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WEED MANAGEMENT IN ELEPHANT FOOT YAM
[*Amorphophallus paeoniifolius* (Dennst.) Nicholson]

By

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(2015-11-015)

THESIS

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DECLARATION

I, Lekshmi Sekhar (2015-11-015) hereby declare that the thesis entitled **"Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]"**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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CERTIFICATE

Certified that the thesis entitled **"Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]"**is a record of research work done independently by **Miss. Lekshmi Sekhar** (2015-11-015)under my guidance and supervision and that it has not been previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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Introduction

1. INTRODUCTION

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is a tropical crop belonging to the family Araceae grown for its underground modified stem known as corm. It is an herbaceous perennial which originated in Southeast Asia or India. Although the plant is a perennial due to its underground stem modification as corm, it is treated as an annual with a duration of 8 to 9 months when cultivated. Known also as elephant yam, in India, other common names include *Suran, Zimikand, Jimmikand, Karunai Kizhangu,* and *Chena*. In many south eastern and Pacific countries, it is locally used as a staple food and vegetable.

Elephant foot yam is considered as a nutritious tuber crop, comprising about 79 per cent moisture, 18.4 per cent carbohydrate, 1.2 per cent protein, 0.8 per cent minerals, and 0.1 per cent each of fat and fibre. The fresh tuber contains many minerals and vitamins such as calcium, phosphorus, iron, vitamin A, thiamine, niacin, and riboflavin. Leaves along with petiole (pseudostem) and rachis are also used as vegetables. The wild and locally available cultivars are used for making vegetable pickles and medicinal preparations for various ailments. In medical phrasing, the tubers are stomachic, restorative, carminative, and tonic.

In India, elephant foot yam is mainly cultivated in the states Andhra Pradesh, West Bengal, Gujarat, Kerala, Tamil Nadu, Maharashtra, Uttar Pradesh, Jharkhand and north eastern states. Elephant foot yam is flexible to low light intensity and is suitable to be grown under intercropping or multiple cropping system (Sen *et al.*, 1996; Santosa *et al.*, 2006). It is a part of home gardens in Kerala and usually grown as an intercrop under coconut or banana plantations. The crop is mainly planted in February - March and harvested during November - December under rainfed conditions in Kerala.

Due to high production potential and productivity in a short growing season and high net returns (Mukhopadhyay and Sen, 1999; Nath *et al*., 2007), elephant foot yam is greatly popular among tropical aroid tuber crops. As it is not commercially cultivated in other countries, this crop also offers export potential in India (Misra and Shivalingaswamy, 1999; Misra *et al*., 2001).

Although, many cultivars are available for cultivation, this crop has gained momentum in India after the introduction of lenient smooth corm type cultivar 'Gajendra' from Andra Pradesh Agricultural University. In addition to 'Gajendra', 'Sree Padma', 'Sree Athira', 'Bidhan Kusum' and 'NDA-9' are some of the promising Amorphophallus varieties released for cultivation in India (AICRPTC, 2006a).

Weed competition is an important constraint in the production of root and tuber crops owing to the initial slow growth of these crops (Moody and Ezumah, 1974; Srinivasan and Maheswarappa, 1993). Being a long duration, widely spaced crop, elephant foot yam takes about 50 to 60 days or more to spread into a full ground cover, and therefore, in the early growth stage of this crop, enough sunlight and space are available in the interspaces. Elephant foot yam is susceptible to weed growth throughout the crop growth period because of less coverage of field by the leaf canopy. Weed competition causes severe yield loss (50 to 70 per cent) and makes harvesting cumbersome, as the economic part is underground. Often, weeds germinate and grow much earlier than the crop because of delay in sprouting of planted corms (Nedunchezhiyan *et al*., 2013). The critical period of crop - weed competition is between 1 to 5 months after planting, as the major crop growth and corm bulking occurs during this period. If weeds are tall in relation to crop plants, weeds shade the crops and the resulting competition for light may cause yield loss (Forbes and Watson, 1992). Although *Amorphophallus* species are considered shade tolerant, Kumari and Sasidhar (1992) reported that the yield of elephant foot yam linearly decreased as the light intensity decreased.

Unlike most other crops, weeding at a later stage of development is important for elephant foot yam because daughter corms start to enlarge significantly 75 days after planting, and less competition with weeds for light, water and nutrients would be favorable for the enlargement of the daughter corms (Santosa *et al.*, 2004).

Manual weeding is the most common method of weed control practiced in elephant foot yam. Two weedings, one at 45 days and the second at 75 days followed by earthing up is recommended in Kerala. High cost of manual weeding and non-availability of labour during peak season are some major constraints in weed management.

The present experiment was planned to evaluate various economic weed management strategies and to study their effects on growth and yield of elephant foot yam. The specific objectives of this study were:

- To investigate the effect of frequency of weeding through various means on the growth and yield of elephant foot yam
- To formulate an economical weeding schedule

Review of literature

2. REVIEW OF LITERATURE

Elephant foot yam is one among the ancient cultivated plants grown in the tropics and sub tropics for its edible corms and cormels. This potential tuber crop is considered as an orphan crop as not much attention has been devoted to it by way of research or development unlike other tuber crops such as potato. Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson], which belongs to plant family Araceae [syn. *Amorphophallus campanulatus* (Roxb.) Blumex Decne] is an integral component of the homesteads in the tropics. It is basically a crop of south eastern Asian origin. Wild forms as well as local cultivars have medicinal properties and are used in therapeutical preparations for various ailments. In India, it is popular in certain pockets due to its production potential and popularity as a food and vegetable. In India, it is cultivated in Andhra Pradesh, West Bengal, Gujarat, Kerala, Tamil Nadu, Maharashtra, Uttar Pradesh, and Jharkhand states. In Kerala also, it has good popularity because of its use in both traditional and modern culinary preparations. Some people call it as the king of tuber crops due to its higher yield potential, higher biological efficiency along with its culinary properties, medicinal utility, and therapeutic values (Saravaiya *et al.*, 2010).

In India, 'Sree Padma', 'Gajendra', 'Sree Athira', 'Bidhan Kusum' and 'NDA-9'are some of the high yielding Amorphophallus cultivars recommended for cultivation (AICRPTC, 2006a). Several local cultivars are also grown by the farmers.

In Kerala, elephant foot yam is planted in February - March and harvested during November - December under rainfed conditions (KAU, 2016). Elephant foot yam grows well under tropical, warm, humid conditions with maximum day time temperature ranging between 25°C and 35°C, minimum night time temperature ranging between 20°C and 25°C and annual rainfall ranging between 1000 and 3000 mm spread over a period of about six to eight months (Ravi *et al.*, 2011). In Kerala, elephant foot yam is second in importance as a tuber crop after cassava and in 2015 - 16, it was grown in 7143 ha (GOK, 2017).

Despite the uses and popularity, information on the production aspect of elephant foot yam is less as scanty research has been conducted in this crop. Available literature pertaining to the present investigation entitled "Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]" is briefly reviewed in this chapter. As details available on the aspect under study are relatively less, attempts have been made to review similar kind of works on related tuber crops as well.

2.1 Morphological characteristics

A. paeonifolius is a robust herbaceous plant, growing to 1.0 m to 1.5 m high. Large dissected tripartite leaves constitute the outspreading crown like foliage, borne on a fairly thick single upright petiole erroneously called "stem". In fact, morphologically, this aerial cylindrical "pseudostem" with characteristic irregular blotches is a leaf petiole (Ravi *et al*., 2009). Although the plant is a perennial due to its underground stem modification as corm, it is treated as an annual in cultivation with a duration of 8 to 9 months. It is usually harvested when the top becomes yellow and withers (8 to 9 months after planting). It flowers once in one to three years. The inflorescence, which appears almost at ground level, consists of a bell shaped spathe surrounding a central yellow spadix borne on a very short stalk. Although wild species flower and set seeds profusely, cultivated species fail to set seeds under normal condition due to extreme protogyny coupled with delay in opening of spathe.

The propagating material in elephant yam is the whole corm, corm pieces, or cormels. The size of cut corms or whole corms for planting ranges from 750 g to 1.0 kg. Amorphophallus corms exhibit dormancy for about three to five months after harvest. Because of this, planting and harvesting are done at a particular time of the year only.

Ordinarily, a single leaf sprout emerges from the cut corm pieces or full corm used as planting material. The time of sprouting of new leaves depends on the dormancy status of the planting material. If the planting material has completed its dormancy before planting, then the new shoot sprout will emerge as soon as it is planted. Leaf emergence is delayed when the apical buds of seed corms are damaged or cut pieces of corm are planted. Leaves emerged earlier when whole corms were used for planting compared to cut corms irrespective of corm size (Sen *et al.*, 1996). Timely receipt of rains is also a factor, which triggers sprouting of corms.

Once the leaf sprout is initiated from the corm, further development of leaf may be completed within 30 days. Leaves are basal, compound, pinnate, solitary and erect. The leaf is composed of a petiole (pseudostem) and three rachises with many leaflets. Up to 150 to 250 leaflets may be produced per leaf, and this may vary between cultivars. Petioles look like the stems of normal plants and cylindrical in shape.

Based on several works on elephant foot yam, it has been reported that the mean shoot length varied between 47.3 cm and 122.5 cm, depending upon the cultivar, plant spacing, or size of planting material used (Ravi *et al.*, 2011). Canopy spread was reported to vary between 70.2 cm and 143.8 cm (Ravi *et al.*, 2011). Ravi *et al.* (2009) reported that shoot height, its basal girth, and dry matter accumulation improved and reached a peak at 120 days to 150 days after planting (DAP) up but subsequently declined.

Njoku and Muoneke (2008) reported that leaf area index of elephant foot yam increases with age. Leaf area index (LAI) ranged from 0.83 to 1.01 at 5 months after planting when the spacing was 90 cm x 90 cm (Nedunchezhiyan, 2014).

The corm production potential of elephant foot yam is 50 to 80 t/ha. Plant growth and corm yield are influenced by the size of planting material (whole corms or corm pieces), plant spacing, nutrient management and water availability.

Food value of elephant foot yam is limited by its acridity in tubers, which causes irritation and burning sensation in the mouth and throat owing to the presence of needle like raphides of calcium oxalate. Sundaresan (2005) reported that calcium oxalate levels in the acrid cultivars varied between 660 to 850 mg/100g, while in non-acrid cultivars, acridity ranges between 120 to 140 mg/100g.

The cultivar "Gajendra", a local selection from Kovvur area of Andhra Pradesh (India), is non-acrid and does not cause any irritation on being eaten. Along with traditional processing systems like pre soaking, addition of ingredients like tamarind, curd etc., in the cooking medium, several processing methods like boiling, baking, frying and drying can also be used to reduce the acridity of tubers. According to Sundaresan and Nambisan (2008), boiling reduced calcium oxalate content by 50 per cent.

2.2 Production constraints due to weeds

Weeds are major constraints in the production of root and tuber crops causing severe yield losses in the range of 50 to 70 per cent. According to Akobundu (1987), weeds could cause 65 per cent yield reduction in root and tuber crops and consumed about 25 per cent of total labour use in production. Rao (2000) pointed out that weed infestation, duration of infestation, and climatic conditions were the factors that determine the severity of yield loss. Weeds generally compete with plants for nutrients, soil moisture and sunlight and by covering over the crops and taking up the space, ultimately affecting crop growth. Weeds could cause loss in tuber yield, which might go up to 100 per cent in cassava (Moody and Ezumah, 1974; Akobundu, 1980; Hahn and Keyser, 1985; Ambe *et al.*, 1992) and 60 per cent in taro (Nedunchezhiyan *et al.*, 1996). By directly competing with the roots and tubers, weeds also affected the quality and made harvest cumbersome, as the economic part was underground (Nedunchezhiyan *et al.*, 2013).

Weeds can cause indirect effect on health, loss of biodiversity, nutrient depletion, and grain quality, which can cause higher economic losses, and according to Nedunchezhiyan *et al.* (2013), root and tuber crops were also amenable to losses of similar magnitude. Studies revealed that the yield of potato (Eberlein *et al.*, 1997), cassava (Olasantan *et al.*, 1994; Alabi *et al.*, 2004), sweet potato (Levett, 1992) and taro (Gurnah, 1985) decreased markedly with increasing weed population.

Arnold *et al.* (1997) pointed out that weed invasion could affect both the quality and quantity of potato by reducing its size, weight and number of tubers. Interference of weeds in potato plants reduced the marketable yield by declining tuber number and size (Ahuja *et al.*, 1999) and also hinderd mechanical harvest (Pandey, 2000). Inadequate weed control caused 20 to 80 per cent tuber yield loss in potato (Baziramakenga and Leroax, 1994; Ivany; 1986). Karimmojeni *et al.* (2013) reported that as the duration of weed infestation increased, total dry biomass and total number of weeds increased in potato.

According to Gurnah (1985), compared to the later stages of crop development, yield reduction by weed competition was more evident at the early stages as the crop canopy could suppress weed growth, if it completely covered the ground. Because of the initial slow growth rate in cassava, yams, cocoyams, Irish potatoes, and similar root crops, at the early stages of growth, they were susceptible to severe weed competition (Onochie, 1978). Unamma and Ene (1984) reported that response of root and tuber crops and weeds were generally similar to the environmental factors involved in plant growth such as water, light, air and nutrients and these generated competition and resulted in their sharing of available resources and consequently led to reduction in crop yield. In cassava growing areas, weed infestation was a major constraint and the major labour consuming activity is weeding (Ravindran and Ravi, 2009).

In elephant foot yam, weeds grow much before shoot development from planted corms because of corm dormancy and delay in sprouting. Under weedy conditions, leaves were smothered under weeds and the number of leaves, total leaf area, leaf thickness and fresh masses of corms decreased markedly (Santosa *et al.*, 2006).

Dominance of weed species varied with place (Ambe *et al.*, 1992; Ravindran and Ravi, 2009). Fields, in which grass weeds like *Cyperus rotundus, Cynodon dactylon* and *Panicum repens* were dominant, posed difficulty in weeding and finally the tuber quality was affected. Nedunchezhiyan *et al.* (1996) stated that loss caused by the weeds depended upon their density, dominance, and ecological success. Nedunchezhiyan *et al.* (1996) also pointed out that weed interference in taro could prevent the optimum leaf area development, which in turn affected the production of necessary assimilates for tuber bulking and weeds could delay the cormel initiation and reduce the number of cormels per plant.

Elephant foot yam is susceptible to weed growth throughout the crop growth period because of less coverage of field by the leaf canopy. Often, weeds germinated and grew much earlier than the crop established because of delay in sprouting of planted corms (Nedunchezhiyan *et al.*, 2013). The critical period of crop - weed competition is between 1 to 5 months after planting as the major crop growth and corm bulking occurs during this period.

Santosa *et al.* (2006) reported that weeds could reduce the growth, yield and quality of the products since they were known to decrease the light intensity and nutrient availability for crop plants and also weeds made it difficult to harvest the crops. Experiments revealed that some weeds could stimulate the elongation of the petioles of elephant foot yams at the expense of thickening and became taller than elephant foot yam.

Lambers *et al.* (1998) reported that the total leaf area and leaf thickness got reduced under shady conditions while the stem and petiole elongation was significantly enhanced in elephant foot yam. As elephant foot yam was capable of tolerating shade, this crop did not compete for light (Das and Maharana, 1995). Kumari and Sasidhar (1992) reported that the yield of elephant foot yam decreased linearly with the decrease of light intensity even though they were considered as shade tolerant. Gurnah (1985) reported that corm production was high when weeds were removed during the period from 1 to 4 months after planting in taro.

Santosa *et al.* (2004) reported that since daughter corms started to significantly enlarge at 75 days after planting, an environment with less competition for light, water and nutrients with weeds would be desired for the enlargement of the daughter corms and suggested that weeding at every month could bring more yield than when weeding was discontinued at four months after planting. Santosa *et al.* (2004) recommended the removal of weeds at two and four months after planting in elephant foot yam in an intercropping system as the weed mass would have significantly increased up to 4 months, and compared with the removal of weeds twice, more work may be necessary to remove the weeds during the period.

Santosa *et al.* (2006) mentioned that number of leaves, total leaf area, leaf thickness and fresh masses of corms decreased markedly under weedy conditions in elephant foot yam in which leaves were submerged under the weeds. With the increase in the frequency of weeding, values of the fresh mass of the corms and cormels, total number of cormels and the number of large sized cormels was significantly increased.

2.3 Diversity of weeds in tuber crops

Nedunchezhiyan *et al*. (1996) reported that in taro under subtropical climate, 23 species of weeds were associated, major weeds being *Celosia argentia, Digitaria sanguinalis* and *Cleome viscosa.* Doll *et al*. (1977) compiled the names of ten most important weeds in cassava fields in Columbia including *Pteridium aquilinium, Imperata cylindrica, Melinism inutiflora, Sida acuta, Cyperus rotundus, Commelina diffusa, Ageratum conyzoides,* and *Portulaca oleracea.*

Goswami and Saha (2006) listed the weed flora in the experimental field of elephant foot yam consisting mainly of grass weeds such as *Cynodon dactylon, Dactyloctenium aegyptium, Eleusine indica, Fimbristylis littoralis,* and *Panicum repens. Amaranthus viridis, Solanum nigrum, Tridax proccumbens,* and *Argemone mexicana* were the major broad leaf weeds and among sedges, *Cyperus rotundus* was the major one.

Unamma and Ene (1984) mentioned the dominant weeds of cassava at eight weeks after planting (from unweeded control plot) as *Boerhavia diffusa, Calapogonium mucunoides, Cleome ciliata, Commelina benghalensis, Eupatorium odoratum, Euphorbia hirta, Talinum triangulare,* and *Trianthema protulacastrum*, among the broad leaf weeds. Major grasses were *Andropogon gayanus, Brachiaria deflexa, Cynodon dactylon, Digitaria horizonta, Panicum maximum, Paspalum orbiculare*, and *Setaria barbata*. The overriding sedges were *Cyperus difformis, C. distans, Fimbristylis barten, Kyllinga nemoralis*, and *Mariscu salternifolius.*

Eshetu *et al.* (2015) reported that *Cynodon* spp., *Cyperus* spp., *Digitaria* spp., *Gyzotia scabra, Nicandra physaloides, Bidens polynchyma, Commelina benghalensis, Ageratum conyzoides,* and *Plantago lanceolata* were the major weeds found in turmeric grown fields of Ethiopia. Mehring *et al.* (2016) reported certain weed species present in the irrigated potato fields of USA included common lambsquarters, redroot pigweed, hairy nightshade, yellow foxtail, Pennsylvania smartweed, common purslane, wild buckwheat, and eastern black nightshade.

Bhullar *et al.* (2015) reported some common weeds in the potato grown fields of Ludhiana as burclover (*Medicago arabica*), common lambsquarters (*Chenopodium album*), littleseed canary grass (*Phalaris minor*), purple nutsedge (*Cyperus rotundus*), scarlet pimpernel (*Anagallis arvensis*), swine cress (*Coronopus didymus*), and toothed dock (*Rumex dentatus*).

Uremis *et al.* (2009) noted the most dominant weed species under early season potato in the Mediterranean conditions of Turkey as wild mustard, canary grass, Johnson grass, Corn chamomile, Italian thistle, redroot pigweed, field bindweed and common cocklebur.

According to various studies conducted in India, grass weeds like *Echinochloa colona, Cynodon indica, Cynodon dactylon, Eleusine indica* and *Dactyloctenium aegyptium;* sedge weeds such as *Cyperus rotundus* and *Fimbristylis miliaceae;* and broad leaf weeds such as *Eclipta alba, Amaranthus viridis, Euphorbia hirta, Amaranthus spinosus, Commelina benghalensis, Corchorus acutangulus, Phyllanthus niruri* and *Cleome viscosa* were observed in elephant foot yam cultivated fields (Bhaumik *et al.*, 1988; AICRPTC, 2004).

