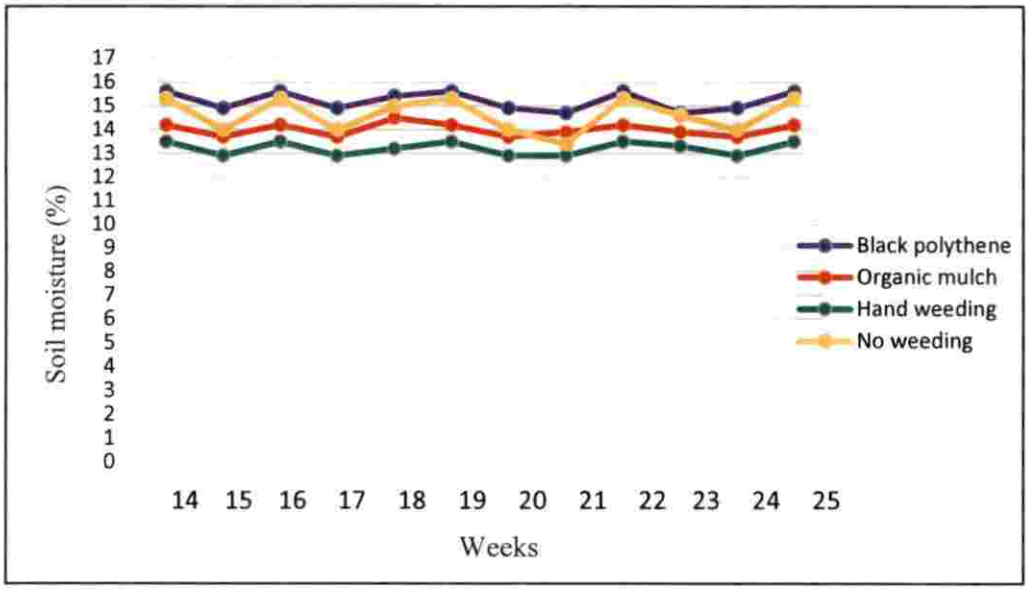


Fig. 13. Effect of weed management on soil moisture (%) at 0-15cm depth

5.4 Effect of growing condition, manuring and weed management on physiological, chemical biochemical observations

5.4.1 Total chlorophyll

Total chlorophyll content was higher under shaded condition at all the growth stages (Table 12 and Fig. 14). According to Schaedle (1975) higher chlorophyll content in leaves under shade helped in trapping the available incident light effectively. Valladares and Niinemetes (2008) reported increased chlorophyll content in leaves when there was decreased light exposure. He explained it as a mechanism for enhanced light harvesting under low light intensity. Manuring influenced the chlorophyll content of Sida hemp (Fig. 14). Higher content of chlorophyll due to application of FYM was recorded in various crops (Ali *et al.*, 2011, Suthar, 2010 and Ahmad *et al.,* 2009). The increase in chlorophyll content due to application of farmyard manure might be due to the activity of microorganisms present in farmyard manure which were colonized in the rhizosphere and stimulated the plant growth biochemical contents. In this experiment weed management practices could not bring about significant influence on chlorophyll content.

5.4.2 Total alkaloid content

Growing of Sida hemp under open condition resulted in higher total alkaloid content in root (Fig. 15). This might be due to positive influence of light intensity (Table 19). Latha and Radahakrishnan (2015) reported higher ephedrine (major alkaloid in sida) content in *Sida cordifolia* under open condition. Influence of sunlight on enhanced production of alkaloids in *Pinellia ternata* was reported by Zhang *et al.* (2009). According to Chen, *et al.* (2017) alkaloid and guanosine content in *Pinellia ternata* was higher under full light intensity. Total alkaloid content of roots remained unaffected by manuring and weed management.

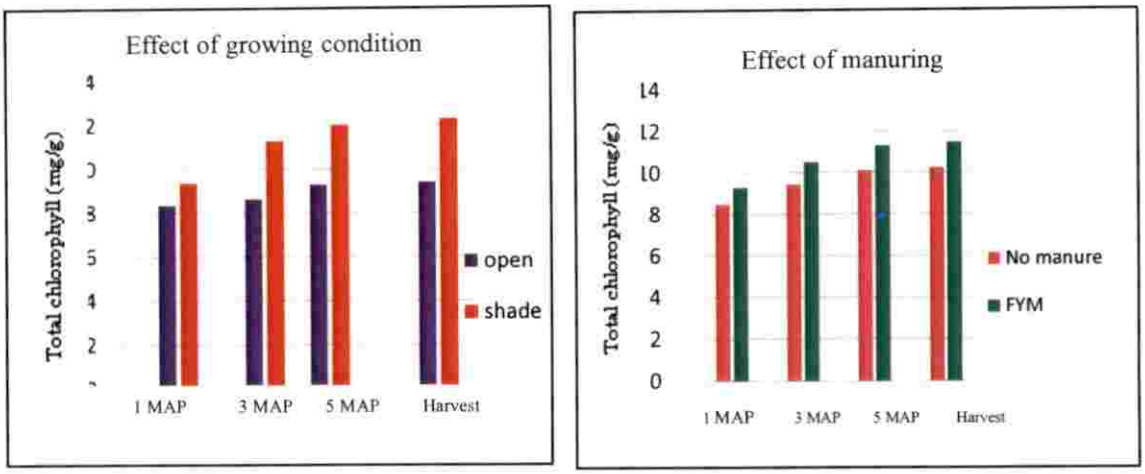


Fig. 14. Effect of growing condition manuring on total chlorophyll at different growth stages

