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Weed Management in Tea - Recent Developments

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ABSTRACT

Weeds compete with tea, reducing the yield. They also interrupt field operations. Managing weeds in tea plantations has become a crucial issue due to high cost of labour and other inputs such as herbicides, especially at a time the end product fetches a lower NSA. Thus, a low cost weed management strategy is of paramount importance for the sustainable productivity of tea plantations. Adoption of cultural, and ecological methods is of great importance as they are environmental friendly and cost effective. They are land preparation, proper bush management, infilling, mulching, establishment of cover crops and green manure crops and leaving desirable weeds on ground. However, use of various herbicides has proven to be the most convenient and effective method and it could minimize soil erosion and eliminate loss of plant nutrients. Various herbicides have so far been recommended by the TRI for weed control in tea fields. There are number of problem weeds in tea fields at present as they are resistant to normal dosage of recommended herbicides. As such, these weeds have to be managed using specific herbicide dosages or cocktail mixtures or by adopting other control measures. For cost effective weed management strategies ensuring healthy growth of tea and good quality of made tea, safe and effective use of herbicides have been emphasized. The decision making on the adoption of aforesaid integrated weed management techniques more rational way would only be the solution for more cost-effective weed management and for healthy tea production.

Key words: Tea, weed management, herbicides, soil erosion, plant nutrients, critical period

INTRODUCTION

As for other crops, weeds compete with tea mainly for light, water, nutrients, thereby growth and yield of tea are affected at varying degree. The yield reduction in tea was found to be 5-15 % in seed tea and 5-9 % in VP tea, when weeding was delayed by 4 and 6 months, respectively (Wettasinghe, 1971, a b). Prematilake *et al.* (1999) reported that the critical period of weed competition in young tea was 8-16 weeks after planting (WAP) and weed infestation for more than 12 weeks adversely affect the growth of tea. Furthermore, a dense cover of weeds also interferes with field practices such as plucking, manuring, forking *etc.* resulting in a high cost of field operations. Besides, some weeds habour pests and diseases. A dense weed cover could also increase the relative humidity thereby providing conducive environment for fungal infections.

The cost of weeding is in the range of 10-14 % of the total cost of field operations. It is also accounted for 4-5% of the total cost of production of made tea and it is second only to plucking and fertiliser application. Cost of weeding is very high as a result of high cost of labour and escalating prices of herbicides. The amount of Rs.350/- per month per ha allocated by estate sector to control weeds in tea fields is not adequate to implement a comprehensive weed management programme. Thus, managing weeds has become a critical issue in the estate sector especially under situation where the end product fetches a lower NSA. However, weed management in tea small holdings has not yet posed as a problem in view of majority of smallholders adopt manual weeding utilising the family labour.

Thus, weed management is one of the most important field operations, which should carried out on a regular basis. Thus strategies for managing weeds in tea plantations at minimum cost are of paramount importance for sustainable productivity of tea.

Occurrence of weeds - Causal factors:

Factors that contribute to profuse weed growth in tea fields have been well recognized. They are ground exposure, high rain fall (2500-3500 mm per annum), regular use of nitrogenous fertilizer and addition of organic matter. There are two critical periods of profuse weed growth in tea due to ground exposure *viz.* new clearing (during first two years after planting) and pruning phases. Furthermore, old tea fields with poor bush stand due to casualties, neglected and abandoned areas provide very conducive conditions for weed proliferation. Negligence of such lands or delayed weeding in tea