2.4 Weed management methods

2.4.1 Manual weeding

Nedunchezhiyan *et al.* (2013) reported that hand weeding was the most common method of weed control practiced in root and tuber crops. Farmers carried out hand weeding at monthly intervals up to 4 months after planting. Each weeding was followed by earthing up. Hand weeding or any cultural methods were the most common measure adopted to control weeds in tuber crops (Lebot, 2009).

Agahiu *et al.* (2011) pointed out that the oldest method of weed control was perhaps hand weeding and consists of hand pulling, hand slashing and hoeing which have constantly proved incompetent and expensive too. Khurana *et al.* (1993) reported that manual hoeing was quite effective but not much effective, if performed in the later stages of plant growth, since it might cause root injury and disturbs root system in potato. Americanos (1994) stated that more than three times hoeing had pessimistic effect on yield of potato.

Santosa *et al.* (2006) showed that the weeding frequency affected the growth and yield of elephant foot yam. To obtain high yield of elephant foot yam, weeding twice during the growing season, *i.e.*, at two and four months after planting, is recommended. Eshetu *et al.* (2015) reported that as frequency of hand weeding increases, rhizome weight and rhizome length in turmeric also increases.

Korieocha (2014) reported that manual weeding in yam was tedious and involved a lot of labour, and also due to increased soil temperature and reduced soil moisture, continuous weeding might cause rotting of tubers. Nelson and Giles (1986) pointed out that even though hoeing was an effectual method to control weeds, it resulted in lower yield, higher weed germination, and loss in soil humidity.

2.4.2 Mulching

Dev (2012) observed better sprouting, conservation of moisture, and reduction of temperature around the corm when the pits were mulched immediately after planting. Kumar *et al.* (1973) reported that mulching with leaves increases the yield, height, and size of the individual corms in elephant foot yam. Studies conducted at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India revealed that weed management through mulching could control weeds effectively, but the economics of this method had to be considered (CTCRI, 2013).

According to Kumar *et al.* (1973), a higher percentage of early sprouting, greater canopy spread, plant height, greater mean corm weight, and total corm yield could be assured through soil moisture conservation methods like mulching. Living and dead mulch exhibited allelopathic properties and could inhibit the light necessary for weed shoot emergence and growth (Liebl *et al.*, 1992; Zimdahl, 1999). According to Eruola *et al.* (2012) the beneficial effects of mulch on tuber yield were probably due to favorable hydrothermal regimes of the soil for emergence and early development of yam plants.

Application of mulches on soil surface is a very common practice in high value crops. Mulching immediately after planting is the most important operation in elephant foot yam. Mulching not only increased the growth and yield of crops but also improved the soil moisture status, weed suppression, disease control, and temperature regulation of upper layers of the soil (Weeratna and Asghar, 1992; Dayal *et al.*, 1995; Solaiappan *et al.*, 1999).

Straw mulching and mulching with polythene showed a greater response and yielded about 11.69 to 14.12 t/ha whereas mulching with live cowpea showed a significantly reduced corm yield (5.68 t/ha) compared to control (7.98 t/ha) (AICRPTC, 2004; 2006b).

Dayal *et al.* (1995) reported that during the stage of seed corm sprouting, organic mulches retained a static soil temperature of 32^0C to 36^0C. Eruola *et al.* (2012) reported 46 per cent increase in emergence rate, seasonal tuber yield of 6 to 8 t/ha, increase in vine length, number of stem branches, number of leaves, and leaf area index (LAI) in yams when mulched compared to that of unmulched plots.

2.4.3 Plastic mulching

Mulching the soil with plastic films increased the crop production efficiency and productivity as it controlled weeds, improved soil conditions for plant growth by influencing the root zone temperature, and provided better assimilation of nutrients by reducing the compaction of soil and leaching of fertilizers in to the soil (Lamont, 2005; Ibarra-Jiménez *et al.*, 2008). Plastic mulches could increase soil temperature and the effect was more pronounced in mulches with darker colors than white, silver, and aluminum mulches with high reflectance (Rangarajan and Ingall, 2001). Plastic mulches could change the microclimate of the plant and also favour growth and vigor, production, and yield of plants (Andino and Motsenbocker, 2004; Díaz-Pérez, 2010).

Goswami and Saha (2006) reported that black polythene mulches increased the corm yield of elephant foot yam by 22.4 to 28.8 per cent over control (no mulch situation), and it gave more yield due to higher level of weed control and it also reduced the excessive loss of water through evaporation from the soil (Ashworth and Harrison, 1983; Swenson *et al.*, 2004). At Kalyani, West Bengal, maximum corm yield of the plants mulched with black polythene was 82.5 t/ha and straw mulch was the next with 64.8 t/ha (AICRPTC, 2004).

Ruíz-Machuca *et al.* (2015) reported that plastic mulching could increase the crop production efficiency, the covering of rows could modify root zone temperature, and plant growth, along with reducing the damage caused by pest and enhance production in cultivated potato plants. Ruíz-Machuca *et al.* (2015) also observed that plastic mulching boosted the growth and tuber yield of potato plants and the highest yield was from black plastic mulch.

Regardless of the film colour, mulching of potato plants resulted in increased total dry weight which might have been due to the modification of balance in radiation between soil surface and the change in the microclimate, which eventually resulted in more dynamic plants due to improved vegetative growth (Lamont, 2005; Kasperbauer, 2000). Kumari (2012) reported a positive effect on production of leaf area, dry matter, and consequently higher yields in potato through plastic mulching.

2.4.4 Mulching with dry grass

Studies conducted by AICRP on tuber crops revealed that compared to routine control practices, maximum plant height, girth, and corm yield were observed in fields mulched with paddy straw (AICRPTC, 2004; 2006). Another study showed reduction in weed population as well as dry weed biomass in fields mulched with straw at the time of planting followed by herbicides like pendimethalin, glyphosate, oxyfluorfen at 1 kg/ha (AICRPTC, 2004; 2006).

Legumes and dry mulch covers were valuable as they could improve soil organic matter content, and in that way, could improve nutrient status of soil, and restrain the weeds (Unamma *et al.,* 1986). Bhullar *et al.* (2015) reported that straw mulch could suppress early germinating annual broadleaf and grass weeds and would be sustainable for a long period if applied in proper time.

Goswami and Saha (2006) reported that due to greater light penetration and delayed decaying process of the straw, mulching with wheat straw showed the lowest weed control efficiency (24.7 to 25.1 per cent). Johnson *et al.* (2004) reported that application of straw mulch at planting suppressed weeds in potato, whereas application of straw after cultivation had fewer outcomes on weeds.

Tuber yield in potato increased when straw mulch was applied at 6 t/ha four weeks after planting (Kar and Kumar, 2007) but with low amounts of straw mulch (2.5 to 5.0 t/ha) any effect on weed suppression and yield was not evident (Doring *et al.*, 2005).

2.4.5 Intercropping and mulching with cowpea

Synchronized growing of two or more crops not only gave more yield and net profit but also reduced the cost of cultivation (Salter, 1986). However, it is common knowledge that inclusion of any intercrop reduced the yield of main crop (Chattopadhyay *et al.* 2008, Singh *et al.,* 2013), although, Quayyam and Ebrahim (1988) reported highest profitability from intercropped treatment. Several studies revealed that intercropping could reduce the vegetative growth of component crops (Amanullah *et al.*, 2006; Silwana and Lucas, 2002; Thirumdasu *et al.*, 2015). When grown in association with a legume, cassava yield was reduced by 19 per cent compared to weed free cassava sole crop (CIAT, 1979; Fening *et al.*, 2009; Leihner, 1980).

In certain cases involving legume intercrops, higher yield of main crops have been reported. For example, studies done as a part of AICRP on tuber crops revealed that compared to control, cowpea live mulch produced greater yield of 41.72 t/ha (AICRPTC, 2006a; 2006b). As the crop would not be able to provide satisfactory level of weed control, intercropping can be adopted as a potential biological tool to suppress weeds at the early stage of crop growth (Dwivedi and Shrivastava, 2011). When compared to plants mulched with rice straw or grass, plants mulched with legume leaves increased vegetative growth of both species and these legumes had a lower C:N ratio and the rice straw (or grass) mulch, which had an elevated C:N ratio, improved the tuber yields by 24 per cent when compared to the legume leaf mulch in this long term tuber crop (Sangakkara *et al.*, 2004).

Akobundu (1980) reported that if soil fertility was sufficient, intercropping of cassava with early maturing cover crops or other crops entailed less weeding than when it was grown as a sole crop. For the management of weeds in cassava, growing of smother crops such as beans, cowpea, maize, groundnut and melon during its initial growth period up to 90 days was found effective (Leihner, 1980; Ossom, 1986; Zuofa *et al.*, 1992; Amanullah *et al.*, 2006).

Abu-Rayyen and Abu-Irmaileh (2004) reported that live mulch with cowpea did not improve the yield of elephant foot yam, as the main crop had to compete for moisture and nutrients with the mulch crop.

The efficiency of a cover crop for weed control was dependent upon the amount of biomass on the soil surface and that incorporated into the soil (Mohler and Teasdale, 1993). Through the properties like competition, allelopathy, weed seed decay in the seed bank, and the proliferation of residue, cover crops controlled the weeds (Conklin *et al.*, 2002).

2.4.6 Use of pre emergence and post emergence herbicides

For managing weeds in most tuber crops including sweet potato, yams, and cocoyams, use of herbicides was not popular (Hauser *et al.*, 2015; Moody and Ezumah, 1974; Nedunchezhiyan *et al.*, 2013; Silva *et al.*, 2013). Probably because of their low specificity, low availability, high cost, and phytotoxicity in comparison to cultural methods of weed control, herbicides were recommended sparsely to control weeds in root and tuber crops when compared to cereals (Donald *et al.*, 1991; Enyong *et al.*, 2013; Melifonwu *et al.*, 2000; Moyo *et al.*, 2010). However, application of herbicides was cheaper than manual weeding and provided superior weed control during the critical stages of yam growth, and was an efficient means of weed control in yam in developed agricultural systems (Korieocha, 2014). The cost and availability were the limiting factors for the use of herbicides by small farmers in tropics (Ravindran *et al.*, 2010). It was feared that quality of the produce would be further reduced by herbicides (Nedunchezhiyan *et al.*, 2011). Ferguson (1970) pointed out that the necessity of weedings was fewer and cost per weeding was cheaper in chemical weed control.

Sarma and Gautam (2010) pointed out that weed control through application of herbicides was an obvious choice as labour was becoming relatively expensive and often scarce especially in the early growth stages of crop. They further noted that hand weeding (manual) or other physical means were effectively utilized for weed control, as far as weed competition was a severe constraint, but chemical method of weed control was rapidly becoming the most promising alternative method. Nedunchezhiyan *et al.* (1996) pointed out that during the peak season, chemical weed control was preferred by farmers due to high cost of hand weeding and non availability of labour.

Nedunchezhiyan *et al.* (2013) observed the preference of farmers for paraquat (2 to 3 ml/L) and glyphosate (4 to 5 ml/L) during 1 - 2 months and 3 - 5 months after planting to control weeds of crop fields in Andhra Pradesh. After transplanting or ridging, directed spray of paraquat with trifluralin had provided adequate weed control in tuber crops (Takabayashi, 1977; 1978).

Phytotoxic symptoms such as yellowing, stunting of plants and reduction in yield had been attributed to pre emergence application of herbicides like oxyfluorfen, pendimethalin, vernolate, and EPTC and by high concentration of glyphosate (greater than 2 per cent) (Liu *et al.*, 1982; Santos *et al.*, 1982: AICRPWC, 1990).

Studies conducted at the Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar revealed that application of glyphosate at 2 kg/ha at 1 to 3 months after planting and the functioning of the weeds as mulch could be effectively utilized for the management of weeds in elephant foot yam. Manickam and Gnanamurthy (1994) pointed out that spraying glyphosate (1 per cent) with 0.5 per cent 2, 4-D sodium salt or 1 per cent ammonium salt could reduce the biomass of nutsedge.

According to James and Follett (2000), elephant foot yam was more tolerant to pre emergence herbicide treatments. Bhaumik *et al*., (1988) reported that pre planting incorporation of fluchloralin at 2.0 L/ha or pre emergence application of pendimethalin 3.3 L/ha or oxyfluorfen 0.5 L/ha or post emergence application of bentazone 1.5 L/ha or bromoxinil 1.5 L/ha were effective in controlling the weeds in elephant foot yam. The crop tolerated pre emergence application of acetochlor, chlopropham, dimethanamid, linuron, methabenzthiazuron, oryzalin, oxadiazon, oxyfluorfen and pendimethalin. It has been reported that post emergence application of asulam, flumetsulam and tribenuron were found to be safe. If applied before the emergence of leaves from developing shoot, bromoxynil was also safe on elephant foot yam (James and Follett, 2000).

Pre emergence application of linuron, pendimethalin and oxyfluorfen and post emergence application of bentazone and bromoxynil have been found effective for weed control in tuber crops (Nakayama, 1974; Bhaumik *et al*., 1988). Hand weeding supplemented more than 80 per cent weed control efficiency in hand weeding, oxyfluorfen 0.1 kg/ha and pendimethalin 0.75 kg/ha (Sheikh, 2005).

2.4.7 Integrated weed management

Swanton and Weise (1991) pointed out that for maintaining crop yield and reducing the use of herbicide, integrated weed management practices could be adopted and taken as a better alternative. For controlling weeds in tuber crops, integrated weed management (IWM) had become a vital tool (Akobundu, 1987; Iyagba, 2010; Labrada and Parker, 1994; Melifonwu, 1994; Nedunchezhiyan *et al*., 2013). Akobundu (1987) commented that, compared to any other type of food crop, integrated weed management was more desirable in root and tuber crops.

To reduce the input levels in chemical or cultural weed control method, it was better to coalesce the exploitation of plant canopy (through changes in row spacing and spatial arrangement of root and tuber crops) with other methods of weed management (Akobundu, 1987). Number of weed seeds reduced considerably in plots receiving herbicide spray + one hand weeding (Mishra and Singh, 2009).

Weed population as well as dry weed biomass could be effectively reduced through mulching with straw at the time of planting followed by herbicides (pendimethalin, glyphosate, oxyfluorfen at 1 kg/ha) (AICRPTC, 2004; 2006). Integrated application of paddy straw mulch and manual weeding showed maximum corm yield (AICRPTC, 2004; 2006).

According to Akobundu (1980), weeds in cassava could be effectively managed by the integrated application of cowpea and pre emergence herbicides such as alachlor or chloramben or fluometuron or mixture of fluometuron and chloramben. Regardless of the dose, except for swinecress and purple nutsedge, a combination of atrazine and straw mulch resulted in greater than 90 per cent weed control at 30 days after transplanting in potato (Bhullar *et al.*, 2015).

Eshetu *et al.* (2015) reported that comparable weight and length of rhizome were found in the plants mulched at the time of planting followed by two hand weedings at 60 and 90 days or mulching at planting followed by hand weeding at 45 and 75 days. AICRPTC (2004) suggested that application of glyphosate along with one hand weeding would result in maximum corm yield of 49.8 t/ha.

2.5 Economics of production

For the cultivation of elephant foot yam in Kerala, Andhra Pradesh and Tamil Nadu, the gross cost of cultivation assessed based on 2002 - 2003 price was Rs. 1,73,105, Rs 93,450 and Rs 1,68,032 per ha and the corresponding benefit - cost ratios were 1.38, 1.38 and 1.50 respectively (Srinivas and Ramanathan, 2005).

Goswami and Saha (2006) reported that surface mulching in elephant foot yam increased cost of production by about 1.7 to 57.1 per cent. Because of high cost, mulching with polythene caused reduction in net income, and B : C ratio was the lowest in polythene mulching. However, the B : C ratio was the highest in organic mulches. In elephant foot yam, compared to polythene mulches (1.8 to 2.09), organic mulches such as water hyacinth and paddy straw produced the highest benefit : cost ratio ranging from 3.12 to 3.38.

As polythene mulches increased soil temperature by 8 to 9^0C more than the normal bare soil temperature, polythene mulches were not economical and not suitable for the crops during summer (Goswami and Saha, 2006). The corm yield and net return from straw mulch treatment was inferior to polythene mulch, but the cost : benefit ratio of straw mulch (1 : 3.18) was superior to polythene mulch and other treatments (AICRPTC, 2004).

Nedunchezhiyan (2008) reported that with the supplementary investment of Rs. 10,000/ha, seed crop gave additional return of Rs.70,000/- per ha (7 tonnes higher yield and higher rate) over marketable crop and could anticipate an overall net returns from elephant foot yam seed crop at Rs. 1,60,000/ha.

Materials & Methods

3. MATERIALS AND METHODS

The study entitled "Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]" was carried out at the Agronomy farm, Department of Agronomy, College of Horticulture, Vellanikkara from March to December 2016. The materials used and methodology adopted for the investigation are detailed in this chapter.

3.1 General details

Location

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

Climate and weather conditions

The area enjoys a typical tropic humid climate. The mean weekly averages of important meteorological parameters observed during the experimental period are presented in Appendix 1.

Soil

The soil of the experimental site is a well drained sandy clay loam with medium texture and is acidic in reaction with a pH of 6.1. The physico-chemical properties are depicted in Table 1.

Season

The experiment was conducted during the period from March to December of 2016. Corm pieces were planted in March before the onset of the south west monsoon.

Table 1. Physico - chemical properties of soil

Particulars	Value	Method used
1. Physical properties		
Particle size composition		
Coarse sand (%)	31.90	Robinson international pipette method (Piper, 1942)
Fine sand (%)	27.30	
Silt (%)	18.64	
Clay (%)	22.16	
2. Chemical properties		
pH	6.10	1: 2.5 soil water ratio (Jackson, 1958)
Organic carbon (%)	1.18	Walkley and Black method (Jackson, 1958)
Available N (kg/ha)	121.42	Alkaline permanganate method (Subbiah and Asija, 1956)
Available P (kg/ha)	12.47	Ascorbic acid reduced molybdo phosphoric blue colour method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965)
Available K (kg/ha)	92.14	Neutral normal ammonium acetate extraction and estimation using flame photometry (Jackson, 1958)

Cropping history of the experimental site

The field was under cassava cultivation during the previous year.

Cultivar

'Gajendra', a popular cultivar of elephant foot yam recommended for commercial cultivation in India was used for this study. 'Gajendra' is a local selection from Kovuur area of Andhra Pradesh and known for its non acrid, well shaped tuber.

The corms of this cultivar are generally devoid of cormels or propagules and are able to yield 50 to 60 t/ha.