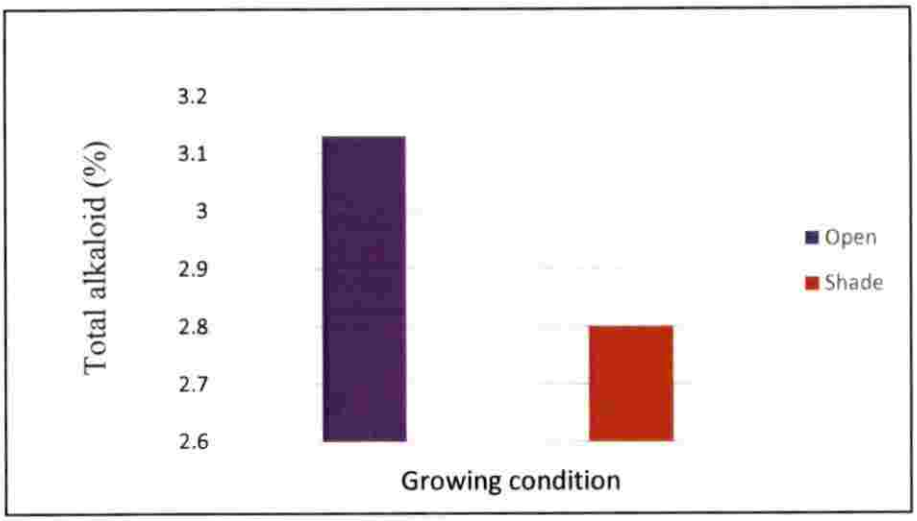
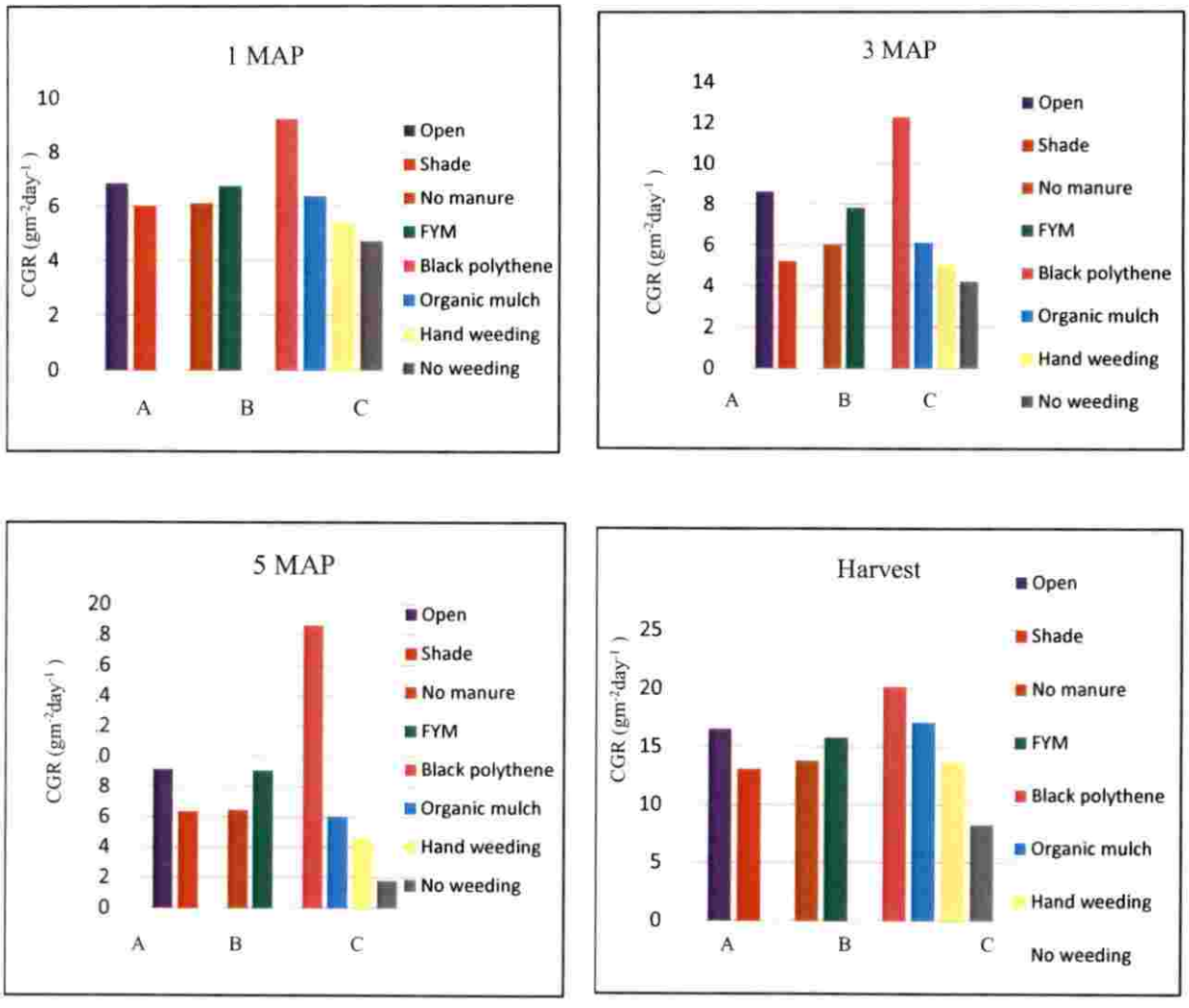


Fig. 15. Effect of growing condition on total alkaloid at harvest

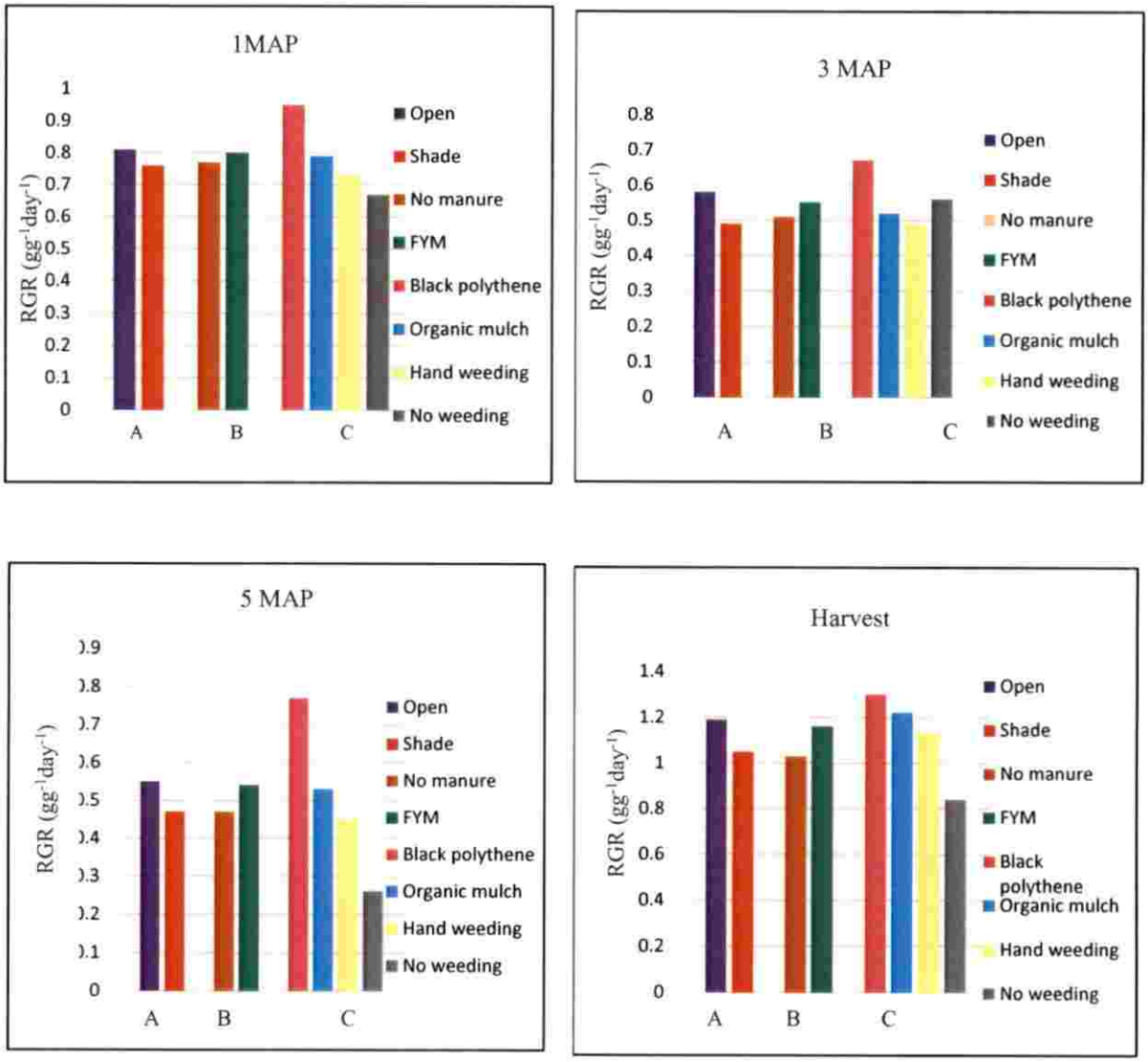
5.4.3 Crop growth rate and Relative growth rate