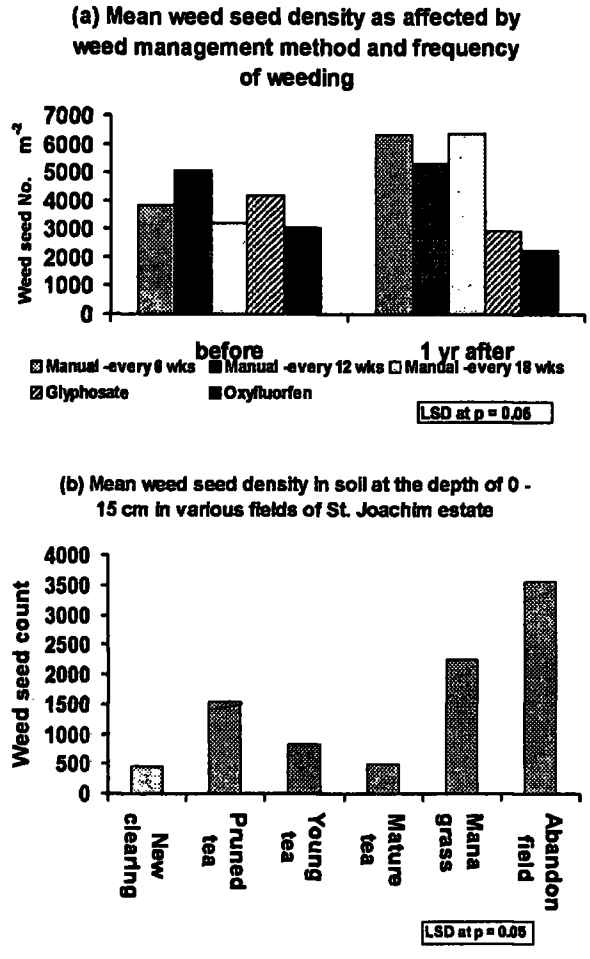

Fig. 1. Mean weed seed density in soil as affected by the method and frequency of weed management and age of the crop [*Source: Prematilake, K.G. (1997)*].

lands thus result in establishment and maintenance of a larger weed seedbank in soil (Fig.1 a & b). During the rest of the period, weed problem is relatively less since tea bush itself could adequately cover the soil. Propagation of weed seeds, cuttings *etc.* through media of compost, mulches *etc.* and; resorting to a single method of weed control are also the other factors that attribute to greater occurrence of weeds. Understanding about the causes of weediness is important for the grower for selecting and integrating the most appropriate weed management method/s.

Integrated weed management in tea

There are various weed management practices in tea cultivation at present such as manual, chemical, cultural, ecological and biological methods. Moreover, adoption of preventive measures also assumes a great importance as a cost-cutting strategy. The term "Weed Control" has become outdated and the current practice of Integrated Weed Management (**IWM**) refers to a combination of some or all of the above techniques in rotation, throughout the year, in order to achieve cost effective and eco-friendly weed management. IWM is virtually a weed management package which utilizes the knowledge and know-how on weeds and their management.

Preventive measures

Adoption of preventive measures is of great importance as it helps to minimize the weed seedbank in soil, thereby mitigating the present and future weed population. As shown in Fig.1a, weed seed number has increased in all three manual weeding treatments. The greater weed seed number in plots manually weeded at 12 and 18 weeks intervals was a consequence of delaying the weeding which in turn results in mass production of seeds *in situ.* However, increased seed number in manual weeding at six week intervals was attributed to seeds of favourable or soft weeds, which are tolerable and not harmful to tea. In contrast, seed density decreased with two herbicide treatments as a result of effective control of weeds before their emergence or at seedling stage i.e. before producing seed. Cleaning of all neglected land areas also greatly helps to lower the weed seed density, consequently the weed menace in the adjoining tea fields (Fig. 1 b). Therefore, control of weeds in their early phase of growth is very essential.

Thus, the following measures could be adopted to overcome some of the aforesaid causes of weediness.

The weed growth has to be constantly checked before they reach flowering phase. Thus, weeding should be undertaken at least every 8-10 weeks so as to control them before they reach a height of 10-15 cm which also facilitate fertilizer application.

The border areas of tea fields, roadsides, steep terrains *etc.* should be kept weed free by slash weeding or using herbicides, in order to avoid continuous dispersal of weed seeds to adjoining tea fields. Also a suitable cover crop or grass spp. can be established in such places. Uncultivated land blocks can be brought under thatch banks or forest blocks.

Planning of a year-round uniform weed management programme without resorting to *ad hoc* methods is also important in order to manage weeds in all fields.

Resorting to one method of weed control for a longer period could lead to dominance of some weeds and also development of resistance to herbicides.

Weed compost and mulch materials have to be used in more rational manner since the vegetative parts, seeds, yams and rhizomes of weeds present,

could serve as breeders of weeds.

Cultural, Ecological and biological methods

Cultural and ecological methods are of great importance among other techniques because some of these techniques could be adopted without incurring an additional cost, as they are conventional agronomic and cultural practices such as soil rehabilitation, land preparation, planting, bringing-into-bearing, pruning and correct methods of plucking which are essential components in tea cultivation. The ground exposure is the most critical factor which attributes to profuse growth of weeds during young tea phase *i.e.* particularly during first-second year, third-fourth year and during first year after pruning. The objective of adoption of cultural and ecological techniques is therefore to suppress the weed growth from very early phase of tea growth through the maintenance of a proper ground cover.