3.2 Experimental details

The study was conducted from March to December of 2016. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and 3 replications. The plot size was 5.4 m x 4.5 m with a plant to plant spacing of 90 cm x 90 cm. One row of plants was left as border all around the plot and the final net area was 3.6 m x 2.7 m. The treatment details are given below:

Treatments

T_1 - Manual weeding twice, 45 and 75 days after planting

T_2 - Manual weeding thrice, 45, 75, and 105 days after planting

T_3 - Manual weeding four times, 45, 75, 105, and 135 days after planting

T_4 - Oxyfluorfen 0.2 kg/ha and manual weeding once, 75 days after planting

T_5 - Pendimethalin 1.0 kg/ha and manual weeding once, 75 days after planting

T_6 - Directed spray of glyphosate 0.8 kg/ha, 30 DAP and manual weeding once, 75 DAP

T_7 - Mulching with black polythene

T_8 - Mulching with dry grasses

T_9 - Intercropping with cowpea

T_{10} - No weeding (control)

Experimental design	: Randomized Block Design (RBD)
Replication	: 3
Spacing	: 90 cm x 90 cm
Gross plot size	: 5.4 m x 4.5 m
Net plot size	: 3.6 m x 2.7 m

Layout

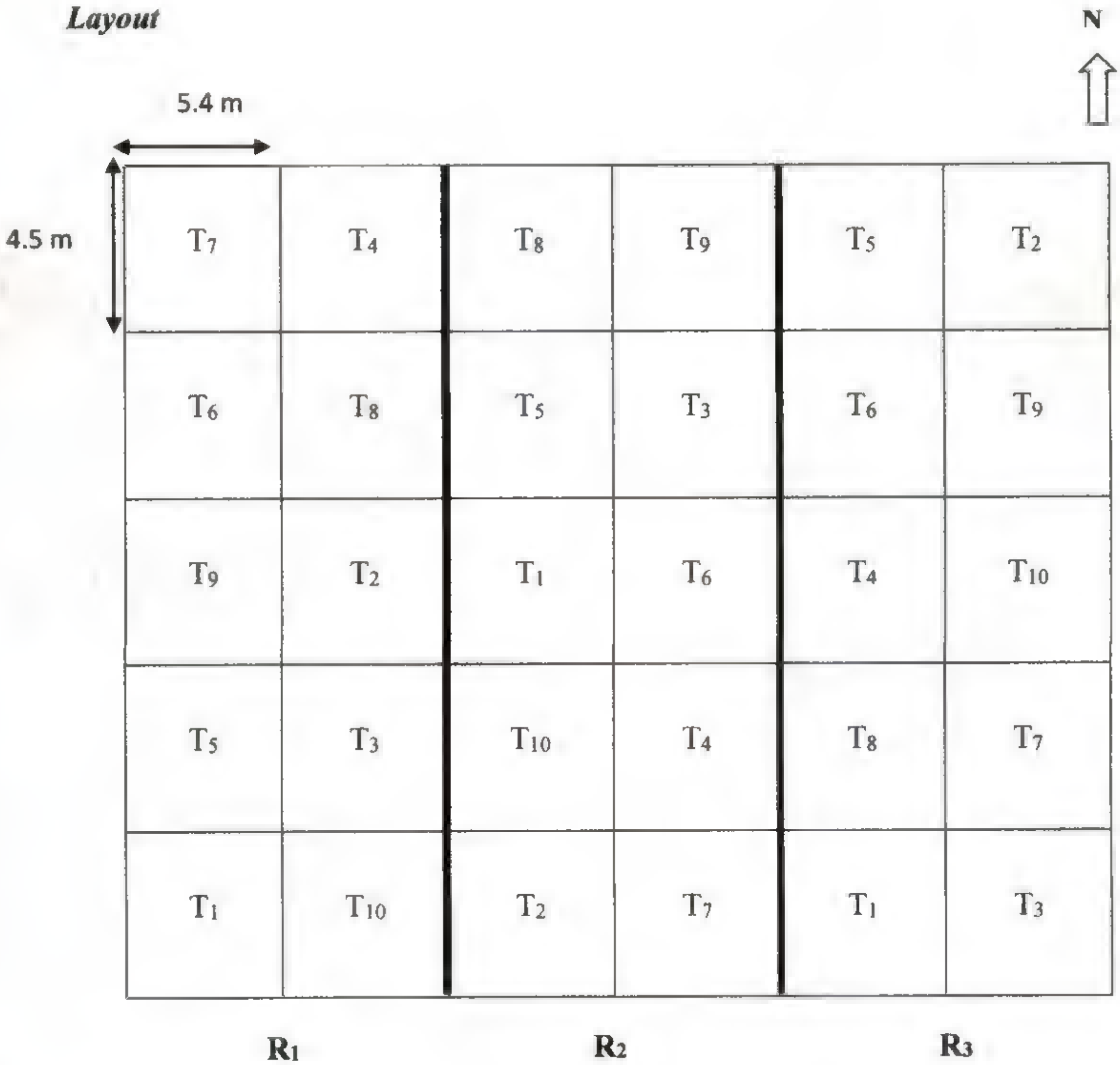

Fig.1. Layout of the experimental field

Land preparation and sowing

The site was ploughed thoroughly with disc plough, and later cultivator was used to produce fine tilth of soil. The gross area of the experiment was 848.25 m^2 and the net area used for experiment was 729 m^2. Pits of 60 cm x 60 cm x 45 cm were dug at 90 cm spacing. Cut corm pieces weighing about 750 g were used for planting. Before planting, these cut pieces were dipped in cow dung slurry and allowed to dry under shade. This treatment was done to prevent drying of cut surfaces. A total of 625 kg of seed material was used for planting the whole area. Elephant foot yam cultivar, 'Gajendra' obtained from Department of Agronomy, College of Horticulture, Vellanikkara was used for planting.

Manures and fertilizers

Manures and fertilizers were applied according to the package of practices recommendations of KAU (KAU, 2011). Farmyard manure at 2.0 kg/pit mixed with topsoil was applied as basal dose during land preparation. Full dose of P_2O_5 and half the dose of N and K_2O were applied at 50 : 50 : 75 kg/ha at 45 days of planting along with intercultivation and weeding. The second dose of N and K_2O fertilizers were applied one month after the first application at the rate of 50 : 75 kg/ha along with intercultivation and earthing up. In black polythene mulch, fertilizers were applied through the holes shaped for plant emergence.

Plant protection

Incidence of sclerotium rot was noticed in the field in all treatments, but severity of incidence was controlled at the early stages itself. Soil drenching and spraying of the fungicide, Saaf® (carbendazim 12 per cent + mancozeb 63 per cent) at 2 g/L was done against sclerotium rot. No insect pest incidence was noticed in the plots.

Weed management

Weed management was done as per treatments. Except for the treatment mulching (with black polythene, dry grass, and cowpea) and herbicides, manual weeding was done at 45, 75, 105, and 135 DAP according to the treatments. In the plots receiving treatment with pre emergence herbicides pendimethalin (Stomp® 30 EC) at 1.0 kg/ha and oxyfluorfen (Goal® 23.5 EC) at 0.2 kg/ha, spraying was carried out after the receipt of the first rain after planting and manual weeding was done at 75 DAP. Directed spray of glyphosate at the rate of 0.8 kg/ha was done on the 30th day of planting along with a follow up manual weeding on 75 DAP. Black polythene sheet of 50 gauge was spread over the plot on the same day of planting. Cowpea seeds were broadcasted in the plots immediately after planting.

Harvesting

The harvesting of crop was carried out after nine months of planting, after the yellowing and drying out of aerial plant parts. All the plants, except the plants in the treatment black polythene mulching showed uniform harvesting maturity. Plants in the treatment black polythene mulching attained harvesting maturity about one month later than other treatments

3.3 ..Observations recorded

3.3.1. Elephant foot yam

Biometric observations before harvest

1. Plant height
2. Length of petiole and rachis
3. Girth of pseudostem
4. Life span of leaves (emergence to yellowing)
5. Leaf area per plant and leaf area index
6. Dry weight of plants

Observations after harvest

1. Height of corm
2. Diameter of corm
3. Volume of corm
4. Fresh weight of corm
5. Dry weight of corm
6. Corm yield per hectare

From each plot, five plants were selected randomly as the sampling unit for biometric observations. Plant height, pseudostem girth, and length of petiole and rachis, were recorded from the selected five plants at 90 and 180 DAP whereas, leaf area and leaf area index were recorded only at 90 DAP. Dry weight of plants at 90, 180 DAP, and at harvest were also recorded. The height, diameter, volume, and fresh weight of harvested corms from each plot were recorded separately and the corm yield per hectare was worked out.

Plant height: The pseudostem height from the base of the plant to the point where the petiole (pseudostem) divides into three rachises and the length of the longest rachis over the ground level was considered as the plant height.

Length of petiole and rachis: The leaf blade with greatest length from the point of attachment with pseudostem was measured as length of petiole and the average length of each rachis in a plant was noted and recorded as length of rachis.

Girth of pseudostem: The diameter of the collar portion of the pseudostem was measured and the average girth from five plants from each plot were considered for the collection of data and finally the average diameter was recorded.

Leaf area and leaf area index: Estimation of leaf area was done according to the formula developed by Ravi *et al*. (2010) and the leaf area index (LAI) of the plant were recorded by the formula given by Watson (1947).

Total leaf area = P x 0.65 x total number of leaflets per plant

(Where, P is the average value of length and breadth of leaflets selected)

Leaf area index = Leaf area /Land area

Dry weight of plants: An uprooted plant including the above and below ground portions from each plot was cleaned and allowed to dry in shade after made into pieces and then kept at about 80^0C in a hot air oven. The dry weight was noted and recorded in grams at 90, 180 DAP, and at harvest.

Height of corm: The data from five plants were taken and finally the average height from ground level to top most part of the corm was recorded in centimetre at harvest.

Diameter of corm: Measurements were taken from one side to another, and the average diameter was then calculated and recorded in centimetre at harvest.

Volume of corm: The quantity of water overflowed from a pail after immersing the corm was recorded as volume of corm (dm^3)

Fresh weight of corm: Five sample plants were considered for the collection of data and fresh weight was noted, and finally average weight was recorded in kilograms.

Dry weight of corm: The weight of harvested corms after cleaning and oven drying at about 80^0C in hot air oven was noted and recorded in grams.

Corm yield per hectare: The yield per plot in kilograms was noted from the net plot yield. From this value, the yield per hectare (Mg/ha) was calculated.

3.3.2 Observation on weeds:

The density, dry weight, and the species wise composition of weeds in each plot was recorded at 45, 75, 105, and 165 days of plant growth.

Species wise composition: Weed count was taken species wise by using 50 cm x 50 cm (0.25 m^2) quadrat from the sampling strip. The quadrat was placed at random in each plot and observations were taken at 45, 75, 105 and 165 DAP.

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.

Density of weeds: The number of weeds from the quadrat divided by the area of quadrat was considered as density of weeds and recorded as number/m^2.

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

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

Weed index: Weed index was worked out using the formula suggested by Gill and Vijayakumar (1969).

$$\mathbf{WI = (X\text{-}Y)/X}$$

(X – Yield from treatment with least weeds, Y – Yield from treated plots)

The highest yield was observed in mulching with black polythene sheet treatment, so the yield of this treatment was taken as the X value for calculating the weed index.

3.3.3 Chemical analysis

3.3.3.1 *Soil analysis*

The pH, organic carbon and the content of major nutrients were estimated before and after the experiment. Soil samples were collected, dried, powdered and passed through 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. The soil pH was analyzed in a soil : water suspension of 1 : 2.5.

3.3.3.2 ***Plant analysis***

The content and uptake of major nutrients viz., N, P and K at 90 DAP from both shoot and corm and from corm at harvest were analyzed by standard procedures. The uptake of N, P and K were calculated as the product of the content of these nutrients and plant dry weight and expressed in kg/ha.

Nitrogen content

Nitrogen content was determined by distillation and titration method (Jackson, 1958).

Phosphorus content

Plant samples were digested with diacid and the P content was determined by the method vanadomolybdo phosphoric yellow colour method (Bray and Kurtz, 1945; Watanabe and Olsen, 1965).

Potassium content

K content in diacid digest was estimated using flame photometer (Jackson, 1958)

3.3.4 Incidence of pests and diseases

The incidence of pests and diseases was observed and recorded.

3.4 B : C ratio

The prevailing labour charge in the locality, cost of inputs and extra treatment costs were considered and gross expenditure computed and expressed in rupees per hectare. The current price of elephant foot yam in the local market was utilized for computing gross returns and expressed in rupees per hectare. The Benefit : Cost ratio (BCR) was worked out according to the formula given below

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

3.5 Statistical analysis

The data collected were subjected to analysis of variance using the statistical package 'WASP. 2' developed by ICAR - GOA. The data on species wise composition of weeds, dry weight, and density of weeds, which showed wide variation, were subjected to square root transformation ($\sqrt{X}+ 0.5$) to make the analysis of variance valid (Gomez and Gomez, 1984).

Plate 1. General view of the experimental field

Plate 2. Black polythene mulched plot after planting

Plate 3. Unweeded control plot at 45 DAP

Plate 4. Manual weeding plot at 45 DAP

Plate 5. Black polythene mulched plot at 75 DAP

Plate 6. Canopy spread of plants at 105 DAP in manually weeded plot

Results

4. RESULTS

The results of the study entitled "Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]" conducted at the Department of Agronomy, College of Horticulture, Vellanikkara during the year 2016 are presented below after subjecting them to appropriate statistical analysis.

4.1 Biometric observations before harvest

4.1.1 Plant height

The data pertaining to the height of plants are presented in Table 2. In elephant foot yam, plant height is the height of petiole (pseudostem) and the length of longest rachis. Plant height was unaffected by any of the treatments at 90 DAP as observed from non-significant observations. At 180 DAP, plant height was found to be significant among treatments and mulching with black polythene recorded the maximum plant height. Mean height at 90 DAP ranged from 113.5 cm to 127.33 cm and that at 180 DAP from 130.86 cm to 157.65 cm.

4.1.2 Pseudostem girth

The data on girth of pseudostem are given in Table 3. Similar to the data on plant height, the girth of pseudostem was non-significant among treatments at 90 and 180 DAP. Mean girth at 90 DAP was 11.26 cm to 16.83 cm and that at 180 DAP was 13.53 cm to 19.1 cm.

4.1.3 Length of petiole and rachis

The data on length of petiole and rachis are presented in Table 4 and Table 5 respectively. The length of petiole and rachis was unaffected by various treatments as observed from non-significant observations at 90 and 180 DAP.

4.1.4 Life span of leaves (emergence to yellowing)

The days from emergence to yellowing of the plants did not vary much among treatments and the data are presented in Table 6. Life span of leaves from emergence to yellowing was found to be non-significant among treatments. It ranged from 232 to 259 days.

4.1.5 Leaf area per plant and leaf area index

The data on leaf area per plant and leaf area index at 90 DAP are depicted in Table 7. Leaf area of the crop varied from 40.46 to 83.11 dm^2. At 90 DAP, mulching with black polythene (T_7) resulted in highest leaf area of 83.11 dm^2. Pre emergence application of oxyfluorfen (T_4) and directed spray of glyphosate (T_6) were next in rank with leaf area of 67.12 and 67.11 dm^2 which were on par followed by pre emergence application of pendimethalin (T_5). All the three plots receiving manual weeding were statistically on par in leaf area. Unweeded control (T_{10}) showed the lowest leaf area at 90 DAP.

Almost a similar trend was observed in leaf area index at 90 DAP. Leaf area index of elephant foot yam varied from 0.50 to 1.02. Black polythene mulch (T_7) showed the highest leaf area index of 1.02 followed by pre emergence application of oxyfluorfen (T_4) and post emergence application of glyphosate (T_6) with LAI 0.82. Plots given manual weeding were statistically on par in leaf area index at 90 DAP. Unweeded control (T_{10}) recorded the lowest leaf area index at 90 DAP.

4.1.6 Dry weight of plants

The data on plant dry weight at various stages are presented in Table 8. Mulching with black polythene (T_7), pre emergence application of oxyfluorfen (T_4), post emergence application of glyphosate (T_6), manual weeding four times

Table 2. Effect of treatments on plant height of elephant foot yam

Treatments		Plant height (cm)	
		90 DAP	180 DAP
T_1	Manual weeding twice, 45 and 75 DAP	116.00^a	140.50^{bc}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	117.56^a	140.66^{bc}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	117.35^a	154.38^{ab}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	121.33^a	149.38^{ab}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	118.93^a	143.83^{abc}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	122.13^a	148.48^{ab}
T_7	Mulching with black polythene	113.50^a	157.65^a
T_8	Mulching with dry grasses	123.66^a	146.26^{ab}
T_9	Intercropping with cowpea	127.33^a	149.33^{ab}
T_{10}	No weeding (control)	123.53^a	130.86^c

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 3. Effect of treatments on pseudostem girth of elephant foot yam

Treatments		Girth of pseudostem (cm)	
		90 DAP	180 DAP
T_1	Manual weeding twice, 45 and 75 DAP	14.75[a]	17.02[a]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	14.70[a]	16.97[a]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	11.26[a]	13.53[a]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	15.00[a]	17.27[a]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	16.10[a]	18.37[a]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	16.66[a]	18.93[a]
T_7	Mulching with black polythene	16.83[a]	19.10[a]
T_8	Mulching with dry grasses	12.16[a]	14.43[a]
T_9	Intercropping with cowpea	14.50[a]	16.77[a]
T_{10}	No weeding (control)	15.80[a]	18.07[a]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 4. Effect of treatments on length of petiole of elephant foot yam

Treatments		Length of petiole (cm)	
		90 DAP	180 DAP
T_1	Manual weeding twice, 45 and 75 DAP	47.66[a]	81.51[a]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	48.00[a]	80.50[a]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	47.66[a]	85.52[a]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	53.33[a]	74.73[a]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	48.66[a]	64.66[a]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	53.00[a]	75.33[a]
T_7	Mulching with black polythene	46.60[a]	80.50[a]
T_8	Mulching with dry grasses	53.33[a]	75.43[a]
T_9	Intercropping with cowpea	53.33[a]	72.00[a]
T_{10}	No weeding (control)	50.66[a]	67.66[a]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 5. Effect of treatments on length of rachis of elephant foot yam

Treatments		Length of rachis (cm)	
		90 DAP	180 DAP
T_1	Manual weeding twice, 45 and 75 DAP	55.90[a]	67.47[a]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	55.42[a]	72.90[a]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	53.05[a]	65.20[a]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	63.25[a]	76.40[a]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	62.43[a]	73.92[a]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	60.21[a]	72.71[a]
T_7	Mulching with black polythene	63.95[a]	76.12[a]
T_8	Mulching with dry grasses	59.36[a]	72.52[a]
T_9	Intercropping with cowpea	70.29[a]	81.78[a]
T_{10}	No weeding (control)	64.18[a]	76.67[a]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 6. Effect of treatments on life span of leaves of elephant foot yam

Treatments		Life span (days)
T_1	Manual weeding twice, 45 and 75 DAP	238 [a]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	238 [a]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	239 [a]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	238 [a]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	234 [a]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	236 [a]
T_7	Mulching with black polythene	259 [a]
T_8	Mulching with dry grasses	232 [a]
T_9	Intercropping with cowpea	235 [a]
T_{10}	No weeding (control)	232 [a]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 7. Effect of treatments on leaf area and leaf area index of elephant foot yam

Treatments		Leaf area (dm^2) 90 DAP	Leaf area index 90 DAP
T_1	Manual weeding twice, 45 and 75 DAP	58.30^d	0.72^d
T_2	Manual weeding thrice, 45, 75, and 105 DAP	58.44^d	0.72^d
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	59.21^d	0.73^d
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	67.12^b	0.82^b
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	63.11^c	0.77^c
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	67.11^b	0.82^b
T_7	Mulching with black polythene	83.11^a	1.02^a
T_8	Mulching with dry grasses	54.88^e	0.67^e
T_9	Intercropping with cowpea	49.03^f	0.60^f
T_{10}	No weeding (control)	40.46^g	0.50^g

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 8. Effect of treatments on dry weight of elephant foot yam

Treatments		Dry weight of plant (g)		
		90 DAP	180 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	149.25^{bc}	545.35^{b}	475.70^{c}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	180.57^{ab}	534.54^{b}	488.25^{bc}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	189.81^{ab}	550.90^{b}	487.47^{bc}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	199.20^{ab}	504.51^{b}	526.51^{ab}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	144.48^{bc}	344.40^{c}	462.50^{cd}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	154.62^{ab}	555.74^{b}	528.00^{ab}
T_7	Mulching with black polythene	211.33^{a}	661.25^{a}	553.40^{a}
T_8	Mulching with dry grasses	149.06^{bc}	286.03^{c}	308.28^{e}
T_9	Intercropping with cowpea	149.36^{bc}	301.30^{c}	421.05^{d}
T_{10}	No weeding (control)	89.23^{c}	123.66^{d}	159.30^{f}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

(T_3) and manual weeding thrice (T_2) recorded plant dry weight of 211.33, 199.20, 154.62, 189.81 and 180.57 g/plant respectively and were on par at 90 DAP.