Both crop growth rate and relative growth rate was found to be significantly influenced by growing condition with greater values under open condition (Figs. 16 and 17). Manuring had significant influence on crop growth rate and relative growth rate. These results were in line with Patel *et al.* (2000) and Rajwade *et al.* (2000). According to them, the increased crop growth rate and relative growth rate in FYM plots might be due to higher dry matter accumulation and translocation of photosynthates from source to sink. Increased photosynthates translocation was in accordance with sufficient availability of major and micronutrients from FYM. Weed management with black polythene sheet resulted in higher CGR and RGR at all growth stages. Soltani, *et al.* (1995) also observed higher CGR and RGR under black polythene mulch. This might be due to higher soil moisture retention, optimum soil temperature and effective weed management under black polythene sheet. Meena *et al.* (2017) reported similar result of increased CGR in weed free treatment.



A-Growing condition B-Manuring C-Weed management

Fig. 16. Effect of growing condition, manuring and weed management on CGR at harvest



A-Growing condition B-Manuring C-Weed management

Fig. 17. Effect of growing condition, manuring and weed management on RGR at harvest

5.5 Effect of growing condition, manuring and weed management on soil microflora

5.5.1 Total population of bacteria, actinomycetes and fungi

Total population of bacteria, actinomycetes and fungi were higher under open condition throughout the growth period as compared to 50 per cent shaded condition (Figs. 18, 19 and 20). According to Patttison *et al.* (1998), under 50% shade, soil could receive reduced rhizodeposites by the host plant due to lower plant growth. Siemann and Rogers (2003) reported that supply of rhizodeposites by the host plant greatly affected the size and functions of the soil microbial community. The higher microbial population in open condition is in accordance with higher soil microbial biomass carbon under full light intensity (Table 15, Fig. 21). Soil microbial biomass carbon had a close relationship with microbial biomass (Brookes, 1995). Among manuring, FYM plots recorded higher population of bacteria, actinomycetes and fungi. According to Yassen *et al.*(2010), when farmyard manure is applied to soil, activity of soil microorganisms increases. Dejene and Lemlem (2012) also reported improved biological properties in soil with the application of FYM. Population of bacteria and actinomycetes were higher under paddy straw mulch where as fungal population were higher under no weeding plots. There are reports of the increased microbial population in soil under organic mulching (Kher *et al.*, 2010; Ogban *et al.*,2001 and Gargi *et al.*,2007). Organic mulching could increase the organic carbon content in the soil, which became food for the useful earthworms and microbes in the soil.

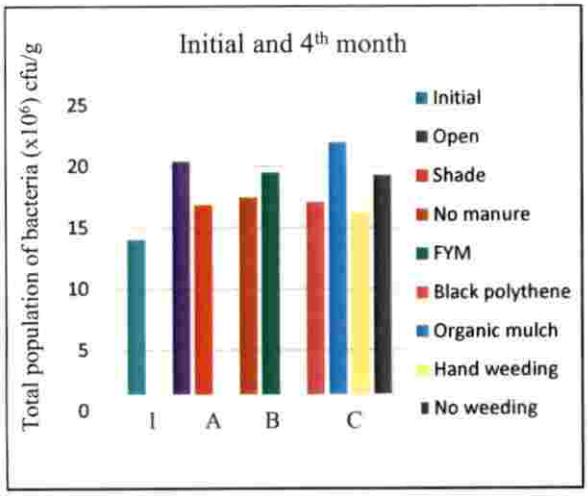
5.5.2 Soil microbial biomass carbon

As compared to the pre experimental soil, higher soil microbial biomass carbon was observed at harvest stage (Table15 and Fig. 21). The population of microbes were higher under open condition. Soil microbial biomass carbon is one of the indicators of soil microbial population. Lalfakzuala *et al.* (2006) reported a linear relationship between soil microbial population and microbial biomass carbon. It is apparent from Fig. 21, that the higher microbial biomass carbon was recorded in FYM applied plots as compared to no manure plots. Goyal *et al.* (1993) observed increased microbial biomass carbon in plots applied with FYM. According to Anderson and Domsch (1980) microbial biomass carbon increased with soil organic carbon. Among

different weed management practices no weeding plots recorded higher microbial biomass carbon followed by organic mulching plots. Higher microbial biomass carbon was recorded from organic mulched plots. This is in line with the reports of Kher *et al.* (2010). According to them organic mulching could increase the organic carbon and microbial population under soil. This might be the reason for higher MBC under organic mulching plots.

5.5.3 Root colonization by arbuscular mycorrhizal fungi

In this experiment, root colonization of AM fungi was observed under open condition only (Table 15 and Fig. 22). No colonization was observed under shade. According to Konvalinkova *et al.* (2015) mycorrhizal growth decreased and eventually became negative under intensive shade or longer shade period from weeks to months. As compared to no manure plots, FYM applied plots recorded higher root colonization of AM fungi. According to Joner and Jakobsen (1995), application of FYM enhanced mycorrhizal infectivity and proliferation of AM fungi hyphae in soil. Root colonization of AM fungi in wheat was enhanced by the application of FYM (Groaker and Sreenivasa, 1994). According to Giovanetti and Avio (1985), FYM application could improve the soil porosity and AMF colonization. Among different weed management practices, AM fungi were found higher under no weeding plots. This is in accordance with the study conducted by Mc Gonigle and Miller (1993). According to them, colonization of AMF in maize was significantly greater in the less disturbed soil. Barbhuiya *et al.* (2005) also reported higher fungal population in undisturbed forest as compared to disturbed forest.



