



Weed Management in Root and Tuber Crops in India: Critical Analysis

M. Nedunchezhiyan¹, C.S. Ravindran² and V. Ravi²

¹Regional Centre of Central Tuber Crops Research Institute, Dumuduma, Bhubaneswar, Odisha 751 019, India

²Central Tuber Crops Research Institute, Sreekariyam, Thiruvananthapuram 695 017, Kerala, India

Corresponding author: M. Nedunchezhiyan; e-mail: mnedun@gmail.com

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Abstract

Weeds are ubiquitous and continue to be an important constraint in the production of root and tuber crops owing to the initial slow growth of these crops. In India, weeding is predominantly done by the use of manual labour and to a limited extent through mechanical means. Weeding consumes about 30% of the total labour input and about 150-200 man days ha⁻¹. The implementation of National Rural Employment Guarantee Scheme of Government of India has seriously affected the availability of labour for agricultural operations. The draught animals which were commonly used for intercultural operations in cassava along with gorru (7 tynes/9 tynes) in Andhra Pradesh are slowly but steadily making an exit because of high maintenance cost. Farmers are beginning to think of alternatives and herbicides are the obvious choice for many. Research results revealed that the pre-emergence herbicides, oxyflourfen, alachlor, butachlor etc. and the post-emergence herbicides, paraquat and glyphosate in combination with hand weeding was effective in weed control of cassava in various agro-climatic conditions of India. Pre-emergence application of isoproturon @ 1.0 kg ha⁻¹ was found effective in taro weed management. In elephant foot yam, straw mulching, pre-emergence herbicide oxyflourfen and post-emergence herbicide glyphosate were effective for weed control. The use of herbicides is expected to grow further in the near future due to non availability of labours and draught animals for weeding. However, negative effect of herbicides on soil microbial population and starch concentration in cassava and other root and tuber crops was reported in certain locations. Mulching using weed control ground cover and diesel operated power weeder are highly suitable for weeding in widely spaced root and tuber crops. Hence, depending upon agro-ecosystem and socio-economic conditions, farmers can opt for any combination of weed control methods for effective management of weeds in root and tuber crops.

Key words: Cassava, elephant foot yam, taro, sweet potato, herbicides, polythene mulching, weed control

Introduction

Weeds are ubiquitous and continue to be an important constraint in the production of root and tuber crops. Weeds compete with the crop for water, nutrient, light and space both below and above ground. Weeds also exhibit allelopathic reactions inhibiting the growth of the crops (Demon et al., 1975; Bhowmick and Doll, 1982; Einhelling, 1985). The prevailing agro-climatic

conditions such as temperature, humidity, day length and edaphic factors, particularly soil moisture and nutrient status determines the composition of weed species, population and their competitive ability. The subsistence farmer of the tropics spends more time, money and energy on weed control than on any other aspect of crop production. Nevertheless, the farmers continue to experience heavy losses in crop yield due to weed interference. A conservative estimate of about 10% loss

in the tropics would amount to a total loss of about 25 m t of food grains, currently valued at approximately Rs. 65000 crores (USD 13 billion) (Yaduraju, 2012). The total economic losses will be much higher if indirect effect of weeds on health, loss of biodiversity, nutrient depletion, grain quality etc is taken into consideration. Losses of similar magnitude would occur in root and tuber crops.

Special attention is required for research on weed management in root and tuber crops owing to the initial slow growing nature of these crops (Moody and Ezumah, 1974; Srinivasan and Maheswarappa, 1993), and the adverse effects of weeds on growth, yield and quality of these crops (Nedunchezhiyan and Misra, 2008 ; Ravindran et al., 2010). The key issues related to weed management are briefly discussed here:

Major issues in weed management

Shortage of labour

Basically Indian agriculture is highly labour intensive. Labour accounts for 60% of the total cost of crop production (Yaduraju, 2012). Weeding is predominantly done manually and to a limited extent through mechanical means. Currently the herbicide use is more in wheat, rice, soybean and tea. The implementation of National Rural Employment Guarantee Scheme of Government of India has seriously impacted the availability of labour for agricultural operations (Yaduraju, 2012).