Land preparation and soil rehabilitation: The land preparation following uprooting of old tea is an essential practice in order to remove all roots, boulders *etc.* from soil. Furthermore, during this process, the existing weeds are automatically controlled and mixing up of soil facilitates the majority of new seeds left on the ground surface to bury in deeper layers and *vice versa.* Thus, exposed seeds, in turn start germination, complete their life cycle or get controlled by manual or chemical means. Some portion of seeds may die due to the sudden exposure to direct sunlight. The establishment of grasses such as Mana (*Cymbopogon confertiflorus*) and Gautemala (*Tripsacum laxum*) for soil rehabilitation prior to replanting at closer spacing for a period of one and a half to two years also provides no room for weed growth, thereby future weed problem through the production of many weed seeds could be minimal. However, in practice this does not happen under field conditions since there are many vacancies resulting from casualties of grass that does not get infilled and get infested with weeds. Weed seed production was greatly reduced in new clearing and young tea fields when compared to that in abandoned field (3558 m^{-2}) (Fig. 2 b) and; 13000-27000 m^{-2} in old tea field as reported by Eden (1949).

Bush management: It must be emphasised that healthy and well-spread nursery plants should be selected for field planting. Such plants could grow more vigorously having good development of frame of the bush. Maintenance of proper bush health, bringing the tea plant in to bearing at correct time, and encouragement of growth of peripheral branches

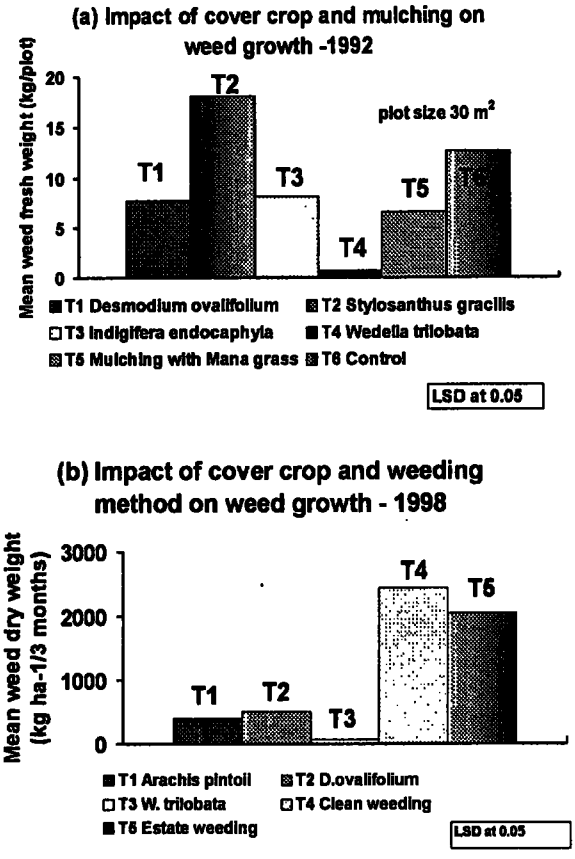

Fig. 2. Impact of cover crop, mulching and weeding method on the suppression of weed growth in low-grown tea at Ratnapura (*Source: Anonymous, 1992*).

of tea through selective plucking and all other Good Agricultural Practices (GAP) including manuring etc. would help in fast development of the frame, thereby early ground cover which could suppress the weed growth.

Spacing: In order to attain an early ground cover, planting of tea at closer spacing would be more favourable than planting at wider spacing [1.2 m x 0.6 m] (4' X 2'). However, the correct spacing will depend on the cultivar selected for planting.

Mulching: Mulching or thatching the ground with a live or dead material is the recommended practice for tea, specially in the new clearings as it smothers the weed growth and conserves the soil and moisture; and improves soil fertility through addition of organic matter (Manipura *et al*, 1969). The loppings of Mana and Gautemala grasses are commonly used for thatching. However, on account of unavailability of lands and lack of labour, the term "maintenance of thatch banks" is gradually erased from the planters dictionary. Among various grass species, Mana produced the highest biomass (Table 1). As per recommendation, mulching should be done at least 2-3 rounds per year and care should be taken to use only uncontaminated grasses without

Table 1: Mean dry weight of loppings of various grasses at St. Joachim estate, Ratnapura.