At 180 DAP, unweeded control (T_{10}) recorded the lowest dry weight (123.66 g/plant). It was followed by mulching with dry grasses (286.03 g/plant), intercropping with cowpea (301.30 g/plant) and pre emergence application of pendimethalin (344.40 g/plant). Dry weight of plants in plots given manual weeding as treatments were found to be on par and showed almost same dry weight as that of pre emergence application of oxyfluorfen (T_4) and post emergence application of glyphosate (T_6).

Black polythene mulched (T_7) plots continued to register superiority in dry weight of plants till harvest and recorded the highest plant dry weight of 553.40 g/plant at harvest. Post emergence application of glyphosate (T_6) and pre emergence application of oxyfluorfen (T_4) were the next best treatments which were on par with respect to dry weight of plants at harvest (528.00 and 526.51 g). Dry weight at harvest was the lowest (159.30 g/plant) in unweeded plots.

4.2 Observations after harvest

4.2.1 Height of corm

Except manual weeding thrice (T_2), all other manual weeding (T_1 and T_3) treatments, glyphosate applied plots (T_6) and oxyfluorfen applied plots (T_4) were statistically on par with black polythene mulch (T_7) in terms of the height of corm at harvest (Table 9). The lowest corm height was noticed in unweeded plots (T_{10}).

4.2.2 Diameter of corm

The data on diameter of corm are presented in Table 9. The superiority of black polythene mulch was again visible by the highest corm diameter of 21.64

cm. Next in order were glyphosate applied plots (T_6) and oxyfluorfen applied plots (T_4) which were statistically on par with diameters of 20.58 cm and 20.62 cm respectively.

Unweeded control (T_{10}) showed the lowest corm diameter of 14.18 cm. The treatments mulching with dry grass (T_8) and pre emergence application of pendimethalin (T_5) were statistically on par in respect to the diameter of corm at harvest. The diameter of the corm ranged from 14.18 cm in unweeded control to 21.64 cm in black polythene mulch.

4.2.3 Volume of corm

The data on the volume of corm are presented in Table 9. The maximum corm volume was in black polythene mulched plots (3.24 dm^3). This was on par with pre emergence application of oxyfluorfen (T_4), directed spray of glyphosate (T_6), and manual weeding four times, with corm volumes of 2.73, 2.59 and 2.56 dm^3.

Manual weeding thrice (T_2), and pre emergence application of pendimethalin (T_5) were statistically on par regarding the volume of corm at harvest. Mulching with dry grasses (T_8) and unweeded control (T_{10}) resulted in lower volume of corm compared to other treatments with volumes 1.70 and 1.04 dm^3 respectively.

4.2.4 Fresh weight of corm

Observations on fresh weight of corm at harvest are given in Table 10. The treatments mulching with black polythene (T_7) recorded higher fresh corm weight (2.89 kg), which was on par with pre emergence application of oxyfluorfen (T_4), directed spray of glyphosate (T_6), and manual weeding four times (T_3) with fresh

Table 9. Effect of treatments on height, diameter and volume of corm

Treatments		Height of corm (cm)	Diameter of corm (cm)	Volume of corm (dm^3)
T_1	Manual weeding twice, 45 and 75 DAP	12.00^{a}	19.71^{abc}	2.51^{bc}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	11.45^{ab}	18.01^{c}	2.27^{bcd}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	12.12^{a}	20.40^{abc}	2.56^{ab}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	12.11^{a}	20.62^{ab}	2.73^{ab}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	11.38^{ab}	18.70^{bc}	2.09^{bcd}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	12.16^{a}	20.58^{ab}	2.59^{ab}
T_7	Mulching with black polythene	12.68^{a}	21.64^{a}	3.24^{a}
T_8	Mulching with dry grasses	10.44^{bc}	18.18^{bc}	1.70^{de}
T_9	Intercropping with cowpea	10.50^{bc}	17.98^{c}	1.85^{cd}
T_{10}	No weeding (control)	9.14^{c}	14.18^{d}	1.04^{e}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 10. Effect of treatments on fresh weight of corm and corm yield per hectare

Treatments		Fresh weight of corm (kg/plant)	Corm yield per hectare (Mg/ha)
T_1	Manual weeding twice, 45 and 75 DAP	2.13^{cd}	26.36^{cd}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	2.19^{bcd}	27.07^{bcd}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	2.52^{abc}	31.13^{abc}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	2.72^{ab}	33.66^{ab}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	1.92^{d}	23.78^{d}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	2.68^{ab}	33.08^{ab}
T_7	Mulching with black polythene	2.89^{a}	35.77^{a}
T_8	Mulching with dry grasses	1.87^{d}	23.15^{d}
T_9	Intercropping with cowpea	1.80^{d}	22.25^{d}
T_{10}	No weeding (control)	1.25^{e}	15.43^{e}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

weights of 2.72, and 2.68 and 2.52 kg respectively. Unweeded control (T_{10}) showed the lowest corm fresh weight of 1.25 kg compared to other treatments.

Manual weeding four times (T_3) recorded higher fresh weight compared to other manual weeding twice and thrice. Mulching with dry grasses (T_8) and intercropping with cowpea (T_9) were statistically on par and recorded 1.87 and 1.80 kg fresh weight respectively.

4.2.5 Dry weight of corm

Dry weight of plants at harvest and dry weight of corm were the same. The data has already been presented in Table 8. Black polythene mulched (T_7) plots showed the highest corm dry weight of 553.40 g/plant at harvest. Post emergence application of glyphosate (T_6) and pre emergence application of oxyfluorfen (T_4) was the next best treatments and were on par with respect to dry weight of corm at harvest. Unweeded plots (T_{10}) showed the lowest corm dry weight of 159.30 g/plant.

4.2.6 Corm yield per hectare

The data on yield of corm per hectare are presented in Table 10. Following the trend in fresh weight of corm at harvest, the highest corm yield per hectare of 35.77 Mg/ha was in plots of black polythene mulch (T_7), which was on par with pre emergence application of oxyfluorfen (T_4), post emergence application of glyphosate (T_6) and manual weeding four times (T_3) with corm yields of 33.66 and 33.08 and 31.13 Mg/ha respectively. The plots receiving manual weeding twice (T_1) and thrice (T_2) recorded corm yields of 26.36 and 27.07 Mg/ha. Unweeded control (T_{10}) recorded the lowest corm yield of 15.43 Mg/ha.

4.3 Observation on weeds

4.3.1 Species wise composition of weeds

The data on species wise composition of weeds are given in Appendix 2. About 37 species of weeds were observed including grass weeds, broad leaf weeds and sedges. Broad leaf weeds were the most dominant weed species during the whole crop growth phase irrespective of the treatments.

At 45 DAP, grass weeds were less in black polythene mulch (T_7) and pre emergence application of pendimethalin (T_5), which were on par followed by pre emergence application of oxyfluorfen (T_4). The highest number of grass weeds was in plots with cowpea as intercrop (T_9) followed by unweeded control (T_{10}). Broad leaf weeds were on par in manual weeding twice (T_1) and thrice (T_2) followed by unweeded control (T_{10}), manual weeding four times (T_3) and intercropping with cowpea (T_9) at 45 DAP and less in black polythene mulch (T_7) followed by pre emergence application of oxyfluorfen (T_4). Manual weeding four times (T_3) and post emergence application of glyphosate (T_6) showed more number of sedges at 45 DAP followed by manual weeding twice (T_1) and all other treatments were statistically on par.

Manual weeding four times (T_3) and mulching with black polythene (T_7) showed lesser number of grass weeds at 75 DAP followed by pre emergence application of pendimethalin (T_5), and directed spray of glyphosate (T_6). Unweeded control (T_{10}) reported the highest number of grass weeds at 75 DAP. Directed spray of glyphosate (T_6) showed better control of broad leaf weeds at 75 DAP followed by black polythene mulch (T_7) and pre emergence application of pendimethalin (T_5). Except in manual weeding twice, the number of sedges was on par in all other treatments at 75 DAP.

At 105 DAP, unweeded control (T_{10}) registered higher number of grass weeds followed by mulching with dry grass (T_8) and intercropping with cowpea (T_9). Mulching with black polythene (T_7), manual weeding thrice (T_2) and directed spray of glyphosate (T_6) showed lesser number of grass weeds which were statistically on par followed by pre emergence herbicides (T_4 and T_5) and manual weeding (T_1 and T_3). Number of broad leaf weeds was less in black polythene mulch (T_7) followed by directed spray of glyphosate (T_6) and intercropping with cowpea (T_9) but higher in pre emergence herbicides (T_4 and T_5) at 105 DAP.

Unweeded control (T_{10}) recorded the higher number of grass weeds at 165 DAP followed by directed spray of glyphosate (T_6) but lesser number were reported by manual weeding four times (T_3) and pre emergence application of pendimethalin (T_5) followed by black polythene (T_7) and other manual weedings (T_1 and T_2). Number of broad leaf weeds was higher in manual weeding thrice (T_2) at 165 DAP. Number of sedges at 165 DAP was found to be on par in all the treatments.

4.3.2 Density of major weeds

The major weeds present during the crop period consisted of *Borreria hispida, Alternanthera bettzickiana, Cleome viscosa, Commelina benghalensis,* and *Digitaria ciliaris*. The data on density of weeds are depicted in Table 11. At 45 DAP, *Borreria hispida* recorded the highest number per m^2 in all the treatments followed by *Alternanthera bettzickiana* (Table 12). Mulching with black polythene recorded the lowest number of major weeds followed by pre emergence application of oxyfluorfen. Pre emergence application of herbicides resulted in lower number of weeds than post emergence application of glyphosate at 45 DAP.

At 75 DAP, number of *Borreria hispida* was highest compared to other major weeds in all treatments, followed by *Alternanthera bettzickiana* (Table 13). Manually weeded plots recorded highest number of major weeds at 75 DAP followed by intercropping with cowpea and unweeded control. The number of plants of *Borreria hispida* (40 nos.) was higher than other weeds in black polythene mulch. Pre emergence application of pendimethalin followed by directed spray of glyphosate, pre emergence application of oxyfluorfen and mulching with dry grasses recorded the lowest number of weeds per m^2 at 75 DAP.

The density *of Borreria hispida* was higher than other weeds at 105 DAP (Table 14) in all the treatments except in mulching with dry grasses and black polythene mulch where, *Commelina benghalensis* (52.0 and 28.0 respectively) were maximum. Unweeded control recorded the highest number of weeds per m^2 at 105 DAP followed by mulching with dry grasses and inter cropping with cowpea. Manually weeded plots recorded the lowest number of weeds per m^2 at 105 DAP after mulching with black polythene and directed spray of glyphosate.

At 165 DAP, the density of *Borreria hispida* was higher in all the treatments except in mulching with dry grasses, intercropping with cowpea and unweeded control. Pre emergence application of pendimethalin recorded the highest density of major weeds at 165 DAP (Table 15).

4.3.3 Dry weight of weeds

The data on weed dry weight are presented in Table 16. Mulching with black polythene (T_7) recorded the lowest weed dry weight followed by pre emergence application of oxyfluorfen (T_4) and pendimethalin (T_5), which were on par. Unweeded control (T_{10}) recorded the highest weed dry weight of 221 g/m^2.

Table 11. Effect of treatments on density of grass, broad leaf and sedge weeds

	Treatments	Grass weeds (No./m^2)				Broad leaf weeds (No./m^2)				Sedges (No./m^2)			
		45 DAP	75 DAP	105 DAP	165 DAP	45 DAP	75 DAP	105 DAP	165 DAP	45 DAP	75 DAP	105 DAP	165 DAP
T_1	Manual weeding twice, 45 and 75 DAP	7.51^{c} (56.0)	2.08^{d} (4.0)	1.76^{d} (2.64)	1.34^{d} (1.32)	24.1^{a} (593.3)	16.56^{a} (274.4)	12.27^{d} (150.6)	5.25^{e} (28.0)	1.34^{b} (1.32)	1.34^{a} (1.32)	2.41^{b} (5.32)	0.70^{a} (0.0)
T_2	Manual weeding thrice, 45, 75, and 105 DAP	6.66^{d} (44.0)	2.4^{d} (5.3)	0.70^{e} (0.0)	1.33^{d} (1.32)	24.5^{a} (602.6)	11.93^{c} (142.4)	12.54^{c} (157.3)	8.48^{a} (72.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	3.12^{a} (9.3)	0.70^{a} (0.0)
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	7.77^{c} (60.0)	0.7^{f} (0)	1.75^{d} (2.64)	0.70^{e} (0.0)	22.4^{b} (501.3)	14.46^{b} (209.3)	11.48^{e} (132.0)	3.97^{g} (16.0)	1.74^{a} (2.64)	0.70^{b} (0.0)	0.70^{d} (0.0)	0.70^{a} (0.0)
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	3.12^{g} (9.3)	5.45^{b} (29.3)	2.08^{d} (4.0)	1.76^{c} (2.64)	7.3^{f} (53.3)	8.07^{ef} (65.3)	13.41^{a} (180.0)	5.65^{d} (32.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	1.34^{c} (1.3)	0.70^{a} (0.0)
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	0.70^{h} (0.0)	1.34^{e} (1.3)	1.72^{d} (2.64)	0.70^{e} (0.0)	9.0^{e} (81.3)	7.64^{g} (58.6)	13.11^{b} (172.0)	6.92^{b} (48.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	0.70^{d} (0.0)	0.70^{a} (0.0)
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	4.65^{e} (21.3)	1.38^{e} (1.4)	0.70^{e} (0.0)	2.35^{b} (5.3)	19.2^{c} (369.3)	7.11^{h} (50.6)	9.23^{h} (85.3)	6.42^{c} (41.3)	1.74^{a} (2.64)	0.70^{b} (0.0)	0.70^{d} (0.0)	0.70^{a} (0.0)
T_7	Mulching with black polythene	0.70^{h} (0.0)	0.7^{f} (0)	0.70^{e} (0.0)	1.34^{d} (1.32)	0.7^{g} (0.00)	7.82^{fg} (61.3)	8.48^{i} (72.0)	3.41^{h} (12.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	1.34^{c} (1.3)	0.70^{a} (0.0)
T_8	Mulching with dry grasses	4.04^{f} (16.0)	3.12^{c} (9.3)	5.2^{b} (26.6)	2.08^{bc} (4.0)	16.5^{d} (274.6)	8.08^{ef} (65.3)	9.59^{g} (92.0)	3.44^{h} (12.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	0.70^{d} (0.0)	0.70^{a} (0.0)
T_9	Intercropping with cowpea	13.03^{a} (169)	3.1^{c} (9.3)	3.10^{c} (9.32)	2.11^{bc} (4.0)	22.63^{b} (512.0)	9.16^{d} (84.0)	9.37^{h} (88.0)	4.46^{f} (20.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	0.70^{d} (0.0)	0.70^{a} (0.0)
T_{10}	No weeding (control)	11.15^{b} (124)	7.24^{a} (52.0)	7.24^{a} (52.0)	5.07^{a} (25.32)	22.66^{b} (513.3)	8.24^{c} (68.0)	10.13^{f} (102.6)	2.8^{i} (8.0)	0.70^{c} (0.0)	0.70^{b} (0.0)	0.70^{d} (0.0)	0.70^{a} (0.0)

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- Original values, $\sqrt{X+0.5}$ transformed values are given in paranthesis

Table 12. Effect of treatments on density of major weeds at 45 DAP

Treatments		Density of weeds (No./ m^2)				
		Borreria hispida	*Alternanthera bettzickiana*	*Commelina benghalensis*	*Cleome viscosa*	*Digitaria ciliaris*
T_1	Manual weeding twice, 45 and 75 DAP	19.64^c (385.3)	10.01^b (100)	2.05^d (4.0)	3.97^{ab} (16.0)	6.22^b (40.0)
T_2	Manual weeding thrice, 45, 75, and 105 DAP	20.65^a (426)	9.51^{bc} (90)	3.47^c (12.0)	3.43^{bc} (12.0)	4.93^c (24.0)
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	19.86^b (394)	2.82^f (8.0)	3.48^c (12.0)	3.45^{bc} (12.0)	6.94^b (48.0)
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	4.84^i (23)	0.70^g (0.0)	1.34^e (1.32)	4.43^a (20.0)	2.85^d (8.0)
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	5.04^h (25)	0.70^g (0.0)	5.67^{ab} (32.0)	3.42^{bc} (12.0)	0.70^e (0.0)
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	15.50^f (240)	9.18^c (84)	3.43^c (12.0)	4.40^a (20.0)	3.47^d (12.0)
T_7	Mulching with black polythene	0.70^j (0.0)	0.70^g (0.0)	0.70^e (0.0)	0.70^d (0.0)	0.70^e (0.0)
T_8	Mulching with dry grasses	11.68^g (136)	6.63^d (44)	5.25^b (28.0)	2.85^c (8.0)	2.78^d (8.0)
T_9	Intercropping with cowpea	16.74^e (280)	12.18^a (148)	5.29^b (28.0)	3.88^{ab} (16.0)	4.47^c (20.0)
T_{10}	No weeding (control)	19.45^d (378)	4.49^e (20)	6.03^a (36.0)	3.42^{bc} (12.0)	10.74^a (116.0)

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- $\sqrt{X+0.5}$ transformed values; original values, are given in paranthesis
- DAP - Days after planting
- MW - Manual weeding

Table 13. Effect of treatments on density of major weeds at 75 DAP

Treatments		Density of weeds (No./ m^2)				
		Borreria hispida	*Alternanthera bettzickiana*	*Commelina benghalensis*	*Cleome viscosa*	*Digitaria ciliaris*
T_1	Manual weeding twice, 45 and 75 DAP	12.95^a (168)	5.69^a (32)	4.88^a (24.0)	0.70^c (0.0)	0.70^d (0.0)
T_2	Manual weeding thrice, 45, 75, and 105 DAP	11.40^b (130)	2.02^e (4.0)	1.92^c (4.0)	0.70^c (0.0)	0.70^d (0.0)
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	13.34^a (178)	2.76^d (8.0)	3.45^b (12.0)	1.34^b (1.32)	0.70^d (0.0)
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	5.46^f (30)	1.72^e (2.64)	3.94^b (16.0)	2.08^a (4.0)	5.22^a (28.0)
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	1.88^g (4)	0.70^f (0.0)	5.17^a (28.0)	2.02^a (4.0)	1.34^d (1.32)
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	5.64^f (32)	2.02^e (4.0)	1.14^d (1.32)	0.70^c (0.0)	1.28^d (1.32)
T_7	Mulching with black polythene	6.28^e (40)	2.88^d (8.0)	1.95^c (4.0)	1.34^b (1.32)	0.70^d (0.0)
T_8	Mulching with dry grasses	5.27^f (28)	4.93^b (24)	1.95^c (4.0)	1.28^{bc} (1.32)	2.10^c (4.0)
T_9	Intercropping with cowpea	7.47^c (56)	4.01^c (16)	1.13^d (1.32)	1.34^b (1.32)	2.08^c (4.0)
T_{10}	No weeding (control)	6.92^d (48)	2.09^e (4.0)	1.99^c (4.0)	2.09^a (4.0)	2.88^b (8.0)