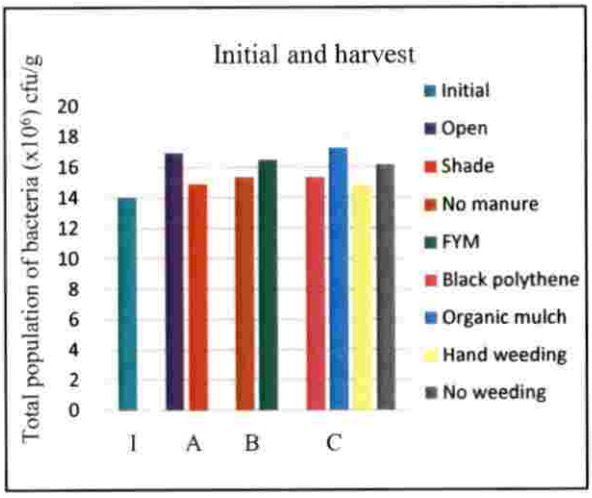
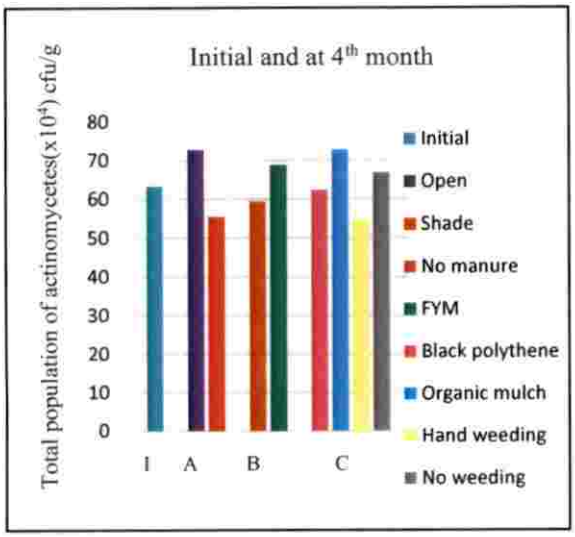
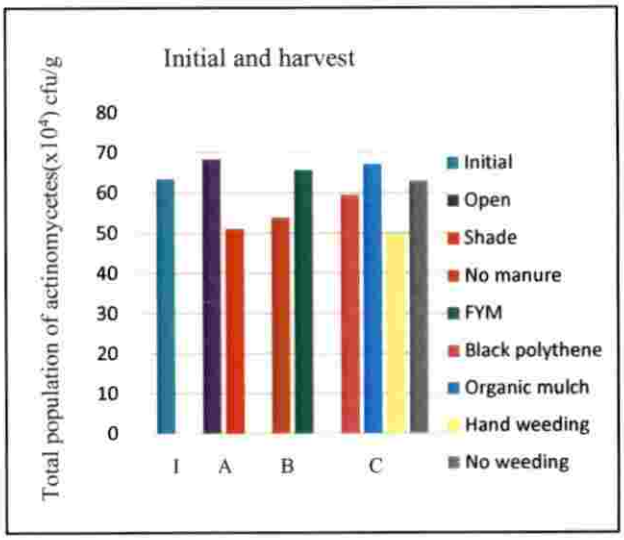


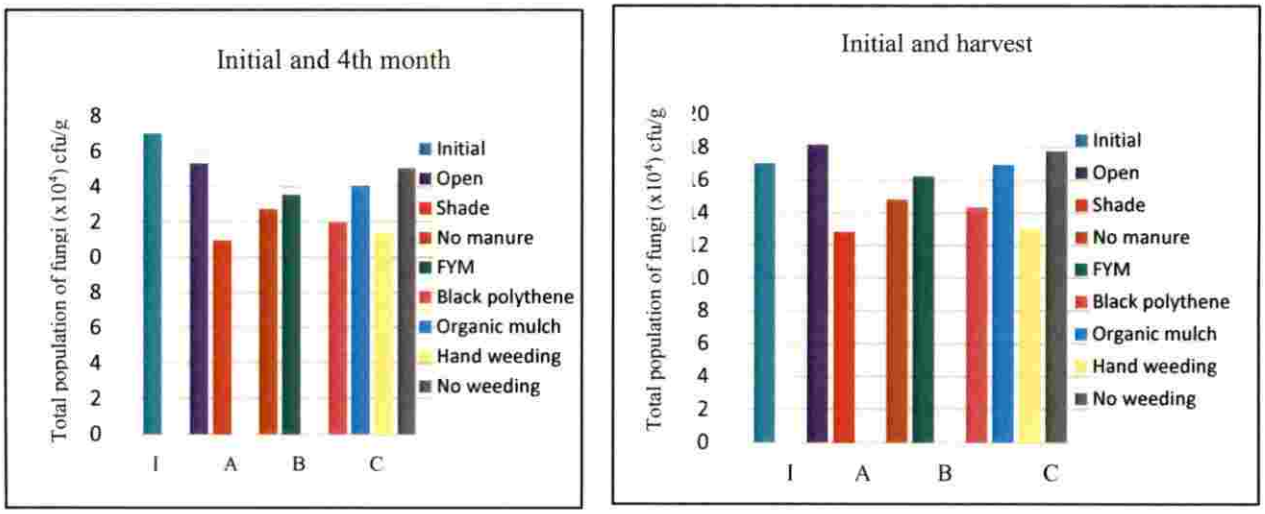
Fig. 18. Effect of growing condition, manuring and weed management on total population of bacteria





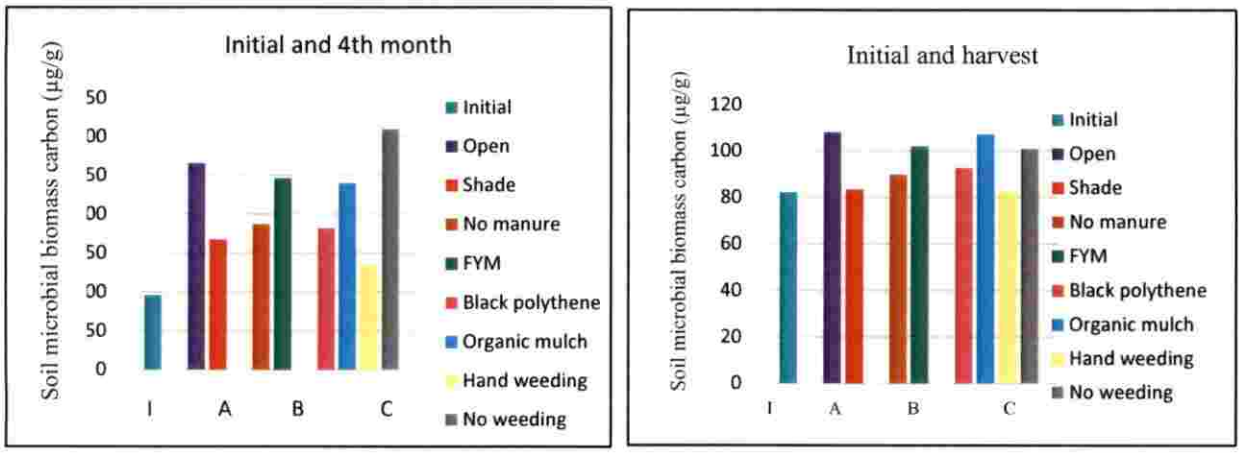
I-Initial A-Growing condition B-Manuring C-Weed management

Fig. 19. Effect of growing condition, manuring and weed management on total population of actinomycetes