Type of Grass	Dry weight of loppings ($t\ ha^{-1}yr^{-1}$)
Mana (*Cymbopogon confertiflorus*)	57.9
Sevendara (*Vetiveria zezesinoides*)	23.0
African Love grass (*Eragrostis curvula*)	8.2
Sugar cane (*Saccharum officinale*) (Var CO-775)	28.3
LSD (p=0.05)	12.7

Source: Anonymous (1992)

vegetative parts of noxious weeds spp. Further, weed biomass production was the least when mulched with Mana except for the cover crop, *Wedelia trilobata* (Fig. 2, a). Prematilake (1997) also showed that the weed growth was reduced significantly ($p<0.05$) by ground application of oxyfluorfen followed by thatching tea inter-rows with Mana grass. Furthermore, slash weeding of hard-to-kill weed, Getakola (*Spermacoce hispida*) followed by mulching with Mana grass resulted in the least dry weight and the density of *S. hispida* (Prematrilake and Gamage, 2003).

Loppings of shade trees, green manure crops, and dead mulches such as refuse tea, coir dust *etc.* could also be used for mulching. However, it is necessary to use dead mulches which are free of rhizomatous weeds and yams.

The exposed tea inter-rows in pruned tea fields could be mulched with pruned litter and loppings of shade trees in order to smother the weed growth.

Use of green manure crops for weed management

Green manure crops such as Ladappa or Wetahira (*Gliricidia sepium*), Dadap (*Erythrina lithosperma*), *Crotolaria* spp are traditionally established in tea fields, in order to provide shade for young tea plants as well as to improve soil fertility by addition of their loppings. Prematilake *et al* (1998) showed that loppings of *Flemingia congesta*, which is a N-fixing species, were also a good source of mulch and smother weed growth in for almost 17-28 week period under low country conditions (Table 2). While, loppings of mana grass were persisting on soil for 18-27 weeks. The '*Effective Life Span*', is defined as "*the period during which weed biomass yield from a mulched treatment differed significantly from that of unmulched treatment*" (Budelman, 1988, a). Thus, *F. congesta*, Mana and Ladappa had shown almost 14, 9 and 5-6 weeks ELS (Prematilake *et al*, 1998). Higher durability of *F. congesta* leaves was attributable for their great tolerance for termites. Hence, *F. congesta* could be exploited as a good source of thatching material. It could be planted on waste lands, fences and vacancies of the tea lands etc. and its shoots could be lopped at every 2 month intervals for thatching in tea fields.

Wild sun flower (Maxican sun flower) (*Tithonia diversifolia*) could also be exploited as a multi-purpose species such as suppression of weed growth, conservation of soil and moisture and improvement of soil nutrients status. The growth of Getakola (*S. hispida*) was suppressed very significantly ($p<0.05$) by mulching with loppings of Mana grass and Wild sun flower after slash weeding, when compared with that of unmulched control and *Eupatorium innulifolium* mulch (Prematilake and Gamage, 2003). Some allelopathic properties of wild sunflower leaves in suppressing seed germination, shoot and root growth, were reported by Tongma *et al* (2001) in Thailand.

Selective weeding and establishment of cover crops

The number of weed species could be considered as desirable (soft weeds) as they do not compete with tea, but they could cover the ground surface while their roots bind the soil colloids together minimizing soil erosion. Thus, they could be left on the field with the practice of selective weeding. Weed species such as *Centella asiatica* (Gotukola), *Desmodium*

Table 2: Weed dry matter production as affected by various mulching materials.

Treatment	Total weed dry weight ($g\ m^{-1}$) Mulching round			Durability of the mulch (weeks)	Effective Life Span [ELS](weeks)
	1	2	3		
Cymbopogon confertiflorus (Mana)	59 ab	42 ab	59 a	18-27	9
Flemingia congesta	47 c	22 b	88 a	24-32	14
Gliricidia sepium (Ladappa)	133 a	78 a	147 a	12-14	5-6
Control	103 a	85 a	85 a	-	-

Source: Prematilake *et al.* (1998)

triflorum (Heen undupiyali), *Drymaria cordata* (Kadala kodi), Oxalis spp (Embul Embiliya), *Euphobia* spp, (Heen dada Keeria), *Lindernia cordifolia*, *Stemodia verticillata*, *Moligo pentaphylla*, *Peparomia pellucida* could thus be considered as soft weeds. Furthermore, species such as *Borreria latifolia*, *B. ocymoides*, which are less competitive at the early stage of growth could also be left on the ground for six-eight weeks, in order to cover the ground and suppress the growth of other weeds (Prematilake, 1997).