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- $\sqrt{X+0.5}$ transformed values; original values, are given in paranthesis
- DAP - Days after planting
- MW - Manual weeding

Table 14. Effect of treatments on density of major weeds at 105 DAP

Treatments		Density of weeds (No./ m^2)				
		Borreria hispida	*Alternanthera bettzickiana*	*Commelina benghalensis*	*Cleome viscosa*	*Digitaria ciliaris*
T_1	Manual weeding twice, 45 and 75 DAP	8.24^e (68)	3.44^b (12)	2.80^f (8.0)	0.99^{cd} (0.66)	0.70^d (0.0)
T_2	Manual weeding thrice, 45, 75, and 105 DAP	9.39^d (83.3)	1.95^d (4.0)	1.14^g (1.32)	1.76^{ab} (2.64)	0.70^d (0.0)
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	9.89^c (98)	1.14^e (1.32)	3.41^e (12.0)	0.70^d (0.0)	0.70^d (0.0)
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	11.66^a (136)	1.61^{de} (2.64)	4.84^{bc} (24.0)	2.05^a (4.0)	1.28^{cd} (1.32)
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	10.75^b (116)	2.78^c (8.0)	4.42^{cd} (20.0)	2.10^a (4.0)	1.76^c (2.64)
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	6.91^g (48)	1.92^d (4.0)	2.79^f (8.0)	1.34^{bc} (1.32)	0.70^d (0.0)
T_7	Mulching with black polythene	4.88^h (24)	1.98^d (4.0)	5.25^b (28.0)	1.73^{ab} (2.64)	0.70^d (0.0)
T_8	Mulching with dry grasses	1.95^i (4)	5.64^a (32)	7.19^a (52.0)	0.70^d (0.0)	2.81^b (8.0)
T_9	Intercropping with cowpea	7.20^g (52)	3.45^b (12)	3.98^d (16.0)	1.34^{bc} (1.32)	1.76^c (2.64)
T_{10}	No weeding (control)	7.74^f (60)	1.89^d (4.0)	5.22^b (28.0)	0.70^d (0.0)	5.56^a (32.0)

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- $\sqrt{X+0.5}$ transformed values; original values, are given in paranthesis
- DAP - Days after planting
- MW - Manual weeding

Table 15. Effect of treatments on density of major weeds at 165 DAP

Treatments		Density of weeds (No./ m^2)				
		Borreria hispida	*Alternanthera bettzickiana*	*Commelina benghalensis*	*Cleome viscosa*	*Digitaria ciliaris*
T_1	Manual weeding twice, 45 and 75 DAP	3.95^{b} (16)	1.88^{b} (4.0)	1.34^{c} (1.32)	0.70^{c} (0.0)	0.70^{c} (0.0)
T_2	Manual weeding thrice, 45, 75, and 105 DAP	4.89^{a} (24)	1.14^{c} (1.32)	0.70^{d} (0.0)	0.70^{c} (0.0)	0.70^{c} (0.0)
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	2.81^{c} (8)	1.61^{bc} (2.64)	0.70^{d} (0.0)	0.70^{c} (0.0)	0.70^{c} (0.0)
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	3.95^{b} (16)	1.56^{bc} (2.64)	2.08^{b} (4.0)	1.34^{b} (1.32)	1.28^{b} (1.32)
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	4.44^{a} (20)	1.95^{b} (4.0)	2.85^{a} (8.0)	2.11^{a} (4.0)	0.70^{c} (0.0)
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	2.81^{c} (8)	1.92^{b} (4.0)	0.70^{d} (0.0)	1.28^{b} (1.32)	0.70^{c} (0.0)
T_7	Mulching with black polythene	1.88^{d} (4)	1.36^{bc} (2.0)	1.21^{c} (1.0)	1.63^{a} (2.64)	1.28^{b} (1.32)
T_8	Mulching with dry grasses	1.14^{e} (1.32)	2.78^{a} (8.0)	0.70^{d} (0.0)	0.70^{c} (0.0)	0.70^{c} (0.0)
T_9	Intercropping with cowpea	1.07^{e} (1.32)	3.13^{a} (10.0)	1.76^{b} (2.64)	0.70^{c} (0.0)	0.70^{c} (0.0)
T_{10}	No weeding (control)	1.12^{e} (1.32)	1.61^{bc} (2.64)	1.34^{c} (1.32)	0.70^{c} (0.0)	2.08^{a} (4.0)

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- $\sqrt{X+0.5}$ transformed values; original values, are given in paranthesis
- DAP - Days after planting
- MW - Manual weeding

Black polythene mulch (T_7) recorded the lowest weed dry weight (32 g/m^2) at 75 DAP. Weed dry weight in plots receiving manual weeding twice (T_1), thrice (T_2) and four times (T_3) were 55, 35, and 43 g/m^2 respectively and were on par with post emergence application of glyphosate (T_6). Unweeded control (T_{10}) recorded the highest weed dry weight (302 g/m^2) followed by mulching with dry grass (T_8) with dry weight of 173 g/m^2 at 75 DAP.

At 105 DAP, black polythene mulch (T_7), and post emergence application of glyphosate (T_6) and pre emergence application of oxyfluorfen (T_4) recorded lower dry weight of 41, 57, and 54 g /m^2 respectively followed by manual weeding four times (T_3). The unweeded control (T_{10}) was the highest (728 g/m^2) in weed dry weight at 105 DAP followed by intercropping with cowpea (T_9) and mulching with dry grass (T_8).

Unweeded control (T_{10}) recorded the highest weed dry weight (1677 g/m^2) at 165 DAP followed by intercropping with cowpea, mulching with dry grass with a dry weight of 750, and 513 g/m^2 respectively. The lowest dry weight (82 g/m^2) of weeds was from manual weeding four times (T_3) followed by manual weeding thrice (T_2) and black polythene mulch (T_7) with a dry weights of 82, 224 and 223 g/m^2.

4.3.4 Weed control efficiency

The data on weed control efficiency at different stages are presented in Table 17. At 45 DAP, higher weed control efficiency of 100 per cent was observed with black polythene mulch (T_7) followed by pre emergence herbicides oxyfluorfen (T_4) and pendimethalin (T_5) with efficiency 79.67 and 78.22 per cent respectively. Intercropping with cowpea (T_9) was found to be the next best in weed control at 45 DAP with an efficiency of 39.74 per cent.

Table 16. Effect of treatments on dry weight of weeds at 45, 75, 105, and 165 DAP

Treatments		Dry weight of weeds/ m^2 (g)			
		45 DAP	75 DAP	105 DAP	165 DAP
T_1	Manual weeding twice, 45 and 75 DAP	14.72^{a} (218.00)	7.45^{ef} (55.86)	10.44^{b} (109.06)	19.99^{cd} (411.86)
T_2	Manual weeding thrice, 45, 75, and 105 DAP	14.22^{ab} (203.73)	5.82^{ef} (35.73)	10.36^{b} (105.6)	14.91^{e} (224.80)
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	12.86^{ab} (165.60)	6.61^{ef} (43.73)	9.18^{bc} (83.3)	9.09^{f} (82.80)
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	6.69^{c} (44.93)	8.32^{de} (69.80)	7.38^{c} (54.13)	18.56^{d} (350.13)
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	6.93^{c} (48.13)	10.42^{cd} (112.53)	9.11^{bc} (82.2)	19.64^{cd} (386.40)
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	12.62^{ab} (164.13)	6.09^{ef} (37.33)	7.54^{c} (57.3)	19.23^{d} (375.73)
T_7	Mulching with black polythene	0.70^{d} (0.00)	5.60^{f} (32.00)	6.53^{c} (41.8)	14.87^{e} (223.20)
T_8	Mulching with dry grasses	12.88^{ab} (165.73)	13.16^{b} (173.60)	14.0^{ab} (195.4)	22.61^{c} (513.30)
T_9	Intercropping with cowpea	10.28^{bc} (133.20)	12.56^{bc} (158.80)	14.16^{ab} (207.7)	27.38^{b} (750.20)
T_{10}	No weeding (control)	14.83^{a} (221.06)	17.23^{a} (302.93)	26.77^{a} (728.22)	40.93^{a} (1677.00)

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- $\sqrt{X+0.5}$ transformed values; original values, are given in paranthesis
- DAP - Days after planting
- MW - Manual weeding

Mulching with dry grasses (T_8), and directed spray of glyphosate (T_6) was found to be on par in weed control efficiency

At 75 DAP, higher weed control efficiency of 95.66, 88.20, 87.67 and 85.56 per cent respectively were noticed in treatments mulching with black polythene (T_7), manual weeding thrice (T_2), directed spray of glyphosate (T_6) and manual weeding four times (T_3) and were on par statistically. The lowest weed control efficiency (42.69 per cent) was recorded in mulching with dry grass (T_6) followed by intercropping with cowpea (47.57 per cent) and pre emergence application of pendimethalin (62.85 per cent).

At 105 DAP, mulching with black polythene recorded higher weed control efficiency of 94.25 per cent followed by pre emergence application of oxyfluorfen (92.56 per cent), directed spray of glyphosate (92.12 per cent), and pre emergence application of pendimethalin (88.70 per cent) and manual weeding four times (88.55 per cent) and were on par. Unweeded control recorded the lowest efficiency followed by intercropping with cowpea (71.46 per cent) and mulching with dry grasses (73.15 per cent). Manual weeding twice and thrice were statistically on par.

Higher weed control efficiency (95.06 per cent) at 165 DAP was observed in manual weeding four times (T_3) followed by mulching with black polythene (T_7), manual weeding thrice (T_2) and pre emergence application of oxyfluorfen (T_4) with efficiency 86.69, 86.59, and 79.12 per cent respectively. Mulching with black polythene (T_7) and manual weeding thrice (T_2) was found to be statistically on par in efficiency to control weeds at 165 DAP. At this stage, intercropping with cowpea (T_9), followed by mulching with dry grasses (T_8) gave a weed control efficiency of 55.26 and 69.39 per cent respectively.

Table 17. Effect of treatments on weed control efficiency

Treatments		Weed Control Efficiency (%)			
		45 DAP	75 DAP	105 DAP	165 DAP
T_1	Manual weeding twice, 45 and 75 DAP	1.38^{ef}	81.55^{ab}	85.01^{b}	75.44^{cd}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	7.84^{e}	88.20^{a}	85.49^{b}	86.59^{b}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	25.08^{d}	85.56^{a}	88.55^{ab}	95.06^{a}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	79.67^{b}	76.95^{ab}	92.56^{ab}	79.12^{bc}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	78.22^{b}	62.85^{bc}	88.70^{ab}	76.95^{cd}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	25.75^{d}	87.67^{a}	92.12^{ab}	77.59^{c}
T_7	Mulching with black polythene	100.0^{a}	95.66^{a}	94.25^{a}	86.69^{b}
T_8	Mulching with dry grasses	25.02^{d}	42.69^{c}	73.15^{c}	69.39^{d}
T_9	Intercropping with cowpea	39.74^{c}	47.57^{c}	71.46^{c}	55.26^{e}
T_{10}	No weeding (control)	0.00^{f}	0.00^{d}	0.00^{d}	0.00^{f}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 18. Effect of treatments on weed index at 45, 75, 105, and 165 DAP

Treatments		Weed Index (%)
T_1	Manual weeding twice, 45 and 75 DAP	26.29[d]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	24.29[d]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	12.96[c]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	5.88[f]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	42.38[c]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	6.07[f]
T_7	Mulching with black polythene	0.00[f]
T_8	Mulching with dry grasses	40.59[b]
T_9	Intercropping with cowpea	49.04[b]
T_{10}	No weeding (control)	64.66[a]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

4.3.5 Weed index

The data regarding weed index are depicted in Table 18. Weed index was calculated taking the yield from black polythene mulched plots as weed free plots.

Naturally, this treatments showed the lowest weed index (0 per cent). Unweeded control, intercropping with cowpea, and mulching with dry grasses were recorded the highest weed index of 64.66, 49.04, 40.59 per cent and were on par. Weed index values of pre emergence application of oxyfluorfen (5.88 per cent) and directed spray of glyphosate (6.07 per cent) were comparatively lower. The plots receiving manual weeding twice, thrice and four times recorded weed indices of 26.29, 24.29, and 12.96 per cent respectively.

4.4 Soil analysis

4.4.1 Soil pH

The data regarding soil pH are presented in Table 19. In general, the soil was acidic. As compared to pre experimental soil status, there was an increase in soil acidity after the experiment in all the treatments. Among the treatments, higher pH of 5.56 was recorded with intercropping of cowpea (T_9). The treatments mulching with dry grass (T_8) and pre emergence application of pendimethalin (T_5) were statistically on par with pH 5.4 followed by mulching with black polythene (T_7), manual weeding twice (T_5) and unweeded control (T_{10}), which were on par. The treatments manual weeding four times (T_3) and pre emergence application of oxyfluorfen (T_4) recorded the lowest pH of 5.14 and 5.12 respectively after the experiment.

4.4.2 Soil organic carbon

The data pertaining to soil organic carbon are depicted in Table 20. Compared to the organic carbon content before experiment, a higher percentage of organic carbon has been reported from all the treatments after the experiment. Higher percentage of organic carbon was recorded from the treatments mulching with dry grasses (T_8), intercropping with cowpea (T_9) and unweeded control (T_{10}) and were on par. Directed spray of glyphosate (T_6) and black polythene mulch (T_7) recorded lower organic carbon contents of 1.25 and 1.28 per cent respectively.

4.4.3 Available N, P and K

The data regarding the available status of major nutrients in soil are depicted in Table 21. The available N content in soil ranged from 123.99 to 160.00 kg/ha. The available nitrogen content was higher in black polythene mulch (T_7) with N content 160.00 kg/ha and the least content of available N (123.99 kg/ha) was observed in unweeded control (T_{10}). All other treatments, except pre emergence application of pendimethalin (T_5) were on par with N content and next to the black polythene mulch.

The available P content in soil ranged from 13.27 to 24.0 kg/ha. The available phosphorus content was higher (24.0 kg/ha) in black polythene mulch (T_7) followed by intercropping with cowpea (T_9) and directed spray of glyphosate (T_6) with available P contents of 22.40 and 22.23 kg/ha respectively. Manual weeding twice (T_2), manual weeding thrice (T_3), and mulching with dry grass (T_8) recorded the lowest content of available P in soil with phosphorus content 13.27, 14.51, and 14.65 kg/ha respectively. The content of available K in soil ranged from 41.66 to 63.49 kg/ha. Higher K content of 63.49 kg/ha was recorded in black polythene mulch (T_7) followed by manual weeding thrice (59.97 kg/ha).

Manual weeding four times (T_3) and directed spray of glyphosate (T_6) were on par with available K content and recorded 51.13 and 51.51 kg/ha respectively. Pre emergence application of pendimethalin (T_5), mulching with dry grasses (T_8), and unweeded control (T_{10}) recorded the lowest content of 41.66, 43.91, and 42.33 kg/ha with regard to available K content in soil and were on par.

Table 19. Effect of treatments on soil pH

Treatments		Soil pH
T_1	Manual weeding twice, 45 and 75 DAP	5.38^{bc}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	5.26^{cde}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	5.14^{de}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	5.12^{e}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	5.44^{ab}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	5.31^{bcd}
T_7	Mulching with black polythene	5.38^{bc}
T_8	Mulching with dry grasses	5.43^{ab}
T_9	Intercropping with cowpea	5.56^{a}
T_{10}	No weeding (control)	5.32^{bc}
Pre experiment		6.1

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 20. Effect of treatments on soil organic carbon

Treatments		Soil organic carbon (%)
T_1	Manual weeding twice, 45 and 75 DAP	1.41^{abc}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	1.43^{abc}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	1.48^{ab}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	1.39^{bc}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	1.35^{cd}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	1.25^{e}
T_7	Mulching with black polythene	1.28^{de}
T_8	Mulching with dry grasses	1.50^{a}
T_9	Intercropping with cowpea	1.49^{a}
T_{10}	No weeding (control)	1.50^{a}
Pre experiment		1.18

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 21. Effect of treatments on available nutrients in soil

Treatments		Available nutrients (kg/ha)		
		N	P	K
T_1	Manual weeding twice, 45 and 75 DAP	144.19^{ab}	14.51^{c}	53.53^{c}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	145.50^{ab}	13.27^{c}	59.97^{b}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	147.84^{ab}	18.40^{abc}	51.13^{cd}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	149.84^{ab}	18.65^{abc}	47.38^{e}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	140.47^{bc}	18.35^{bc}	41.66^{f}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	148.00^{ab}	22.23^{ab}	51.51^{cd}
T_7	Mulching with black polythene	160.00^{a}	24.0^{a}	63.49^{a}
T_8	Mulching with dry grasses	143.79^{ab}	14.65^{c}	43.91^{f}
T_9	Intercropping with cowpea	153.87^{ab}	22.40^{ab}	50.50^{d}
T_{10}	No weeding (control)	123.99^{c}	17.20^{bc}	42.33^{f}
Pre experiment		121.42	12.47	92.14

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

4.5 Plant analysis

4.5.1 Nitrogen content in plant parts

The data on the content of nitrogen in shoot and corm at 90 DAP and harvest are presented in Table 22. At 90 DAP, N content in shoot was non-significant among treatments. N content of shoot at 90 DAP varied between 2.5 and 3.5 per cent. The N content in corm ranged between 0.98 to 1.95 per cent at 90 DAP and significantly varied among treatments. Intercropping with cowpea (T_9) recorded the highest N content of 1.95 per cent followed by black polythene mulch (T_7) with 1.50 per cent. Unweeded control recorded the lowest content of N in corm at 90 DAP. All other treatments were on par regarding N content in corm at 90 DAP.

The N content of corm at harvest was significantly different among treatments and varied from 1.02 to 2.16 per cent. Intercropping with cowpea recorded the highest content of N in corm at harvest and was on par with manual weeding four times. Unweeded control recorded the lowest N content of 1.02 per cent followed by mulching with dry grasses having N content of 1.16 per cent. Manual weeding thrice followed by black polythene mulch recorded the next highest N content after intercropping with cowpea and manual weeding four times.

4.5.2 Phosphorus content in plant parts

The data on phosphorus content in shoot and corm at 90 DAP and harvest are depicted in Table 23. The content of P in shoot at 90 DAP varied between 0.22 to 0.44 per cent. The highest content of 0.44 per cent was reported by intercropping with cowpea (T_9) followed by 0.37 per cent in black polythene mulch (T_7). Unweeded control (T_{10}) recorded the lowest content (0.22 per cent) of P in shoot at 90 DAP and was on par with dry grasses mulch. All other treatments including manual weeding and application of herbicides recorded on par values with respect to P content at 90

DAP. The P content in corm at 90 DAP varied between 0.08 to 0.15 per cent and was non-significant among treatments.

The content of P in corm at harvest was significantly different among treatments and varied between 0.12 to 0.21 per cent. Unweeded control recorded the lowest P content followed by mulching with dry grasses and manual weeding twice. Directed spray of glyphosate recorded the highest content of P at harvest. All other treatments were statistically on par.

4.5.3 Potassium content in plant parts

The data on the content of potassium in shoot and corm at 90 DAP and harvest are given in Table 24. The K content in shoot varied from 4.0 and 6.9 per cent at 90 DAP. The highest content (6.9 per cent) of K in shoot at 90 DAP was recorded by pre emergence application of oxyfluorfen (T_4) followed by directed spray of glyphosate (T_6) and mulching with black polythene (T_7) with contents 5.9 and 5.8 per cent respectively, and were on par. Unweeded control recorded the lowest content (3.7 per cent) of K in shoot at 90 DAP followed by manual weeding thrice and twice, which were on par.