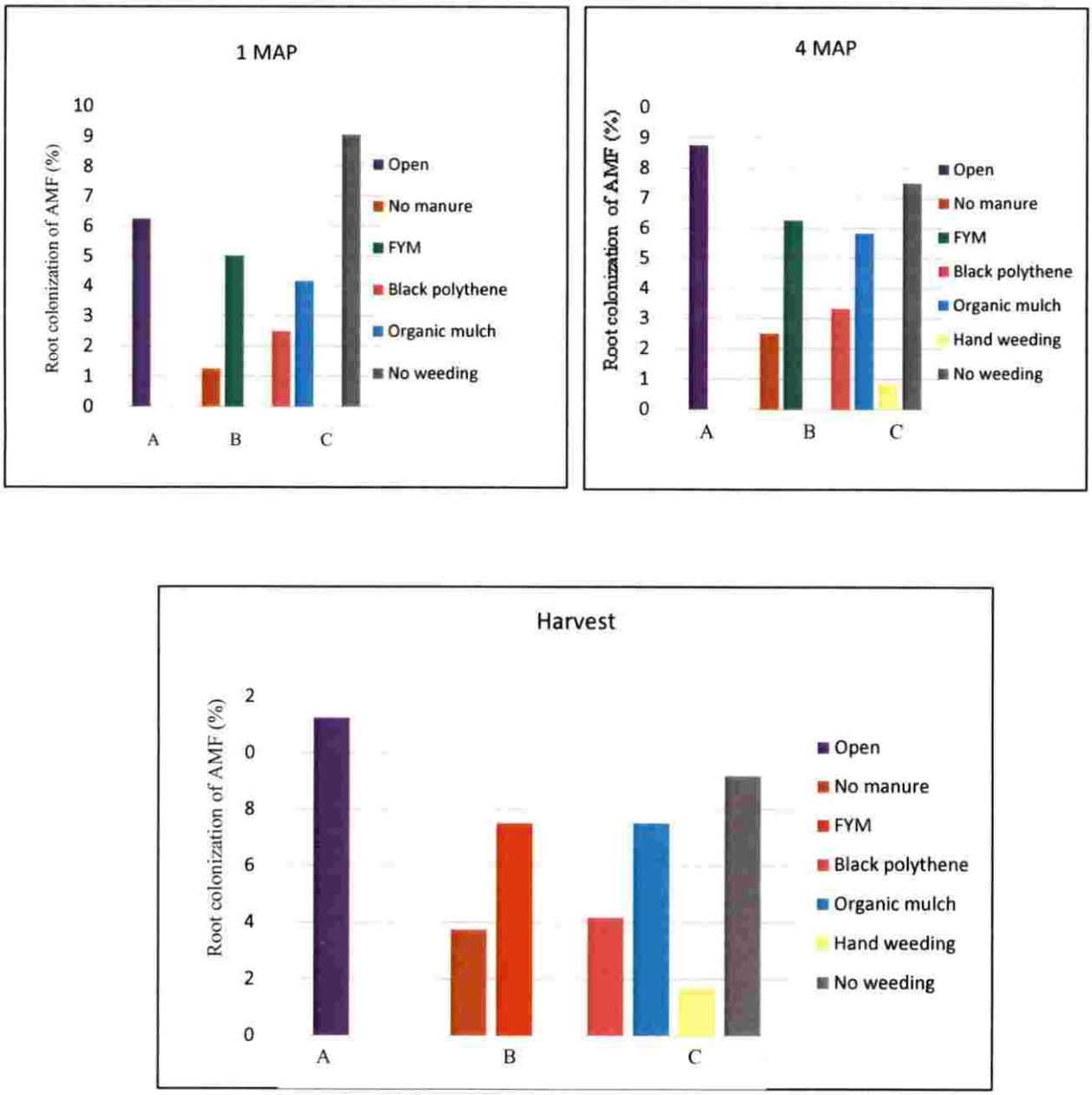
I-Initial A-Growing condition B-Manuring C-Weed management

Fig. 20.Effect of growing condition, manuring and weed management on total population of fungi



I-Initial A-Growing condition B-Manuring C-Weed management

Fig. 21. Effect of growing condition, manuring and weed management on soil microbial biomass carbon



A-Growing condition B-Manuring C-Weed management

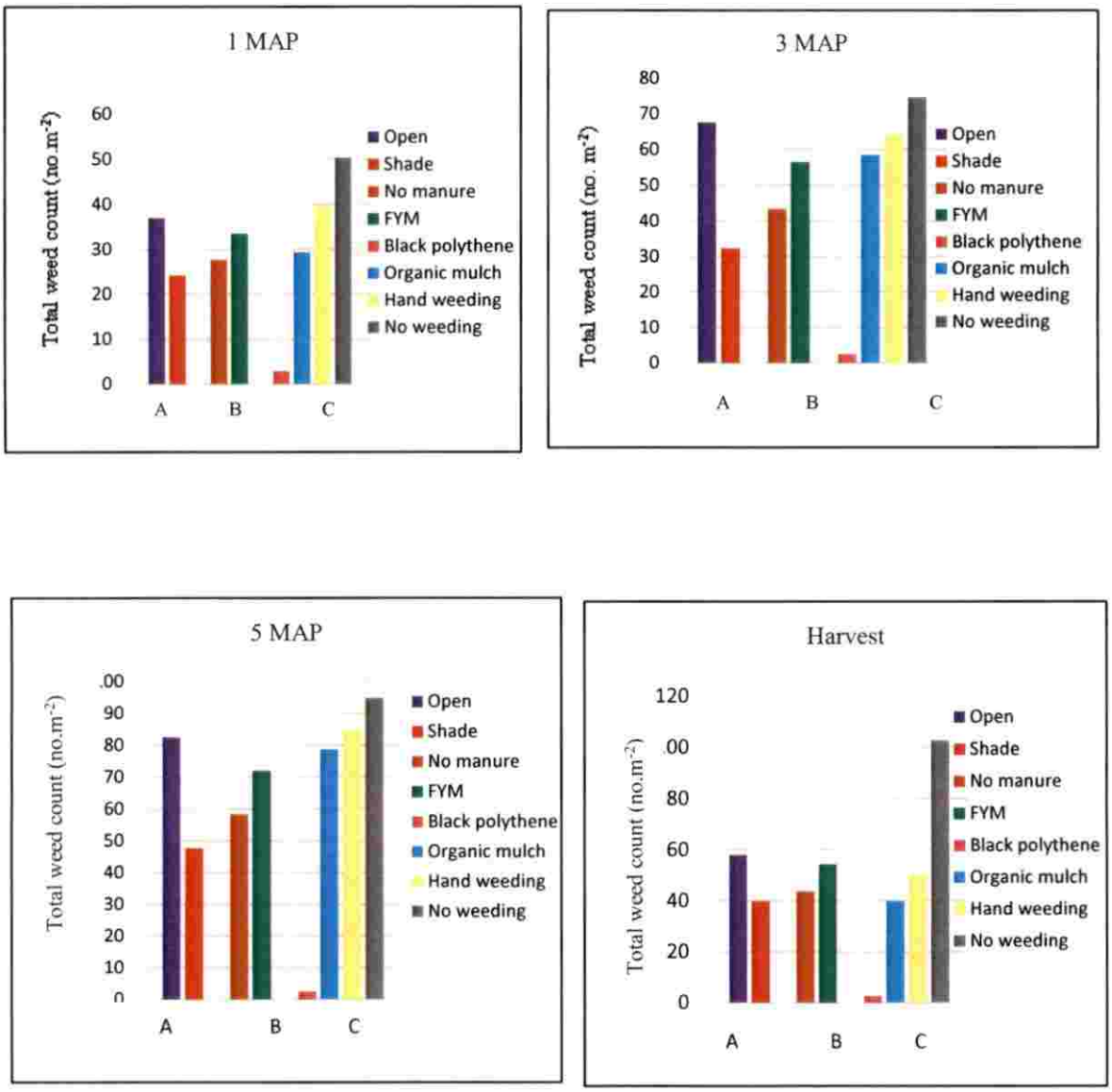
Fig. 22. Effect of growing condition, manuring and weed management on root colonization of AMF (%)