Weeding has never been a priority operation for majority of the farmers due to several reasons. The present situation of labour shortage and increase in wages has only worsened the situation. Farmers are beginning to think of alternatives and herbicides are the obvious choice for many. For these reasons the use of herbicides is expected to grow in the near future.

Mechanization

The labour shortage has also forced farmers to go for machines in a big way. The drought animals which were commonly used for land preparation and inter-cultivation operations are slowly but steadily making an exit. Increased pressure on land and high cost of rearing the animals are the principal reasons for this shift. Diesel operated power weeders of 0.5 HP is now available in India, which can be suitably modified for weeding in

root and tuber crops without affecting the crops. It is time to popularize the use of mechanical weeders in a big way.

Herbicide resistant crops (HRC)

The herbicide resistant soybean, cotton and maize have been under controlled condition trials for quite some time in India (Yaduraju, 2012). Herbicide resistant crops presently occupy nearly 60% of the total global area of 160 m ha under genetically modified (GM) crops. HRCs allow cultivation of crops with no or minimal problem of weeds of all kinds. However, several important risks associated with HRCs should be examined before its widespread adoption is permitted. The greatest risk is the potential for transfer of the gene conferring the herbicide resistant trait to related wild and weedy relatives. This could lead to increased weediness or invasiveness. However, this may not pose danger in India in crops such as cassava, sweet potato and elephant foot yam, because of lack of wide genetic diversity and closely related species.

The role of herbicides

At present, weed control is done by hand weeding (manual) or other physical means, but in areas where labour is becoming relatively expensive and often scarce especially during the early stages of crop growth when weed competition is severe, chemical weed control through application of herbicides is rapidly becoming the most promising alternative method. Further, under difficult- to-work field conditions, use of herbicide is an obvious choice (Sarma and Gautam, 2010). Herbicides can be applied as pre-emergence before the crop and weeds emerge from the ground or as post-emergence and remain active until the critical period of weed competition has passed. Furthermore, weed control through herbicide application will be faster than manual weeding. The use of herbicides by the small farmers in tropics is limited by cost and availability (Ravindran et al., 2010). Further, herbicide reduces the quality of the produce (Nedunchezhiyan et al., 2011). Nevertheless, with scarcity of labour at times when weeding is most critical, the farmer will be compelled to use herbicides. Chemical weed control has another advantage that fewer weeding are necessary and cost per weeding is cheaper (Ferguson, 1970).

Pesticide market in India is small when compared to global. It is about 1 billion USD compared to 33 billion

USD in the world market. The overall pesticide consumption also is very low at 362 g ha⁻¹, the bulk of which are insecticides (67%). The share of herbicide is nearly 20% and is growing. Although herbicides have been in use for over three decades, its use has increased only recently. With the labour shortage looming large, the demand for herbicides is expected to grow substantially. With the increased use of herbicides, the issues such as herbicide residue in soil, water, and food, resistance to herbicides in weeds etc. would come into prominence and such issues should be addressed. Herbicide industry and weed scientists have a greater responsibility in educating the farmers and the extension staff on judicious and sustainable use of herbicides.

An overview of weed management in tropical tuber crops is briefly dealt with:

Weed management in tuber crops

Cassava (*Manihot esculenta*)