The content of K in corm at 90 DAP ranged between 2.2 to 3.62 per cent and the higher content was reported in black polythene mulch (T_7) followed by directed spray of glyphosate (T_6) with K content of 3.14 per cent. The lowest content (2.2 per cent) of K in corm at 90 DAP was recorded by unweeded control (T_{10}) followed by mulching with dry grasses (2.43 per cent) intercropping with cowpea (T_9) of K content 2.30 per cent. All the plots receiving manual weeding treatments were on par.

At harvest, the K content in corm varied from 2.86 to 3.76 per cent. Unweeded control (T_{10}) recorded the lower content of K at harvest. Mulching with black polythene (T_7) recorded a higher K content of 3.76 per cent followed by directed spray of glyphosate (3.33 per cent). Manual weeding twice (T_1), manual

Table 22. Effect of treatments on content of N in shoot and corm of plant

Treatments		N content in shoot (%)	N content in corm (%)	
		90 DAP	90 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	3.5[a]	1.12[bc]	1.86[abc]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	2.9[a]	1.20[bc]	2.00[ab]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	2.6[a]	1.27[bc]	2.10[a]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	3.3[a]	1.30[bc]	1.56[abcd]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	2.5[a]	1.18[bc]	1.34[bcd]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	3.0[a]	1.23[bc]	1.53[abcd]
T_7	Mulching with black polythene	3.1[a]	1.50[ab]	1.88[ab]
T_8	Mulching with dry grasses	2.9[a]	1.06[bc]	1.16[cd]
T_9	Intercropping with cowpea	3.4[a]	1.95[a]	2.16[a]
T_{10}	No weeding (control)	3.0[a]	0.98[c]	1.02[d]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 23. Effect of treatments on content of P in shoot and corm of plant

Treatments		P content in shoot (%)	P content in corm (%)	
		90 DAP	90 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	0.33^{b}	0.14^{a}	0.17^{b}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	0.34^{b}	0.15^{a}	0.19^{ab}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	0.35^{b}	0.14^{a}	0.19^{ab}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	0.32^{b}	0.11^{a}	0.18^{ab}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	0.31^{b}	0.12^{a}	0.18^{ab}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	0.33^{b}	0.11^{a}	0.21^{a}
T_7	Mulching with black polythene	0.37^{b}	0.11^{a}	0.19^{ab}
T_8	Mulching with dry grasses	0.24^{c}	0.10^{a}	0.17^{b}
T_9	Intercropping with cowpea	0.44^{a}	0.10^{a}	0.19^{ab}
T_{10}	No weeding (control)	0.22^{c}	0.08^{a}	0.12^{c}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 24. Effect of treatments on content of K in shoot and corm of plant

Treatments		K content in shoot (%)	K content in corm (%)	
		90 DAP	90 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	4.0^{cd}	2.86^{bc}	3.03^{cd}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	4.2^{cd}	2.90^{bc}	3.11^{bcd}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	4.9^{bcd}	2.91^{bc}	3.21^{bc}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	6.9^{a}	2.66^{bcd}	3.22^{bc}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	5.1^{bc}	2.54^{bcd}	3.04^{bcd}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	5.9^{ab}	3.14^{ab}	3.33^{b}
T_7	Mulching with black polythene	5.8^{ab}	3.62^{a}	3.76^{a}
T_8	Mulching with dry grasses	5.56^{b}	2.43^{cd}	2.98^{cd}
T_9	Intercropping with cowpea	5.60^{b}	2.30^{cd}	3.01^{cd}
T_{10}	No weeding (control)	3.7^{d}	2.20^{d}	2.86^{d}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

weeding thrice (T_2), and manual weeding four times (T_3), recorded K contents of 3.03, 3.11, and 3.21 per cent respectively.

4.5.4 Uptake of nitrogen by plant

The data on the uptake of nitrogen by shoot and corm at 90 DAP and harvest are depicted in Table 25. The uptake of N in shoot at 90 DAP was non-significant among treatments, but ranged from 16.56 to 37.48 kg/ha. Mulching with black polythene (T_7) reported the highest N uptake in corm at 90 DAP followed by pre emergence application of oxyfluorfen (T_4) and intercropping with cowpea (T_9) with uptakes of 17.28 and 16.66 kg/ha respectively. Unweeded control (5.57 kg/ha) recorded the lowest uptake of N in corm at this stage followed by pre emergence application of pendimethalin (6.49 kg/ha).

At harvest, black polythene mulch (T_7) showed the highest uptake (128.95 kg/ha) of N in corm and was on par with manual weeding for times and three times (124.05 and 120.75 kg/ha). Manual weeding twice (109.71 kg/ha), pre emergence application of oxyfluorfen (101.60 kg/ha), directed spray of glyphosate (99.49 kg/ha) and intercropping with cowpea (112.75 kg/ha) were on par. Unweeded control (T_{10}) reported the lowest uptake (20.04 kg/ha) of N in corm at harvest followed by an uptake of 45.46 kg/ha by mulching with dry grasses (T_8).

4.5.5 Uptake of phosphorus by plant

The data on the uptake of P in shoot and corm at 90 DAP and harvest are given in Table 26. The lowest value (1.23 kg/ha) of uptake of P in shoot at 90 DAP was reported in unweeded control (T_{10}) followed by mulching with dry grasses (2.35 kg/ha). Intercropping with cowpea (T_9) reported the highest uptake (4.40 kg/ha) of P in shoot and was on par with manual weeding four times (4.06 kg/ha). All other treatments were on par.

The uptake of P in corm at 90 DAP varied from 0.44 to 1.99 kg/ha and the highest uptake was recorded by mulching with black polythene (T_7), which were on par with manual weeding four times (T3). Unweeded control (T_{10}) reported the lowest uptake (0.44 kg/ha) of P in corm at 90 DAP.

At harvest, directed spray of glyphosate (T_6) reported the highest uptake (13.75 kg/ha) of P in corm followed by black polythene mulch (T_7). Manual weeding thrice and four times were on par with P uptake of 11.64 and 11.72 kg/ha. Unweeded control (T_{10}) reported the lowest uptake (2.45 kg/ha) of P in corm at harvest followed by mulching with dry grasses (T_8).

4.5.6..Uptake of potassium by plant

The data on the uptake of potassium in shoot and corm at 90 DAP and harvest are depicted in Table 27. The uptake of K in shoot at 90 DAP was non-significant and the uptake ranged between 20.55 to 77.75 kg/ha. Black polythene mulch (T_7) reported the highest uptake (61.05 kg/ha) of K in corm at 90 DAP followed by manual weeding four times and pre emergence application of oxyfluorfen (35.32 and 35.54 kg/ha respectively).

Unweeded control (T_{10}) gave a lower uptake (12.10 kg/ha) in corm at 90 DAP followed by pre emergence application of pendimethalin (15.06 kg/ha). At harvest, mulching with black polythene (T_7) reported the highest uptake (257.12 kg/ha) in corm followed by directed spray of glyphosate (T_6) with uptake 217.23 kg/ha. Unweeded control (T_{10}) reported the lowest uptake (56.24 kg/ha) of K in corm at harvest followed by mulching with dry grasses (113.52 kg/ha).

Table 25. Effect of treatments on uptake of N in shoot and corm

Treatments		N uptake in shoot (kg/ha)	N uptake in corm (kg/ha)	
		90 DAP	90 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	30.11[a]	10.86[bcde]	109.71[ab]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	30.24[a]	14.97[bc]	120.75[a]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	31.14[a]	14.24[bc]	124.05[a]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	37.48[a]	17.28[b]	101.60[ab]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	29.57[a]	6.49[de]	76.62[bc]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	24.69[a]	13.78[bcd]	99.49[ab]
T_7	Mulching with black polythene	28.06[a]	25.37[a]	128.95[a]
T_8	Mulching with dry grasses	28.34[a]	9.45[cde]	45.46[cd]
T_9	Intercropping with cowpea	33.80[a]	16.66[bc]	112.75[ab]
T_{10}	No weeding (control)	16.56[a]	5.57[e]	20.04[d]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 26. Effect of treatments on uptake of P in shoot and corm

Treatments		P uptake in shoot (kg/ha)	P uptake in corm (kg/ha)	
		90 DAP	90 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	2.84[ab]	1.38[abc]	10.03[d]
T_2	Manual weeding thrice, 45, 75, and 105 DAP	3.52[ab]	1.72[ab]	11.64[bcd]
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	4.06[a]	1.82[a]	11.72[bcd]
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	3.65[ab]	1.55[abc]	12.03[abc]
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	3.63[ab]	0.76[cd]	10.60[cd]
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	2.84[ab]	1.18[abcd]	13.75[a]
T_7	Mulching with black polythene	3.46[ab]	1.99[a]	13.30[ab]
T_8	Mulching with dry grasses	2.35[bc]	0.94[bcd]	6.74[e]
T_9	Intercropping with cowpea	4.40[a]	0.91[bcd]	9.87[d]
T_{10}	No weeding (control)	1.23[c]	0.44[d]	2.45[f]

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 27. Effect of treatments on uptake of K in shoot and corm

Treatments		K uptake in shoot (kg/ha)	K uptake in corm (kg/ha)	
		90 DAP	90 DAP	Harvest
T_1	Manual weeding twice, 45 and 75 DAP	34.60^{a}	27.93^{bcd}	177.99^{de}
T_2	Manual weeding thrice, 45, 75, and 105 DAP	45.03^{a}	33.38^{bc}	187.53^{cd}
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	58.72^{a}	35.32^{b}	193.29^{bcd}
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	77.75^{a}	35.54^{b}	209.52^{bc}
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	60.10^{a}	15.06^{de}	173.95^{de}
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	47.83^{a}	34.21^{bc}	217.23^{b}
T_7	Mulching with black polythene	52.74^{a}	61.05^{a}	257.12^{a}
T_8	Mulching with dry grasses	52.88^{a}	21.62^{cde}	113.52^{f}
T_9	Intercropping with cowpea	55.65^{a}	19.45^{de}	156.75^{e}
T_{10}	No weeding (control)	20.55^{a}	12.10^{e}	56.24^{g}

- In a column, means followed by common letters do not differ significantly at 5% level in DMRT
- DAP - Days after planting
- MW - Manual weeding

Table 28. Effect of the treatments on benefit : cost ratio

Treatments		Cost of cultivation (Rs/ha)	Income (Rs/ha)	Net returns (Rs/ha)	B: C ratio
T_1	Manual weeding twice, 45 and 75 DAP	5,88,131	10,54,400	4,66,269	1.79
T_2	Manual weeding thrice, 45, 75, and 105 DAP	6,01,256	10,82,800	4,81,544	1.80
T_3	Manual weeding four times, 45, 75, 105, and 135 DAP	6,14,381	12,45,200	6,30,819	2.02
T_4	Oxyfluorfen 0.2 kg/ha and MW once, 75 DAP	5,89,339	13,46,400	7,57,061	2.28
T_5	Pendimethalin 1.0 kg/ha and MW once, 75 DAP	5,90,710	9,51,200	3,60,490	1.61
T_6	Glyphosate 0.8 kg/ha, 30 DAP + MW 75 DAP	5,88,189	13,23,200	7,35,011	2.24
T_7	Mulching with black polythene	6,12,385	14,30,800	8,18,415	2.33
T_8	Mulching with dry grasses	6,50,126	9,26,000	2,75,874	1.42
T_9	Intercropping with cowpea	5,79,857	8,90,000	3,10,143	1.53
T_{10}	No weeding (control)	5,48,757	6,17,200	6,84,43	1.12

- Labour charges (Men - Rs. 525/day and Women - Rs. 425/day)
- Cost of planting material - Rs. 3,45, 660/ha
- Cost of polythene sheet - Rs. 6.17/m^2
- Cost of herbicides (Oxyfluorfen- Rs. 575/ 250 ml, Pendimethalin- Rs. 502/500 ml, Glyphosate- Rs. 380/L)
- Sale price for elephant foot yam- Rs. 40/kg

4.6 Incidence of pests and diseases

Incidence of sclerotium rot was noticed in the field in all treatments, but severity of incidence was controlled at the early stages itself by soil drenching and spraying of the fungicide, Saaf® (carbendazim 12 per cent + mancozeb 63 per cent) at 2 g/L. No insect pest incidence was noticed in the plots.

4.7 Benefit - Cost ratio

The data regarding benefit: cost ratio are presented in Table 28. The highest B: C ratio of 2.33 was obtained in black polythene mulch (T_7). The B : C ratio of pre emergence application of oxyfluorfen (T_4) and post emergence spray of glyphosate (T_6) were 2.28 and 2.24 respectively. Among manually weeded plots, weeding four times (T_3) resulted the highest B: C ratio of 2.02. Unweeded control (T_{10}) recorded the lowest B: C ratio of 1.12.

Discussion

5. DISCUSSION

The experiment entitled "Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]" was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during the year 2016. The results obtained from the experiment presented in the previous chapter are discussed below.

5.1 Effect of weed management practices on growth characteristics

The height of elephant foot yam ranged from 113.50 cm to 127.33 cm and 130.86 to 157.65 cm at 90 DAP and 180 DAP respectively. The height was not influenced by the treatments at 90 DAP (Table 2). In elephant foot yam, leaf petiole resembling the pseudostem and its height along with the length of longest rachis is taken as plant height. As Ravi *et al.* (2011) reported, cultivars, plant spacing and size of planting material affected plant height. Among these, size of planting material is the major factor (George and Nair, 1993). It seems that weed competition was influential enough to affect the height of plant in elephant foot yam.

In general, the girth of pseudostem, length of petiole, and length of rachis of elephant foot yam increased from 90 DAP to 180 DAP. However, like pseudostem height, these parameters was not influenced by the treatments at 90 DAP and 180 DAP. The girth varied from 11.26 cm to 16.83 cm at 90 DAP and 13.53 cm to 19.10 cm at 180 DAP. The lengths of petiole ranged from 46.60 cm to 53.33 cm at 90 DAP and 64.66 cm to 85.52 cm at 180 DAP. The length of rachis varied from 57.37 cm to 74.61 cm and 65.20 cm to 81.78 cm at 90 DAP and 180 DAP respectively.

The days from emergence to yellowing of the plants (life span) ranged from 232 to 259 days and varied significantly among treatments. Life span of leaves from emergence to yellowing was non-significant among treatments. However, plants mulched with black polythene took about 259 days for yellowing, which was almost

27 days more than that of other treatments (Table 6). The emergence of plants in the plot mulched with black polythene also lagged behind other treatments. Plants in the unweeded control completed their life cycle earlier than other treatments and was more or less similar to the plants mulched with dry grass. Similar results were recorded by Santosa *et al.* (2006) in elephant foot yam under agroforestry system. Severe infestation of weeds might have reduced the life span of crop.

Leaf area at 90 DAP of elephant foot yam varied from 40.46 to 83.11 dm^2 (Table 7; Fig. 2.). Mulching with black polythene recorded the highest leaf area of 83.11 dm^2 followed by the application of herbicides. Kumari (2012) reported a positive effect on production of leaf area, and dry matter, and consequently higher yields in potato through plastic mulching. Unweeded control recorded the lowest leaf area at 90 DAP followed by intercropping with cowpea and mulching with dry grasses. Nedunchezhiyan *et al.* (1996) pointed out that weed interference in taro can prevent the optimum leaf area development, which in turn affects the production of necessary assimilates for tuber bulking, and weeds can delay the cormel initiation and reduce the number of cormels per plant. Lambers *et al.* (1998) reported that the total leaf area get reduced under shady conditions due to weeds.

A similar trend to that of leaf area was observed in leaf area index at 90 DAP (Table 7; Fig. 3). Leaf area index of elephant foot yam at 90 DAP varied from 0.50 to 1.02. Black polythene mulch recorded the highest leaf area index of 1.02 followed by pre emergence application of oxyfluorfen and post emergence application of glyphosate with LAI 0.82. Nedunchezhiyan (2014) observed a similar LAI of 0.02 to 0.79 in elephant foot yam at 3 months after planting. Walker *et al.* (1988) stressed the importance of canopy structure, leaf area and light penetration in determining the interference among plant species. The growth rate of plants is dependent on their photosynthetic rate, which in turn is a function of leaf area and light incident on that leaf area.

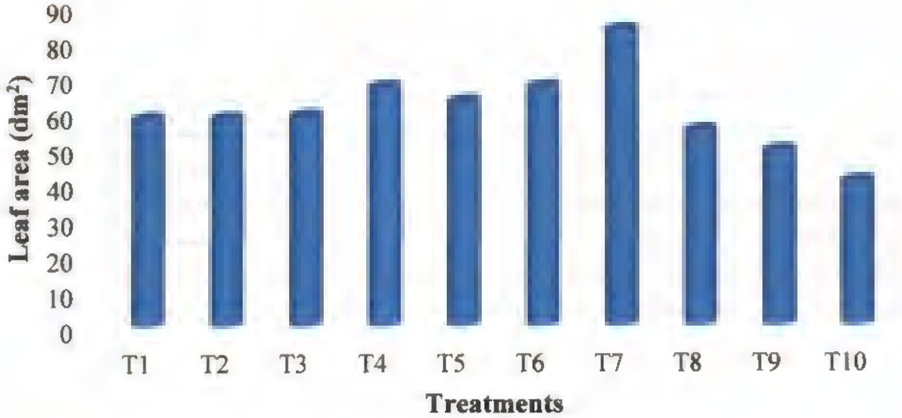

Fig. 2. Effect of treatments on leaf area at 90 DAP

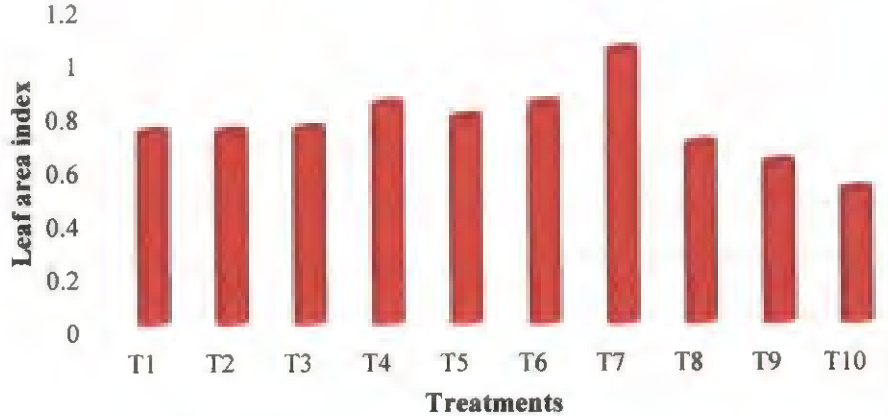

Fig. 3. Effect of treatments on leaf area index of plants at 90 DAP

Irrespective of the stage of crop, black polythene mulch produced higher plant dry weight throughout the crop period (Table 8). The dry weight of the plant varied from 89.23 to 211.33 g/plant, 123.66 to 661.25 g/plant, and 159.30 to 553 g/plant at 90 DAP, 180 DAP and harvest respectively. Ravi *et al.* (2011) reported that biomass production of shoots (leaf and pseudostem/petiole) increased up to 150 DAP and declined thereafter, whereas corm dry weight and total dry matter production showed a steady increase up to maturity. Unweeded control recorded the lowest plant dry weight in all the stages. Since the weed competition was profound in unweeded control, mulching with dry grasses and intercropping with cowpea, the resulted plant dry weight was lower throughout the growth period.

5.2 Effect of weed management practices on yield parameters

The corm height at harvest varied from 9.14 cm to 12.68 cm. The height of corm was significantly influenced by the treatments (Table 9). Black polythene mulch recorded the highest corm height of 12.68 cm. Directed spray of glyphosate, manual weeding four times and pre emergence application of oxyfluorfen were found to be the next best treatments and were on par with black polythene mulch. Unweeded control plots recorded the lowest corm height, which might be due to the presence of weeds throughout the crop period. Among manual weeding, manual weeding four times recorded the highest corm height.