5.6 Effect of growing condition, manuring and weed management on weed growth

Typical upland weeds were found mainly in experimental field. The main grass weeds observed were *Eleusine indica*, *Panicum maximum* and *Ischaemum indicum*. The broad lead weeds were *Borreriahispida, Mollugodisticha, Emilia sonchifolia* and *Phyllanthusamara.* Weed count was significantly influenced by growing condition. As compared to open, weed count was less under shade (Table 16 and Fig. 23). Taller plants of Sida hemp were observed under 50% shaded condition. The reduced light availability to weeds due to taller crop plants might be the reason for reduced weed growth under shade. In general, FYM applied plots recorded higher weed count and weed dry weight (Figs. 23 and 24). Similar results were reported by Jama *et al*, (1997). According to them, weed biomass and weed density were increased by the application of FYM. Miyazawa *et al.* (2004) reported FYM as a source of weed seeds. FYM enhanced the weed population by supplying essential nutrients (Ali *et al*., 2011). Among weed management practices the highest weed count and weed dry weight were recorded under no weeding plots, since no weeding was practiced in these plots. The lowest weed count and weed dry weight were observed under black polythene mulching. According to Schonbeck and Evanylo (1998) black polythene mulch supresses the weeds, except few which emerged through the planting hole. According to Gunasekaran and Shakila (2014) weed suppression in black polythene mulch was by increasing the soil temperature which killed the weed seeds in early stages and by inhibited light availability.

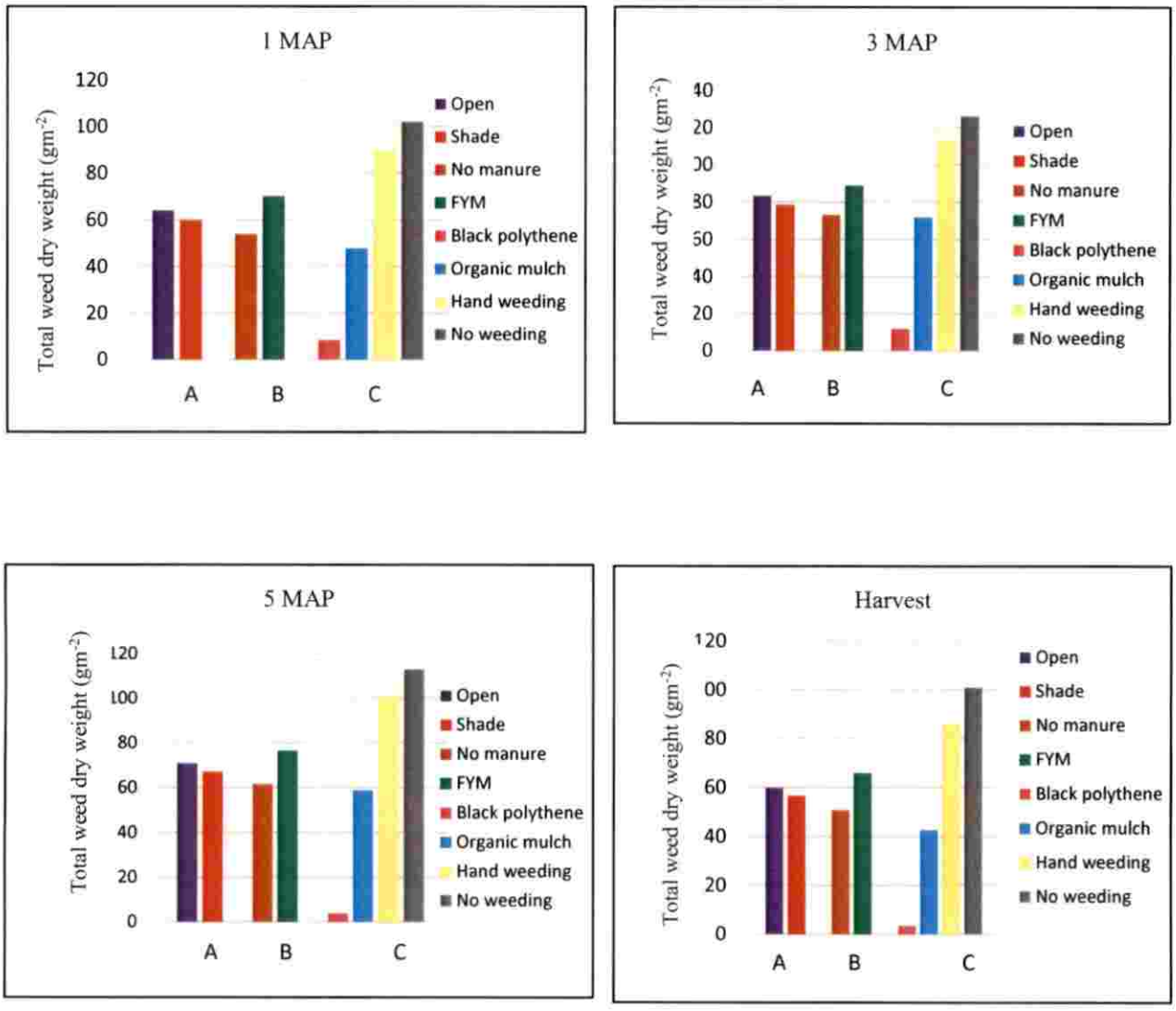
5.7. Economic of cultivation

Highest B:C ratio was obtained from black polythene mulch with FYM under open condition followed by black polythene mulch without FYM under open condition (Table 68 and Fig. 25). Higher B:C ratio under open condition highlights the suitability of growing Sida hemp under open condition. Lower B:C ratio was obtained from hand weeding under shade with and without FYM. This might be due to lower yield and higher cost incurred for hand weeding. Planting under open condition with FYM and black polythene mulching is found to be the ideal for better yield, quality and B:C ratio of *Sida alnifolia.*