In India, cassava is largely grown in the states viz., Tamil Nadu, Kerala, Andhra Pradesh, Maharashtra, Gujarat, Odisha and North-Eastern States in a total area of 2,43,970 ha with annual production of 99,43,590 tonnes of tubers (NHB, 2013). Cassava has a slow initial growth phase and requires wider spacing (90 cm x 90 cm) to accommodate later growth. Its early growth period (1-4 months) provides space for weeds to flourish. Addition of farmyard manure, non availability of labour for timely intercultural operations and lack of proper land preparation contribute to weed growth in cassava fields. Tuber yield losses in cassava due to weeds may go up to 100% (Moody and Ezumah, 1974; Akobundu, 1980; Hahn and Keyser, 1985; Ambe et al., 1992). Ravindran and Ravi (2009) reported that weed infestation is one of the major constraints in cassava growing areas and weeding is the major labour consuming activity. Dominance of weed species varies with place (Ambe et al., 1992; Ravindran and Ravi, 2009). When grasses like *Cyperus rotundus*, *Cynodon dactylon*, *Panicum repens* etc. were dominant, harvesting was difficult and tuber quality was affected.

Hand weeding is the most common method of weed control in cassava. In Tamil Nadu, farmers do up to 5 manual weedings, costing Rs 10,500 ha⁻¹ (Ravindran and Ravi, 2009). In Andhra Pradesh, 'Gorru' (It is an animal drawn cultivator and has two rows of tynes attached to

its frame in staggered form. Frame length is 75-90 cm suitable to work between wide spaced rows and the distance between the tynes is adjustable) is used for weed control at the early stage of crop growth. Seven tynes 'Gorru' is used when weed density is less (Fig. 1). Nine tynes 'Gorru' is used when weed density is high and weeds are taller. Seven tynes 'Gorru' is drawn by single bullock, whereas nine tynes 'Gorru' is drawn by two bullocks. 'Gorru' can be operated only at appropriate soil moisture conditions when cassava is planted in flat beds. Cassava when grown as sole crop usually forms a canopy after 3-4 months. Therefore, suppression of weed growth by 3-4 months is important for maximum productivity of cassava (Villamayor and Reoma, 1987; Ambe et al., 1992). Weeding cassava during the first four months resulted in yield similar to that obtained when the crop was weeded throughout the season. Cassava grown weed free mechanically yielded 10% less than a crop grown weed free chemically and this was attributed to soil disturbance causing root injury (Doll and Piedrahita, 1973; Barrios, 1973). Smother crops such as beans, cowpea, maize, groundnut, melon growing along with cassava during its initial growth period up to 90 days was found effective in controlling weeds (Leihner, 1980; Ossom, 1986; Zuofa et al., 1992; Mohamed Amanullah et al., 2006). Although intercropping can be a potential biological tool to manage weeds, the system by itself would not be able to provide satisfactory level of weed control at early stage of crop growth due to inadequate crop canopy development to suppress the weeds (Dwivedi and Shrivastava, 2011). Integrated use of cowpea and pre-emergence application of alachlor or chloramben or fluometuron or mixture of fluometuron



Fig. 1. Seven tynes 'Gorru'

and chloramben effectively controlled the weeds in cassava (Akobundu, 1980).

In Tamil Nadu, farmers apply glyphosate (6-8 ml l⁻¹ water) through hand sprayer during the initial crop growth period (1-1.5 months) to control weeds when cassava is a sole crop. When cassava is intercropped with onion, oxadiazon (2 ml l⁻¹ water) or pendimethalin (8 ml l⁻¹ water) is power sprayed within 3 days after planting cassava and onion to control emerging weeds. During survey, we observed that in Andhra Pradesh, farmers preferred paraquat (2-3 ml l⁻¹ water) during 1-2 months after planting and glyphosate (4-5 ml l⁻¹ water) 3-5 months after planting to control weeds (Fig. 2). Pre-emergence application of oxyflourfen, pendimethalin,



Fig. 2. Five days after glyphosate applied cassava field

vernolate, EPTC and high concentration of glyphosate (>2%) resulted in phytotoxicity which caused yellowing, stunting of plants and reduction of yield (Liu et al., 1982; Santos et al., 1982; AICRPWC, 1990). Recent observation at Central Tuber Crops Research Institute (CTCRI), Thiruvananthapuram, Kerala, India has proved that weed control ground cover can control weeds effectively, but the economics of this practice has to be worked out (CTCRI, 2013).