The treatments have significant influence on the diameter of corm at harvest and varied from 14.18 cm to 21.64 cm (Table 9). Black polythene mulch greatly influenced the diameter of corm followed by manual weeding, directed spray of glyphosate and pre emergence application of oxyfluorfen. Goswami and Saha (2006) reported similar results in elephant foot yam. Among manual weeding, weeding four times resulted in highest corm diameter. Intercropping with cowpea resulted in lesser corm diameter which might due to the competition from weeds and the intercrop, which was almost similar to the diameter recorded from unweeded control. Several studies revealed that intercropping could reduce the vegetative growth of component crops (Amanullah *et al.*, 2006; Silwana and Lucas, 2002; Thirumdasu *et al.*, 2015). When grown in association with a legume, cassava yield was reduced by 19 per cent compared to weed free cassava sole crop (CIAT, 1979; Fening *et al.*, 2009; Leihner, 1980).

The volume of corm at harvest showed almost similar results as that of height and diameter of corm. Black polythene mulch showed its superiority over other treatments with regard to the volume of corm. The volume of corm ranged from 1.04 dm^3 to 3.24 dm^3 (Table 9 and Fig. 4). Among the herbicides used, pre emergence application of oxyfluorfen and post emergence application of glyphosate resulted in higher corm volume than the pre emergence application of pendimethalin. Mulching with dry grasses and intercropping with cowpea did not show any profound effect on volume of corm and they were just above that in unweeded plots. It is assumed that the increased weed competition in unweeded plots resulted in lesser height, diameter and volume of corms. Mean individual corm weight was higher in black polythene mulched plots. Pre emergence application of oxyfluorfen and post emergence application of glyphosate also showed higher fresh weight. Increase in frequency of manual weeding also caused significant effects on fresh weight of corm (Fig. 5). Weed interference in unweeded control resulted in lower leaf area, which might affects the production of necessary assimilates for tuber bulking. As expected, the weeds might have utilized the resources outcompeting the plants resulting in lower fresh corm weight.

Among different treatments, black polythene mulch significantly influenced the corm yield per hectare (35.77 Mg/ha) as discernable from Table 10 and Fig 6.In general, corm yields varied from 15.43 Mg/ha to 35.77 Mg/ha, the lowest in unweeded plots. Pre emergence application of oxyfluorfen and directed spray of glyphosate showed almost similar results with on par values. Application of

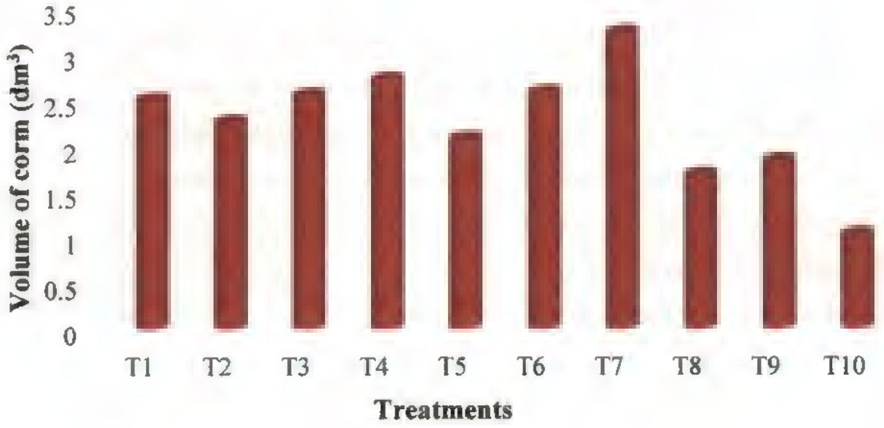

Fig. 4. Effect of treatments on volume of corm at harvest

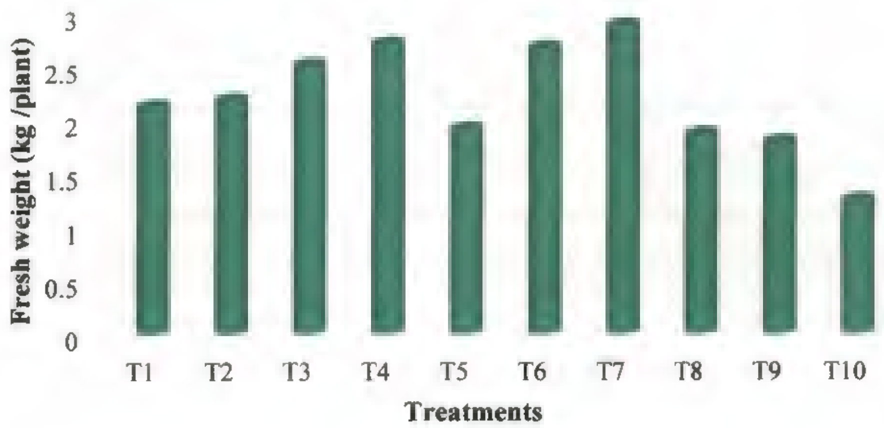

Fig. 5. Effect of treatments on fresh weight of corm at harvest

Glyphosate along with one hand weeding was already reported as an option for weed control in elephant foot yam (AICRPTC, 2004).

Mulching with dry grasses, intercropping with cowpea and pre emergence application of pendimethalin were not very effective in obtaining a better corm yield of elephant foot yam. As reported, live mulch with cowpea did not improve the yield of elephant foot yam, as the main crop had to compete for moisture and nutrients with the mulch crop (Abu-Rayyen and Abu-Irmaileh, 2004). Mulching with black polythene recorded 63 per cent higher yield than unweeded control. Mulching with black polythene recorded comparatively higher yield (52.8 Mg/ha) due to higher level of weed control (92.1 per cent) and the capacity to lessen undue water evaporation from the soil (Ashworth and Harrison, 1983; Swenson *et al.* 2004). Goswami and Saha (2006) reported that black polythene mulches increased the corm yield of elephant foot yam by 22.4 to 28.8 per cent over control (no mulch situation).

5.3 Effect of weed management practices on weed growth

During the crop period, 37 species of weeds were observed in the crop field, which could be classified into grass weeds, broad leaf weeds, and sedges (Appendix2). Broad leaf weeds were the most dominant weed species during the whole crop growth phase irrespective of the treatments. The major broad leaf weeds were *Borreria hispida*, *Alternanthera bettzickiana*, *Commelina benghalensis*, and *Cleome viscosa*. *Digitaria ciliaris*, *Panicum maximum*, and *Cynodon dactylon* were the major grass weeds and *Kyllinga monocephala* was the major sedge weed found during the crop growth period. Melifonwu(1994) reported that of all the species present, about 71 to 78 per cent of weeds were constituted by broad leaf weeds, which were most frequent in the area and 17 to 19 per cent constituted grasses and only 4 to 7 per cent was contributed by sedges.

Irrespective of the growth stages, number of grass weeds was higher in unweeded control. Black polythene much recorded the lowest number of grass weeds

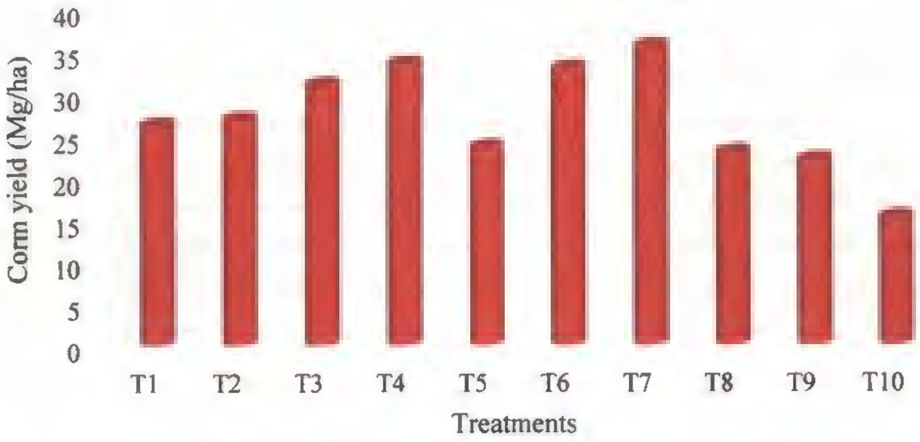

Fig. 6. Effect of treatments on corm yield per hectare

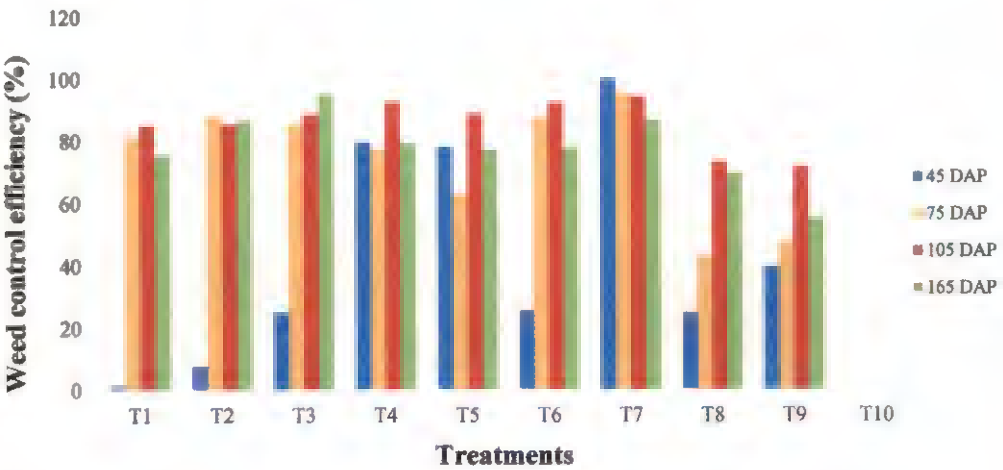

Fig. 7.Effect of treatments on weed control efficiency

in all the stages except at 165 DAP but was found to be the third best option in controlling the grass weeds following manual weeding four times. Similar to grasses, broad leaf weeds were lesser in black polythene mulch.

Borreria hispida was the weed with highest number per unit area in all the treatments followed by *Alternanthera bettzickiana*. Unweeded control recorded the highest number of weeds per square metre at 105 DAP. Pre emergence application of herbicides resulted in lower number of weeds than post emergence application of glyphosate at 45 DAP. Pre emergence application of pendimethalin followed by directed spray of glyphosate, pre emergence application of oxyfluorfen and mulching with dry grasses recorded the lowest number of weeds per square metre at 75 DAP. Manually weeded plots recorded the lowest number of weeds per square metre at 105 DAP after mulching with black polythene and directed spray of glyphosate. Population of broad leaf weeds, grasses and sedges was less in plots mulched with black polythene compared to other organic and inorganic mulches (Goswami and Saha, 2006).

Considerable influence of weed control methods on weed dry weight throughout the crop period was evident as seen from Table 16. Black polythene was the best option to manage weeds in elephant foot yam fields at all growth periods. Similar results were reported by Goswami and Saha (2006). Mulching with dry grasses and intercropping with cowpea could not effectively manage the weeds and produced greater weed dry weight after unweeded control throughout the season. Due to the low canopy development during the early stages of crop growth, intercropping may not be able to suppress the weeds and failed to provide satisfactory weed control (Dwivedi and Shrivastava, 2011). The plots receiving manual weeding were able to maintain lower weed dry weight throughout the period and manual weeding four times recorded the lowest weed dry weight at 165 DAP. Application of herbicides also limited the weed dry weight largely but pre emergence application of pendimethalin was not that effective compared to oxyfluorfen and glyphosate.

Mulching with black polythene maintained highest weed control efficiency at all the stages except at 165 DAP (Fig. 7). However, black polythene mulch gave consistent weed control efficiency at 165 DAP after manual weeding four times and recorded the second best values in controlling the weeds at this stage too (Table 17). Goswami and Saha (2006) reported higher weed control efficiency (89.0 to 95.2 per cent) in black polythene mulch with least weed population. Pre emergence application of oxyfluorfen and directed spray of glyphosate were the next best in controlling weeds efficiently. A combination of herbicide and hoeing was suggested by Melifonwu (1994) for the successful weed control in cassava. At the early stages, intercropping with cowpea, mulching with dry grasses and pre emergence application of pendimethalin gave better control but failed thereafter. As reported by Laurie *et al.* (2015), weed control efficiency of grass straw mulch plots deteriorated subsequently and was futile in suppressing the weeds at later stages. Johnson *et al.* (2004) reported that application of straw mulch at planting suppressed weeds in potato, whereas application of straw after cultivation had fewer outcomes on weeds. According to Leela (1993), pre emergence application of pendimethalin was only effective in short duration crops and gave weed control up to 30 days only.

All the manual weeding treatments were on par at the first and second stages of observation, but, manual weeding four times controlled weeds better than black polythene mulch at 165 DAP. Mulching with black polythene and manual weeding thrice were on par in efficiency to control weeds at 165 DAP. In general, unweeded control recorded the lowest efficiency followed by intercropping with cowpea and mulching with dry grasses. Goswami and Saha (2006) reported that due to greater light penetration and delayed decaying process of the straw, mulching with wheat straw recorded the lowest weed control efficiency of 24.7 to 25.1 per cent.

Weed index was lower in plots with black polythene mulch, pre emergence application of oxyfluorfen and post emergence spray of glyphosate indicating their efficacy in enhancing competitiveness of the plant and ensuring better crop yield

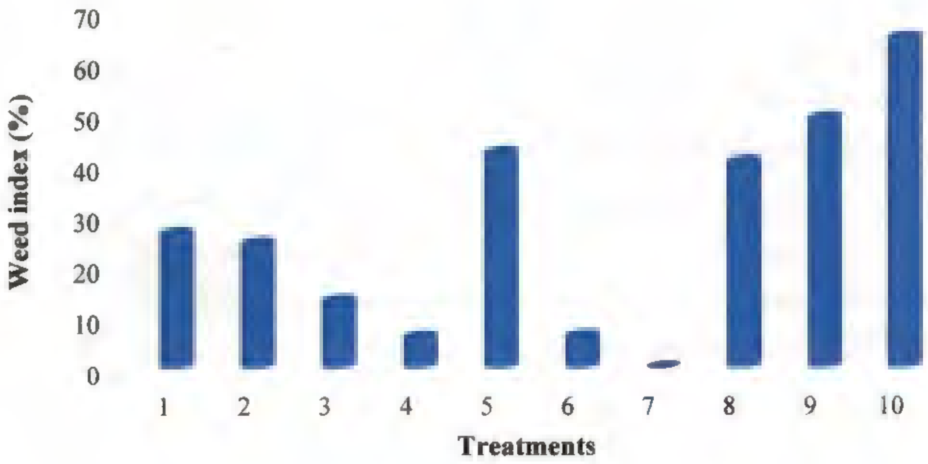

Fig. 8. Effect of treatments on weed index

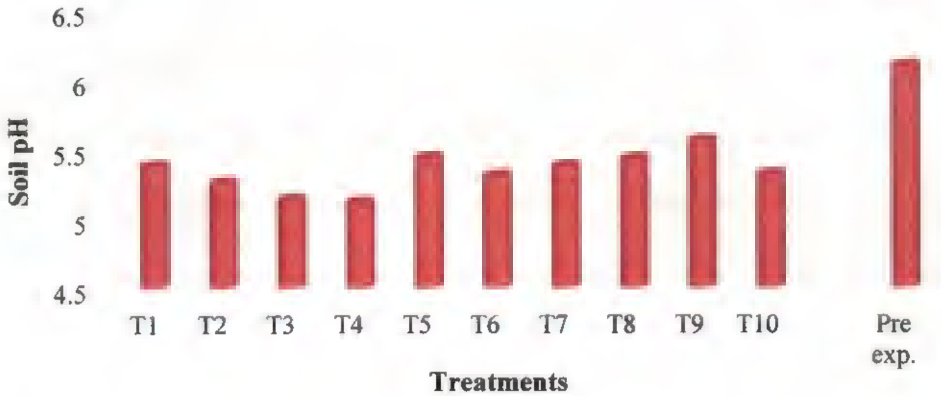

Fig. 9. Effect of treatments on soil pH

compared to other treatments (Fig. 8). Goswami and Saha (2006) obtained a weed index of 10.8 per cent in elephant foot yam plots mulched with black polythene. As reported by Mishra and Singh (2009), the plots receiving herbicide spray + one hand weeding was able to reduce the number of weed seeds considerably. Unweeded control recorded highest weed index of 64.66 per cent followed by intercropping with cowpea (49.04 per cent) and mulching with dry grasses (40.59 per cent) and pre emergence application of pendimethalin (42.38 per cent). Snapp *et al.* (2005) reported that cover crop residues were not efficient to manage weeds for the whole growing season.

5.4 Effect of weed management practices on soil chemical properties

The initial status was pH 6.1 and after the experiment, pH ranged from 5.12 to 5.56 (Table 19). As compared to pre experimental soil, there was an increase in soil acidity after the experiment in all the treatments, and in general, the soil became more acidic. It is presumed that the addition of acid forming fertilizers and the decomposition of organic residues by microorganisms reduced pH values.

Organic carbon content in the soil after experiment was higher in all the treatments than the pre-experiment value. Considerable influence of treatments on soil organic carbon was evident (Table 20). The carbon content recorded before experiment was 1.18 per cent. Directed spray of glyphosate and black polythene mulch resulted in lower organic carbon contents of 1.25 and 1.28 per cent respectively, which could be due to the heavy dry matter production of crop. The treatments mulching with dry grasses, intercropping with cowpea and unweeded control were on par. Dahiya *et al.* (2008) reported that organic mulches can increase the soil organic carbon by 18 per cent and Mupangwa *et al.* (2013) observed an increase in soil organic carbon by straw mulching. Shivaprasad *et al.* (2005) reported that due to heavy dry matter production of crops and weeds, organic carbon content in soil got depleted.