A-Growing condition B-Manuring C-Weed management

Fig. 23. Effect of growing condition, manuring and weed management on total weed count



A-Growing condition B-Manuring C-Weed management

Fig. 24. Effect of growing condition, manuring and weed management on total weed dry weight

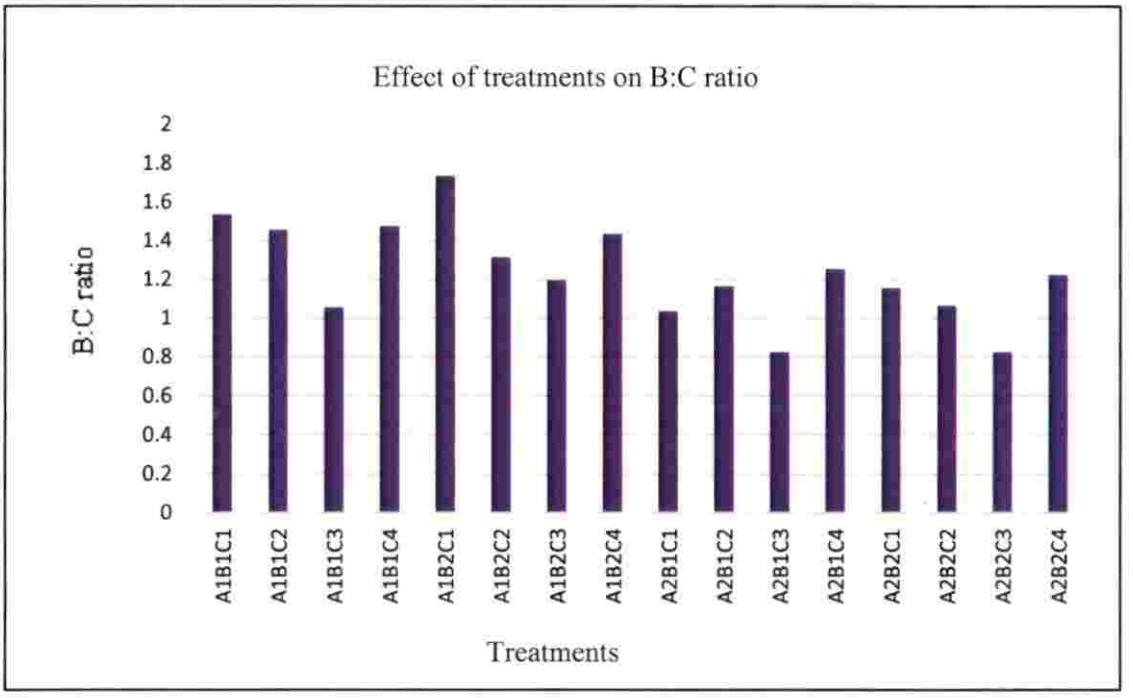


Fig. 25. Interaction effect of growing condition, manuring and weed management on economics of cultivation

Summary

6. SUMMARY

The current research work entitled "Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management" was carried out to assess the effect of variations in growing conditions, manuring and weed management on photosphere variations, and on growth, yield and quality of *Sida alnifolia.* The experiment was conducted at the Agronomy farm, Department of agronomy, College of Horticulture, Vellanikkara, Thrissur. The trial was laid out in Randomized Block Design (factorial) replicated thrice. The treatment consisted of two growing conditions viz., open and 50 per cent shade, two levels of manuring viz., No manures and FYM @ 10 t/ha and four weed management practices viz., black polythene mulching, organic mulching, hand weeding and no weeding. Observations were taken on soil analysis, micro climatic parameters, soil microflora, biometric characters, physiological, chemical and biochemical analysis, and observations on weeds. Economics cultivation was also worked out. The salient findings are summarised and presented here.

Effect of growing condition

Open condition:

- Higher per plant biomass yield, per plant root yield, root:shoot ratio and total root yield were noticed.
- Growing condition significantly influenced the growth and yield of crop, soil temperature and light intense with higher values under open condition.
- Available K content of soil after the experiment was higher under open condition.
- Total alkaloid content in roots, crop growth rate and relative growth rate were higher under open condition.
- Open condition enhanced the growth of bacteria, actinomycetes and fungi in plant rhizophere.
- Percent root colonization of AMF and soil microbial biomass carbon was higher under open condition.
- Open condition resulted in higher weed count and weed dry weight.

Shaded condition:

- Throughout the growth stages plant height was higher under shaded condition.
- Higher total chlorophyll content was recorder from plants grown under shaded condition throughout the growth stages.
- Among micro climatic parameters, higher soil moisture was observed under shaded condition.
- Available P content was higher under shaded condition.

Effect of Manuring

- Plant height, biomass yield per plant, root yield per plant and root:shoot ratio were higher in FYM applied plots throughout the growth stages.
- Total root yield at harvest was higher in plants which received FYM @ 10 t/ha.
- Microclimatic parameters viz, soil temperature, soil moisture and light intensity were not influenced by manuring.
- Higher available N, P and K contents were estimated from plots with FYM.
- Higher chlorophyll content was observed in plants which received application of FYM.
- Total alkaloid content was not significantly influenced by manuring.
- Plants which received application of FYM @ 10 t/ha recorded higher crop growth rate and relative growth rate.
- FYM application enhanced the growth of total population of bacteria, actinomycetes and fungi, percent root colonization of AMF and soil microbial biomass carbon.
- Higher weed count and weed dry weight were also recorded from FYM applied plots.

Effect of weed management

- Black polythene mulching resulted in higher plant height, biomass yield per plant, root yield per plant and root:shoot ratio.
- The highest total root yield was recorded from plots with black polythene mulching.
- Micro climatic parameters viz, soil temperature and soil moisture (except from 2nd week to 13th week) were higher under black polythene mulching.
- Light intensity was not influenced by weed management practices.
- Among soil chemical characters, soil pH and organic carbon were not influenced by weed management methods.

- Higher available N, P and K contents of soil was estimated from organic mulched plots.
- Among physiological, chemical and biochemical observations, total chlorophyll content and total alkaloid content were not influenced by weed management practices.
- Higher CGR and RGR were recorded in plants with black polythene mulching.
- Total population of bacteria and actinomycetes were higher in organic mulched plots.
- Total population of fungi were higher in unweeded plots.
- Higher root colonization (%) of AMF and soil microbial biomass carbon were recorded from unweeded plots.
- The lowest weed count and dry weights were observed in plots with black polythene mulching.

Interaction effect of growing condition, manuring and weed management

- Tallest plants were observed in plots with black polythene mulch and FYM under shaded condition.
- Interaction effect of growing condition, manuring and weed management had significant influence on biomass yield per plant, root yield per plant, root:shoot ratio and total root yield with higher values in black polythene mulching with FYM under open condition.
- Higher soil temperature was recorded in black polythene mulching with FYM under open condition.
- Higher soil moisture was recorded under shade in black polythene mulched plots with FYM.
- The interaction effect was significant on light intensity and the highest light intensity was recorded at 23rd week, in no manure, hand weeding plot under open condition.
- The interaction between growing condition, manuring and weed management on soil chemical characters were non significant except for available potassium.