Yam (*Dioscorea* spp.)

Yam, a long duration crop requires frequent and effective weeding for high tuber yield. The critical period of crop-weed competition appears to be between 3 and 6 MAP (Roy Chowdhury and Ravi, 1994) because it is during this period yam plants develop maximum leaf area and total dry matter production. A weed free period of 10

to 12 weeks results in optimum yam yield (Beale, 1983). Yam was more affected by weeds between 10 and 22 weeks than at other times (Unamma et al., 1980). The adverse effect of weed interference in the tuber bulking phase was 65% greater than the maximum root development phase (Njoku et al., 1973). In India, earthing up along with weeding and fertilizer application is an essential intercultural practice followed for yam cultivation. No herbicide has been recommended for cultivation of yams. Pre-emergence herbicides like oxyflourfen and pendimethalin can be successfully used for weed control, as the crop takes 15-20 days to emerge. Weed control ground cover was found effective for weed control at CTCRI, Thiruvananthapuram, Kerala, India.

Sweet potato (*Ipomoea batatas*)

In India, sweet potato is largely grown in the states of Bihar, Odisha, Uttar Pradesh, West Bengal and North Eastern states in a total area of 1,11,170 ha with an annual production of 10,88,880 tonnes of tubers and productivity of 9.79 t ha⁻¹ (NHB, 2013). Wide variation in yield loss due to weeds was reported by Moody and Ezumah (1974) in sweet potato. Nedunzhiyan (1996) reported that in sweet potato, *Celosia argentia*, *Digitaria sanguinalis* and *Cleome viscosa* are the dominant community with *Cyperus rotundus* as co-dominant under acid laterite soil. The critical period of crop-weed competition varied from 14-28 days (Talatala et al., 1978) to 21-63 days (Kassasian and Seeyave, 1967). A weed free period of 45 days reduced the weed dry weight by 80% (Nedunzhiyan, 1996). Weed dry matter accumulation proved to be a better indicator of weed interference (Wooley, 1989). Yield reduction of 91% was found in sweet potato due to weed competition. Critical period of crop-weed competition was found to occur from 30 to 45 days after planting under Bhubaneswar conditions (Nedunzhiyan et al., 1998). Pre-emergence application of isoproturon @ 1 kg ha⁻¹ effectively controlled the weeds in sweet potato (Nedunchezhiyan and Satapathy, 2002a; Nedunchezhiyan and Satapathy, 2002b). Weed intensity in spreading type varieties is lesser than semi-spreading type. To suppress the weed growth, Odisha farmers plant sweet potato very closely, sometimes two to three cuttings together per hill. Sweet potato – rice rotation is followed in upland ecosystem in Odisha to check weed spread. Weed population in rice fields was lesser, when sweet

potato was taken as preceding crop (Nedunchezhiyan et al., 2006).

Taro (*Colocasia esculenta*)

Taro plays an important role as a vegetable in India when other vegetables are scarce in the market due to various climatic limitations (Nedunzhiyan et al., 1996). Taro has a shallow root system (Mohankumar and Sadanandan, 1990) and competes with the weeds almost in the same layer of the soil. Taro root length and root volume progressively decreased at the later period of crop growth. Weed management practices appreciably affected root development in taro and therefore weed free period of up to 60 days was essential for proper root development (Nedunzhiyan, 1995; Nedunchezhiyan and Satapathy, 2003). The effect of weed interference in taro prevents the development of optimum leaf area, which in turn affects the production of necessary assimilates for tuber bulking. The presence of weeds throughout the crop growth period reduced yield of taro by 60% (Nedunzhiyan et al., 1996). Besides delaying the normal process of cormel initiation in taro, the presence of weeds reduced the cormel number per plant (Nedunzhiyan et al., 1996). Loss caused by the weeds depends upon their density, dominance and ecological success (Nedunzhiyan et al., 1996). Nedunzhiyan et al. (1996) reported that under sub-tropical climate 23 weed species were associated with taro, which mostly belonged to Poaceae and constituted *Celosia argentea*, *Digitaria sanguinalis* and *Cleome viscosa* as the major weed community.