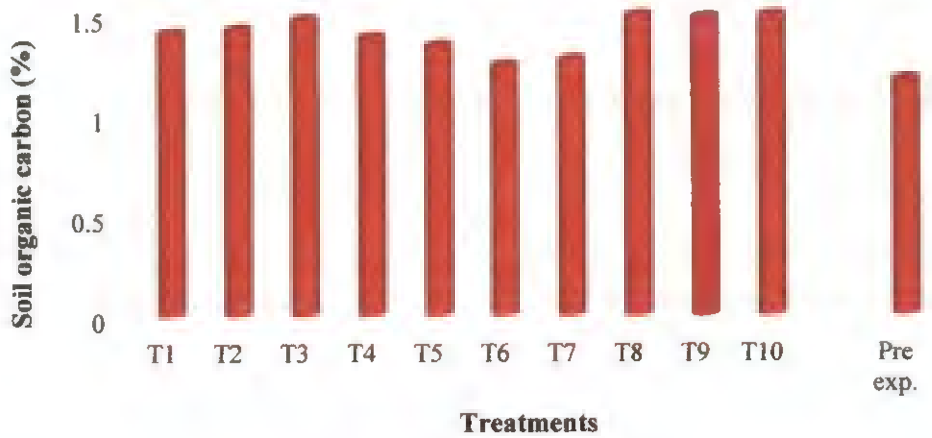

Fig. 10. Effect of treatments on soil organic carbon content

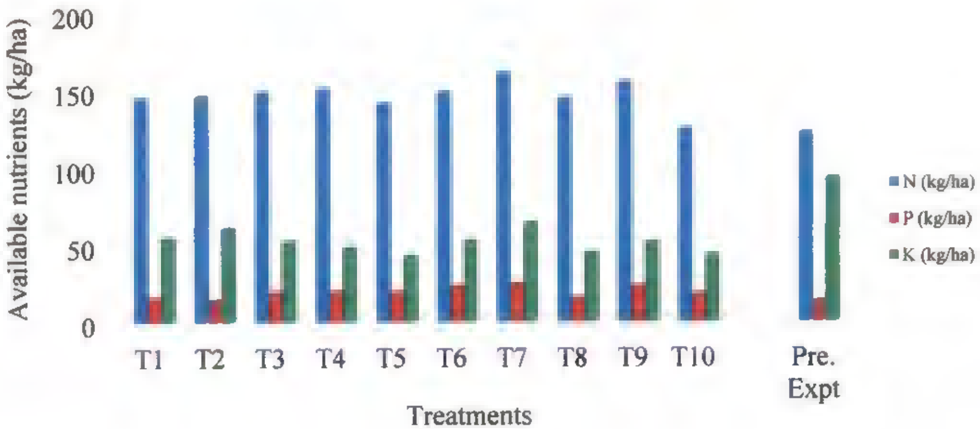

Fig. 11. Effect of treatments on available nutrients in soil

Nutritional status of the soil was significantly inclined by different treatments. Compared to the pre experimental soil status, the available N and P status of the soil was enhanced after the experiment, whereas, the available K status decreased after the experiment. In general, black polythene mulch recorded higher content of all major nutrients in soil. This may be due to the reduced loss of nutrients by sparse weed population and due to the enhanced mineralization of nutrients under black polythene mulches. As reported by Lalitha *et al.* (2010), higher mineralization of organic N resulted in the higher content of mineral N content (NO_3 and NH^{4+}) in soil under black polythene mulches. Release of soluble nutrients like NO_3, NH^{4+}, Ca^{2+}, Mg^{2+}, K^+ and fulvic acid to the soil by the breakdown of organic material also resulted in increased nutrient availability in soil. Higher nutrient removal by weeds might have led to the lower status of available nutrients in unweeded control. Intercropping with cowpea was effective in maintaining status of all the available major nutrients in soil. According to Padmapriya *et al.*, (2008), soil nitrogen content was improved after cassava was intercropped with cowpea.

Mulching with black polythene recorded higher available P and was about 44 per cent more than the P content before experiment. In general, the available K status of the experimental field was low. The content of available K was lesser in the soil after the experiment in all the treatments compared with before experiment values. This reduction of K status in soil can be linked to the luxurious consumption of K by crop plants resulting in higher plant uptake of K.

5.5 Effect of weed management practices on nutrient uptake by crop

The uptake of nutrients is a reflection of total dry weight and content of nutrients in plant parts. In general, shoot uptake of all the major nutrients was higher than that of corm uptake at 90 DAP. Mulching with black polythene maintained higher N and K content in corm at 90 DAP and harvest. This may have caused due to the efficient utilization of nutrients by crop due to the lower competition offered by weeds. Unweeded control recorded the lowest content of all nutrients *viz*, N, P, and K in shoot and corm at 90 DAP and harvest. Uptake of major nutrients was higher in black polythene mulch for all nutrients and unweeded control recorded the lowest uptake of all major nutrients. Rigorous weed infestation might have reduced the nutrient recovery by crops in unweeded control. As expected, severe weed infestation along with higher nutrient removal by weeds than crops have caused lower crop yield in unweeded control.

5.6 Economics of weed management practices

The net returns from black polythene mulch was higher, but the cost required for cultivation was also higher. This treatment showed the highest B: C ratio of 2.33 primarily due to higher yields and higher prices of elephant foot yam. Goswami and Saha (2006), however, reported lower benefit : cost ratio in polythene mulching (1.88 - 2.09) and the net income dropped in polythene mulches due to their high cost (Rs 20,000 - 40,000/ha). Pre emergence application of oxyfluorfen (2.28) and directed spray of glyphosate also gave comparatively better B : C ratios (2.24).

According to Melinfowu (1994), weed management using chemical methods was economical compared to hoe weeding in cassava. Among manually weeded plots, weeding four times (T_3) showed the highest B: C ratio of 2.02. Intercropping with cowpea recorded a B: C ratio of 1.60, which was much below the best treatments. In terms of weed management, legume cover was a failure as shown by lower weed control efficiency (Table 17) and higher weed index (Table 18). Moreover, as Melinfowu (1994) reported because of the higher cost of seeds and labour for the establishment, use of legume cover would be expensive.

Summary

6. SUMMARY

Elephant foot yam, an important tuber crop often grown in homesteads, is susceptible to weed competition throughout the crop growth period. Manual weeding is the most common method of weed management practiced in elephant foot yam, but high cost and non-availability of the labour during the peak growing season makes weeding a difficult operation. Therefore, alternative labour saving and less costly methods of weed management are in great demand. To advocate alternatives to manual weeding, a field study was conducted to evaluate the effect of various weed management techniques, both chemical and non-chemical, on the growth and yield of elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson].

The study was conducted at the Department of Agronomy, College of Horticulture, Vellanikkara during March, 2016to December, 2016using the cultivar "Gajendra". The experiment was laid out in randomized block design with 10 treatments and 3 replications and the plot size was 5.4 m x 4.5 m. The treatments included manual weeding (twice, thrice, and four times), weed management by herbicides, that is, pre emergence application of oxyfluorfen 0.2 kg/ha plus manual weeding at 75 DAP, pre emergence application of pendimethalin 1.0 kg/ha plus manual weeding at 75 DAP and post emergence application of glyphosate 0.8 kg/ha plus manual weeding at 75 DAP, mulching with black polythene sheet, mulching with dry grasses, intercropping with cowpea, and unweeded control.

The weed management practices did not show any significant difference with respect to growth parameters such as plant height at 90 DAP, girth of pseudostem, length of petiole, length of rachis, and life span of leaves. However, mulching with black polythene recorded the highest leaf area and leaf area index at 90 DAP. Pre emergence application of oxyfluorfen 0.2 kg/ha plus manual weeding at 75 DAP and post emergence application of glyphosate 0.8 kg/ha plus manual weeding at 75 DAP were the next better treatments.

All the plots receiving manual weeding were on par with respect to leaf area and leaf area index. Mulching with black polythene was the best treatment in terms of leaf area per plant and leaf area index. Mulching with black polythene produced higher plant dry weight throughout the crop period irrespective of the crop growth stage. The treatments, mulching with dry grasses and intercropping with cowpea were not effective in suppressing weeds to any marked level as shown by lesser crop dry weight throughout the growth period.

The treatment, mulching with black polythene greatly influenced the corm and yield parameters such as height, diameter, and volume of corm. Pre emergence application of oxyfluorfen 0.2 kg/ha plus manual weeding at 75 DAP and post emergence application of glyphosate 0.8 kg/ha plus manual weeding at 75 DAP were also good treatments followed by manual weeding four times at 45, 75, 105, and 135 DAP. Mulching with black polythene also positively influenced the corm weight, recording the highest fresh weight of 2.70 kg/ plant and corm yield of 35.77 Mg/ha, which was 63 per cent higher than unweeded control. Increase in frequency of manual weeding also caused significant effects on weight of corm and corm yield per hectare. Mulching with dry grasses, intercropping with cowpea, and pre emergence application of pendimethalin were not very effective in obtaining higher corm yields.

Black polythene mulching was the best option to manage weeds in elephant foot yam fields at all growth stages and maintained the highest weed control efficiency at all the stages except at 165 DAP. However, mulching with black polythene gave consistent weed control efficiency up to 105 DAP after manual weeding four times, and at 165 DAP, it was the second best in controlling weeds and weed index was the lowest in black polythene mulched plots. In general, application of herbicides limits the weed dry weight greatly but pre emergence application of pendimethalin was not that effective compared to oxyfluorfen and glyphosate.

An increase in soil acidity and organic carbon content was observed after the harvest of crop. In general, mulching with black polythene recorded higher contents of all nutrients except N in soil. Mulching with black polythene resulted in higher nutrient contents in corms both at 90 DAP and harvest. Uptake of major nutrients was also higher in this treatment. Among manually weeded plots, weeding thrice and four times has shown on par uptake of N and P at harvest. Among the plots receiving herbicides, higher nutrient uptake was shown by the treatments, directed spray of glyphosate and pre emergence application of oxyfluorfen.

Benefit-cost ratio was the highest (2.33) in plots, which received mulching with black polythene. The B: C ratio of pre emergence application of oxyfluorfen and post emergence spray of glyphosate were 2.28 and 2.24 respectively. Manual weeding four times has shown a B: C ratio of 2.02.

From the studies, it can be concluded that mulching with black polythene, pre emergence application of oxyfluorfen, and post emergence application of glyphosate are effective weed management options in elephant foot yam. Pre emergence application of oxyfluorfen and post emergence application of glyphosate are better substitutes to eliminate the need of one manual weeding. The results clearly indicate the possibility of reducing the number of manual weeding by resorting to mulching with black polythene or judicious use of herbicides.

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Appendices

Appendix 1. Weekely weather data during experimental period

Std. Week No.	Date	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)			Wind speed (Km/hr)	Mean Sunshine hours	Rainfall (mm)	Rainy days (No.)	Mean evap. (mm)	Soil temp. (°C) (10 cm depth)
				Morning	Evening	Mean						
10	05/3 - 11/3	36.7	25.0	081	042	061	3.1	8.2	000.0	0	4.7	31.0
11	12/3 - 18/3	36.1	25.0	089	051	070	2.0	7.8	000.0	0	4.6	32.1
12	19/3 - 25/3	35.8	27.3	092	056	074	2.0	7.4	000.0	0	4.3	32.0
13	26/3 - 01/4	36.8	25.5	088	051	070	2.1	8.5	000.0	0	4.5	31.8
14	02/4 - 08/4	36.4	25.8	087	052	069	2.1	8.9	000.0	0	4.8	32.9
15	09/4 - 15/4	35.0	26.3	088	059	074	1.8	7.0	023.6	2	4.0	31.1
16	16/4 - 22/4	35.9	26.4	085	057	071	2.0	6.7	002.2	0	4.6	32.6
17	23/4 - 29/4	36.0	26.6	084	056	070	2.5	8.8	000.0	0	5.1	33.8
18	30/4 - 06/5	36.2	25.9	082	056	069	2.3	9.3	000.0	0	5.3	34.4
19	07/5 - 13/5	36.0	23.9	089	058	074	2.5	7.4	047.2	1	5.0	31.9
20	14/5 - 20/5	32.1	23.5	095	074	084	1.4	2.8	157.9	4	2.4	28.3
21	21/5 - 27/5	33.0	24.6	091	068	079	1.6	5.3	035.9	1	3.2	28.0
22	28/5 - 03/6	31.3	22.6	093	079	086	1.4	3.3	148.4	5	2.4	27.6
23	04/6 - 10/6	29.8	22.9	096	089	093	0.9	1.5	220.6	6	2.2	27.4
24	11/6 - 17/6	30.8	22.0	095	079	087	1.4	2.2	094.6	5	2.4	27.5
25	18/6 - 24/6	29.8	20.7	093	081	087	1.5	2.4	072.7	4	2.1	27.1
26	25/6 - 01/7	28.7	20.9	097	083	090	1.1	0.3	147.4	5	1.8	26.2
27	02/7 - 08/7	29.9	21.5	096	080	088	1.6	2.8	058.5	5	2.2	27.2
28	09/7 - 15/7	29.2	20.0	096	081	089	1.1	0.6	214.8	6	2.5	26.0
29	16/7 - 22/7	30.4	21.2	095	071	083	1.4	3.0	025.5	3	2.6	27.6

Std. Week No.	Date	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (%)			Wind speed (Km/hr)	Mean Sunshine hours	Rainfall (mm)	Rainy days (No.)	Mean evap. (mm)	Soil temp. (°C) (10 cm depth)
				Morning	Evening	Mean						
30	23/7 - 29/7	30.1	22.5	097	072	084	1.7	2.8	088.4	5	2.8	26.9
31	30/7 - 05/8	30.3	23.1	096	072	084	1.9	4.0	051.2	4	2.9	27.2
32	06/8 - 12/8	30.3	22.7	095	070	082	1.6	5.1	051.2	6	2.7	27.5
33	13/8 - 19/8	30.0	23.4	096	073	085	2.3	4.2	055.4	6	3.0	27.9
34	20/8 - 26/8	30.9	23.8	096	067	082	1.7	6.1	018.7	2	3.0	28.4
35	27/8 - 02/9	30.2	23.3	095	071	083	1.6	3.4	016.3	3	2.6	27.3
36	03/9 - 09/9	30.0	22.8	094	066	080	1.2	3.8	012.0	1	2.5	26.7
37	10/9 - 16/9	30.8	24.1	095	066	081	2.0	6.5	010.2	1	3.3	27.7
38	17/9 - 23/9	30.6	23.4	095	067	081	2.2	6.5	040.8	4	3.4	27.2
39	24/9 - 30/9	29.9	24.0	095	075	085	1.9	3.7	018.9	3	2.7	27.6
40	01/10 - 07/10	31.5	22.5	093	063	078	1.5	9.1	000.0	0	3.3	27.1
41	08/10 - 14/10	31.1	23.1	091	068	080	1.2	5.7	014.5	1	3.0	27.1
42	15/10 - 21/10	32.1	23.2	094	070	082	0.7	4.2	000.6	0	2.6	27.6
43	22/10 - 28/10	31.1	22.2	094	069	082	0.7	3.1	003.5	1	2.4	26.8
44	29/10 - 04/11	32.0	22.4	094	070	082	0.9	4.5	018.7	2	2.4	27.1
45	05/11 - 11/11	32.3	21.3	088	053	071	1.0	6.3	002.9	0	2.9	26.1
46	12/11 - 18/11	33.2	23.0	082	053	068	2.2	5.6	010.9	1	2.9	26.7
47	19/11 - 25/11	34.0	22.5	074	048	061	3.0	6.7	000.0	0	3.3	26.7
48	26/11 - 02/12	32.5	21.3	083	055	069	1.7	4.5	000.8	0	3.1	26.6
49	03/12 - 09/12	32.8	22.5	083	052	068	2.7	6.3	046.3	2	3.3	25.7
50	10/12 - 16/12	30.8	21.8	091	061	076	1.5	4.0	005.8	1	2.4	25.2
51	17/12 - 23/12	33.3	22.8	085	046	066	3.6	9.0	000.0	0	3.8	25.8
52	24/12 - 31/12	32.9	22.6	079	046	062	4.3	7.8	000.0	0	4.0	26.3

Appendix 2. Species wise composition of weeds during crop growth period

Grass weeds	**Broad leaf weeds**	**Sedges**
Panicum maximum	*Borreria hispida*	*Kyllinga monocephala*
Cynodon dactylon	*Alternanthera bettzickiana*	
Pennisetum purpureum	*Commelina benghalensis*	
Digitaria ciliaris	*Cleome viscosa*	
Stenotaphrum secundataum	*Blainvillea rhomboidea*	
	Mimosa invisa	
	Sida spp.	
	Centrosema pubescens	
	Mucuna prurita	
	Melochia corchorifolia	
	Spilanthus calva	
	Scoparia dulcis	
	Trianthema portulacastrum	
	Phyllanthus amara	
	Ageratum conyzoides	
	Crotalaria juncea	
	Manihot esculenta	
	Peperomia pellucida	
	Curculigo orchioides	
	Clitoria ternatia	
	Mitracarpus verticillatus	
	Chromolaena odorata	
	Hemidesmus indicus	
	Ludwigia parviflora	
	Synedrella nodiflora	
	Mollugo pentaphylla	
	Mikania micrantha	
	Eclipta alba	
	Peuraria phaseloides	
	Emilia sonchifolia	
	Physalis minima	

WEED MANAGEMENT IN ELEPHANT FOOT YAM
[*Amorphophallus paeoniifolius* (Dennst.) Nicholson]

By
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ABSTRACT OF THE THESIS
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(Agronomy)

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ABSTRACT

Elephant foot yam (*Amorphophallus paeoniifolius* (Dennst.) Nicolson) is a popular tropical tuber crop grown in Kerala because of high production potential and net returns. In Kerala, elephant foot yam is second in importance as a tuber crop after cassava and in 2015 - 16, it was grown in 7143 ha. In general, weed competition is an important constraint in the production of tuber crops owing to their initial slow growth. Elephant foot yam, being a widely spaced crop, takes 50 - 60 days or more to spread into full ground cover. Therefore, in the early growth stage of this crop, enough sunlight and space are available for weeds to flourish. Manual weeding is the most common method of weed control practiced in elephant foot yam, and two weedings, one at 45 days and the second at 75 days followed by earthing up, are recommended in Kerala. However, the high cost of manual weeding and non-availability of labour are major constraints in weed management, and so, farmers seek alternate methods of weed control.

The present experiment entitled "Weed management in elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson]" was conducted in the Department of Agronomy, College of Horticulture, Vellanikkara during March to December 2016 to study the effect of frequency of weeding and various weed management techniques on the growth and yield of elephant foot yam. Treatments included manual weeding (twice, thrice, and four times), weed management by herbicides, mulching with black polythene sheet, mulching with dry grasses, intercropping with cowpea, and unweeded control.

Among various treatments, mulching with black polythene displayed superior biometric characters and yield. Mulching with black polythene showed the highest per plant leaf area of 83.11 dm^2 and leaf area index of 1.02. The treatments with herbicides were next in order. All the plots receiving manual weeding were on par

with respect to leaf area and LAI. Irrespective of the stage of crop, mulching with black polythene produced higher plant dry weight throughout the crop period. The treatments, mulching with dry grasses and intercropping with cowpea were not effective in suppressing weeds to any marked level as shown by lesser crop dry weight throughout the growth period.

Mulching with black polythene greatly influenced the height, diameter, and volume of corm followed by pre emergence application of oxyfluorfen and directed spray of glyphosate. Mulching with black polythene also positively influenced the fresh weight of corm, recording the highest fresh weight of 2.70 kg/ plant and corm yield of 35.77 Mg/ha, which was 63 per cent higher than unweeded control. Increase in frequency of manual weeding also caused significant effects on fresh weight of corm and corm yield per hectare. Mulching with dry grasses, intercropping with cowpea, and pre emergence application of pendimethalin were not very effective in obtaining higher corm yields.

Mulching with black polythene was the best option to manage weeds in elephant foot yam fields at all growth stages. In general, application of herbicides limits the weed dry weight greatly but pre emergence application of pendimethalin was not that effective compared to oxyfluorfen and glyphosate. Mulching with black polythene maintained the highest weed control efficiency at all the stages except at 165 DAP. However, mulching with black polythene gave consistent weed control efficiency upto 105 DAP after manual weeding four times, and at 165 DAP, it was the second best in controlling weeds.

An increase in soil acidity and organic carbon content was observed after the harvest of crop. In general, mulching with black polythene recorded higher contents of all nutrients except N in soil. Mulching with black polythene resulted in higher nutrient contents in corms both at 90 DAP and harvest. Uptake of major nutrients was also higher in this treatment. Among manually weeded plots, weeding thrice and four times resulted in on par uptake of N and P at harvest. Directed spray of glyphosate and pre emergence application of oxyfluorfen resulted in higher nutrient uptake among the plots receiving herbicidal application.

The highest benefit - cost ratio of 2.33 was recorded with mulching with black polythene. The B : C ratio of pre emergence application of oxyfluorfen and post emergence spray of glyphosate were 2.28 and 2.24 respectively. Manual weeding four times resulted in a B : C ratio of 2.02. From this experiment, it can be concluded that mulching with black polythene, pre emergence application of oxyfluorfen and post emergence application of glyphosate can be effectively utilized for weed management in elephant foot yam.