- Higher amount of available K was recorded from organic mulched plots with FYM under open condition which was on par with no weeding plots with FYM under open condition.
- A non significant interaction was observed for total chlorophyll content.
- A significant interaction was observed for total alkaloid content of roots at harvest. Higher total alkaloid content was recorded from plants grown with FYM @10 t/ha and black polythene mulching under open condition. However, it was on par with all other treatment combinations of manure and weed management methods under open condition.
- At harvest, higher CGR and RGR were recorded in black polythene mulch with FYM @ 10 t/ha under open condition which was on par with black polythene mulch without manure under open condition.
- Total population of bacteria and actinomycetes were higher in plots with organic mulch with FYM @ 10 t/ha under open condition, whereas, higher population of fungi were recorded from unweeded plots with FYM @ 10 t/ha under open condition.
- Higher percent root colonization of AMF and soil MBC were recorded from open condition without weeding and application of FYM @ 10 t/ha.
- Higher count of weeds were observed in unweeded plots with FYM under open condition throughout the growth stages, however, the interaction was non significant.
- Black polythene mulch with FYM @ 10 t/ha under shade and black polythene mulch without manure under open condition exhibited more than 90 per cent weed control efficiency.
- Minimum weed index was in organic mulch plots without manure under shade.

Correlation studies

- Plant height showed a significant negative correlation between root:shoot ratio and yield.
- Biomass yield per plant was positively correlated with root:shoot ratio and yield.

- A significant positive correlation was observed between root:shoot ratio and yield.
- Soil temperature had significant negative correlation with soil moisture
- Soil temperature had significant positive correlation with yield and total alkaloid content.
- Soil moisture recorded a significant negative correlation with light intensity.
- There was a significant positive correlation between light intensity, yield and total alkaloid content.
- Yield and total alkaloid contents were positively correlated.

Economics of cultivation

- A higher B:C ratio of 1.73 was obtained from black polythene mulch with manure under open condition.
- Hand weeding with and without manure under shaded condition recorded lower B:C ratio (0.82).

From the present study it can be concluded that optimum growing condition, manuring and weed management for Sida hemp is open condition, FYM @ 10 t/ha and black polythene mulching.

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Appendices

Appendix 1. Monthly weather data during experimental period (June 2018-December 2018)

	Max temp (^{0}C)	Min temp (^{0}C	RH %	Rainfall (mm)	Rainy days	Total Evp (mm)	Sunshine hours
June	29.8	23.2	89	730.0	23	65.7	51.2
July	29.6	22.5	88	793.2	22	79.6	58.0
Aug	29.2	22.2	87	928.0	21	70.7	68.4
Sep	32.2	22.5	75	29.0	1	99.6	216.2
Oct	32.8	22.9	76	393.0	13	94.4	176.0
Nov	32.7	23.3	68	66.6	5	102.3	207.5
Dec	33.0	22.5	63	0.0	0	109.5	215.7

Phytosphere variations of Sida hemp [*Sida alnifolia* L.] under varying agronomic management

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Quality of raw drug is as important as its quantity in medicinal plant cultivation. Since bulk of the present requirement is met by wild collection from natural habitats, when the crop is brought under cultivation, with improved management techniques, it is indispensable to ensure its quality. Cultivating plants under a micro climate similar to its niche original is found to be the viable solution for ensuring its therapeutic properties.

Sida alnifolia is a valued medicinal plant, belonging to family Malvaceae and known as *Kurunthotti* in Malayalam. Considering market potential, the State Medicinal Plant Board of Kerala recommended this crop for commercial cultivation.

The present study was taken up in the Department of Agronomy, College of Horticulture, Vellanikkara to assess the effect of variations in growing conditions, manuring and weed management on phytosphere variations and on growth, yield and quality of Sida hemp [*Sida alnifolia* L.]. 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, two levels of manuring *viz*., no manure and FYM @10 t/ha and four weed management practices, *viz*., black polythene mulching, organic mulching, hand weeding and no weeding.

Growing condition, manuring and weed management significantly influenced the plant height, biomass yield per plant, root:shoot ratio and total root yield of Sida hemp. The highest root yield was obtained from open condition (882 kg/ha), FYM @ 10 t/ha (825 kg/ha) and black polythene mulching (1111 kg/ha).Interaction between growing conditions, manuring and weed management was also significant with the highest root yield in treatment combination of black polythene mulching with FYM @ 10 t/ha under open condition (1466 kg/ha).

The management methods also influenced the soil micro climatic factors such as soil temperature and soil moisture. Higher soil temperature and moisture content were observed under treatments with black polythene mulching.

Among different soil chemical properties studied, content of available P and K were significantly influenced by treatments. Direct effect of growing condition on available N was non significant, although, it was significantly influenced by manuring and weed management.

Physiological, chemical and biochemical parameters were also significantly influenced by growing condition and manuring, but however were unaffected by weed management practices. Total chlorophyll content at the time of harvest was higher under shade (12.28mg g^{-1}) and FYM@ 10 t/ha (11.45mg g^{-1}). Higher total alkaloid content was recorded from open condition (3.13 %). As in the case of root yield, combination of FYM @ 10 t/ha, black polythene mulching and open condition resulted

in higher total alkaloid content of 3.31 %. Crop growth rate and relative growth rates were also higher in this treatment combination.

Total population of bacteria, actinomycetes and fungi were higher under open condition and FYM @ 10 t/ha applied plots. Regarding the effect of weed management practices, total population of bacteria and actinomycetes were higher under organic mulched plots whereas fungi population was higher under unweeded plots. Higher root colonization by AMF and soil microbial biomass carbon were observed under open condition, with the application of FYM @ 10 t/ha in unweeded plots throughout the growth stages.

Weed count and weed dry weight were significantly influenced by the treatments. Lower weed count and weed dry weight were observed under shade, in unmanured plots mulched with black polythene. Among different weed management methods, black polythene mulching was the best practice, followed by organic mulching. Highest weed control efficiency was recorded in unmanured plot with black polythene mulching under shade (93 %) and minimum weed index was recorded in organic mulched plots without manure under shade (26 %).

Simple linear correlation between climatic parameters with yield and quality showed a significant positive correlation between soil temperature, biomass yield, root:shoot ratio and root yield. Soil moisture was positively correlated with plant height and negatively correlated with root yield and alkaloid content of roots. Negative correlation was observed between light intensity and plant height, whereas the correlation was positive with root:shoot ratio.

A higher B:C ratio of 1.73 was obtained from black polythene mulch with manure under open condition. Hand weeding with or without manure under shaded condition recorded lower B:C ratio (0.82).

From the present study, the combination of open condition, application of FYM @ 10 t/ha and weed management by black polythene mulching can be recommended as optimum for better yield, quality and B:C ratio of Sida hemp.