Mulching of taro has been practiced to control weeds and conserve moisture (Mohankumar and Sadanandan, 1988; Singh et al., 2003) (Fig. 3). Maximum weed infestation (dry weed mass 573 g m⁻²) was found in taro field without mulching (Singh et al., 2003). Mulching with coconut fronds and banana leaves effectively controlled weeds (Fetuesi et al., 1991). Black polyethylene mulching and 60 cm x 20 cm plant spacing resulted in effective weed control (dry weed mass of 97 g m⁻²) in taro, but paddy straw mulching was found to be economical with less weed infestation and maximum corm and cormel yield as compared to field without mulching (Singh et al., 2003). The yield reduction in unweeded field was due to cumulative effects of competition for available space and nutrients. The

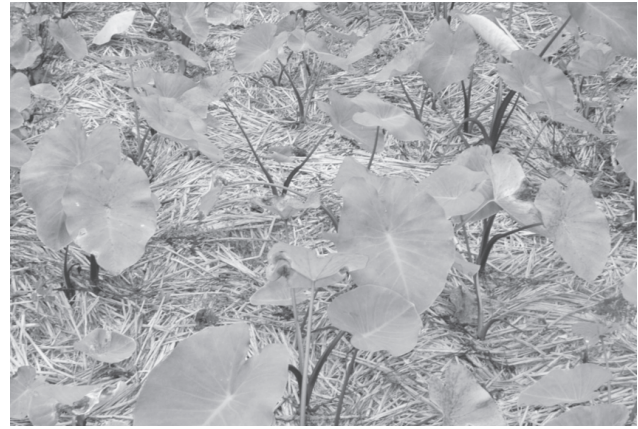


Fig. 3. Paddy straw mulching in taro

combined presence of taro and nutsedge resulted in depletion of soil N and K as compared to weed free conditions (Nedunzhiyan, 1995).

Several herbicides have been recommended for weed control in taro field. Nedunchezhiyan et al. (2002c) reported that pre-emergence application of isoproturon @ 1 kg ha⁻¹ controlled the weeds effectively in taro. Nitrofen has been claimed to have excellent weed control when it is applied through irrigation water (Plucknett and de la Pena, 1971). Application of ametryn @ 3.2 kg or terbutryn @ 2.0 kg ha⁻¹ or terbutryn + prometryn each @ 1.6 kg ha⁻¹ (Meneses et al., 1981) or atrazine or simazine or nitrofen @ 1.0 kg ha⁻¹ (Mishra and Mishra, 1985) as pre-emergence effectively controlled weeds in taro field.

Elephant foot yam (*Amorphophallus paeoniifolius*)

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 germinate and grow much early than the crop establish because of delay in sprouting of planted corms. Weed growth is maximum in unweeded fields (AICRP, 2004; 2006). The critical period of crop-weed competition is between 1-5 months after planting as the major crop growth and corm bulking occurs during this period. In India, grasses (*Echinochloa colonum*, *Cynodon indica*, *Cynodon dactylon*, *Eleusine indica* and *Dactyloctenium aegyptium*), sedges (*Cyperus rotundus*, *Fimbristylis miliaceae*) and broad leaved weeds (*Eclipta alba*, *Amaranthus viridis*, *Euphorbia hirta*, *Amaranthus spinosus*, *Commelina banghalensis*, *Corchorus*

acutangulus, *Phyllanthus niruri* and *Cleome viscosa*) were observed (Bhaumik et al., 1988; AICRP, 2004).

Hand weeding is the most common method of weed control practiced. Farmers carried out hand weeding at monthly intervals up to 4 months after planting. Each weeding is followed by earthing up. Due to high cost of hand weeding and non availability of labour during peak season, farmers prefer chemical methods of weed control (Nedunzhiyan et al., 1996). Planting at wider spacing coupled with the plant morphology of elephant foot yam (erect single pseudostem) allows herbicide spraying up to 4 months after planting (till complete coverage of foliage). Research conducted at the Regional Centre of Central Tuber Crops Research Institute, Bhubaneswar revealed that the application of glyphosate @ 2 kg ha⁻¹ between 1 and 3 months after planting effectively controlled the weeds and the slow death of weeds acted as mulch in the elephant foot yam field. Application of fluchloralin @ 2.0 l ha⁻¹ as preplanting incorporation or pendimethalin @ 3.3 l ha⁻¹ or oxyflourfen @ 0.5 l ha⁻¹ as preemergence or bentazone @ 1.5 l ha⁻¹ or bromoxinil @ 1.5 l ha⁻¹ as post-emergence were effective to control the weeds in elephant foot yam fields (Bhaumik et al., 1988).

Straw mulch at the time of planting followed by herbicides (pendimethalin, glyphosate, oxyflourfen @ 1 kg ha⁻¹) could effectively reduce weed population as well as dry weed biomass as compared to control (AICRP, 2004; 2006). At Kovvur, Andhra Pradesh, application of oxyflourfen resulted in corm yield of 45.1 t ha⁻¹, which was on par with cowpea live mulch (41.7 t ha⁻¹) (AICRP, 2006). Evaluation of the different weed management methods at Kalyani, West Bengal indicated that maximum corm yield was obtained due to black polythene mulch (82.5 t ha⁻¹) and the next being straw mulch (64.8 t ha⁻¹). Among herbicide treatments, application of glyphosate coupled with one hand weeding resulted in maximum corm yield (49.8 t ha⁻¹) (AICRP, 2004). At Dholi, Bihar, pendimethalin and oxyflourfen @ 1 kg ha⁻¹ resulted in maximum corm yield. At Thiruvananthapuram, Kerala, paddy straw mulch and manual weeding resulted in maximum corm yield (AICRP, 2004; 2006). Weed control ground cover was found effective in weed control throughout the crop growth period of elephant foot yam at CTCRI, Thiruvananthapuram, Kerala, India.

Conclusion and Future Prospects

- Weeds are the major constraints in root and tuber crop production.
- It causes severe yield loss (50-70%) and makes harvesting cumbersome in root and tuber crops as the economic part, root, is underground.
- Weeds also affect the quality of the roots and tubers by directly infesting/feeding on the roots and tubers.
- No single method of weed control is effective in controlling weeds as the weed flora and their growth habits vary widely.
- Best results are therefore obtained when a number of practices are simultaneously followed.
- Proper land preparation such as ploughing twice or thrice and removal of dried weeds from the field before planting the crop, is essential for weed control. *Cyperus* sp and *Cynodon dactylon* are perennial and noxious weeds as their rhizomes remain deep 1 feet below the ground and resurrects. Field preparation particularly ploughing thrice and removal of weeds and their rhizomes/tubers before planting is very important to eradicate these weeds.
- Crop varieties showing vigorous growth can successfully compete with weeds.
- Adopting multiple cropping systems with close growing ephemerals such as black gram, green gram, cowpea, onion etc. appears to be promising for weed management.
- The possibility of weeding through mechanical devices like power weeder and other such tools needs to be explored.
- With the labour shortage looming large and cattle population dwindling rapidly, use of power weeder, herbicides and polythene mulching becomes inevitable for proper weed management.
- Due to increased use of herbicides, the issues such as herbicide residues in the soil, water and food, resistance to herbicides in weeds etc. would come into prominence and such issues warrants attention.
- The research related to herbicides must go beyond herbicide screening into application techniques, enhancing herbicide efficiency etc.

- More studies on ecology and biology of very serious weeds in relation to their management are needed.

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