Cover crops such as *Arachis pintoii* (Ekanayake, 1996 b), *Desmodium overlifolium* and *Indigofera endocaphyla* could also be established to cover the ground particularly in old tea fields with many vacancies. Weed growth is greatly suppressed by these cover crops as they creep and properly cover the ground (Fig. 2 a, b).

Proper management of low and high shades in tea fields also helps to maintain a healthy and vigorous growth in tea, thereby proper ground cover by tea itself helps to suppress weed growth.

Infilling

Infilling vacant patches with a tea clone which exhibits fast growth, is also important to establish an early ground cover thereby to make a minimum room for weeds. In addition, suitable grasses such as Mana, Guatemala or Vetiver grass (*Vetiveria zizaniodes*) should be planted until such time the vacancies get infilled with tea. The vacant patches which are not suitable for infilling with tea due to shallow soil and those in old tea fields should be planted with a grass as given above or green manure crops such as Wild Sunflower (*Tithonia diversifolia*) or *F. congesta* or cover crops such as *Arachis pintoii* and *Desmodium ovelifolium* in order to cover the ground and to supply loppings for mulching.

Use of double hedgerow system or "SALT" on weed management

Hedgerow system could also be established in new clearing and mature tea fields. With regular lopping of hedgerow species a large volume of biomass could be obtained which helps to suppress weed growth in tea fields. Emphasis should be given in the selection of suitable hedgerow plant species because such species should have more coppicing ability and the durability of leaf materials on soil should be higher. As mentioned above, *F. congesta* is ideal for such purpose as it is highly durable on soil thereby field could be kept weed-free at least for a period of four months (Table 2). Wild sunflower (*T. diversifolia*) could also be planted on hedge rows and lopped branches could be used for thatching the bare ground and ameliorate the soil.

Biological method

Biological weed control is defined as an activity aimed at decreasing the population of a weed to acceptable level by means of a living organism or virus. As far as weeds in tea is concerned, biological control can also be termed as an *Ecological control* since there are a few competitive plant species which can control another weed species by competing with it for one or more growth factors (water, nutrient and light). For instance, Couch grass (*Panicum repens* L.) could be controlled by planting *Brachiaria brizantha* grass together, where growth of couch rhizomes is suppressed due to allelopathy (Ekanayake, 1996 a). In addition, species such as *W. trilobata* (local name: Arunadevi) are naturally controlled by a plant parasite, *Cuscuta chinensis* [local name: Aga mula nethi wela], which grows on the canopy of Wedelia (Prematikale, 2002). *Mikania scandens* (local name: Watupalu) is also partially controlled by the same parasitic plant.

Manual weeding

Manual weeding is the safest method of weed control although it is a costly and strenuous operation when compared to chemical weeding. Manual weeding could be undertaken in two ways, *i.e.* hand pulling alone or by "slash weeding". Hand pulling is the removal of weeds totally by hands. Slash weeding is the removal of weeds by cutting them at the base using a hoe, knife or mechanical weeder. Woody and deep rooted perennial weeds resist removal by hand or to herbicides should be slashed. However, the recovery of growth is faster with this system. Whereas, tools such as "Sorandi" and mammoty should not be used for scraping soil because the use of "Sorandis" was banned in 1951 under a parliamentary act, as it caused severe soil erosion particularly in steep lands. A soil loss of 52 and 40 tonnes ha^{-1} yr^{-1} from one year old clonal tea in the up country and old seedling tea in the mid country, respectively where the land is steep, was reported due to scraper weeding. With scraper weeding, there was also a significant decrease in soil physical and chemical properties with the loss of top soil. Further, the nutrient loss from soil by carrying away of removed weeds is approximately 32, 3.6 and 41 kg $ha^{-1}yr^{-1}$ and 30, 1.8 and 38 kg $ha^{-1}yr^{-1}$ of N, P and K, in clonal tea and seedling tea, respectively (Anonymous, 1991,1992).

All creeping weeds such as Lokapalu (*Mikania scandens*), Heen Madu Wel (*Ipomoea angustifolia*), Morning glory (*Ipoemia learii*), Passali kodi (*Anredera cordifolia*) and *Puraria phaseoloides etc.* which grow over the tea bush should be removed manually.

Weed management in organic tea fields

Weed management in organic tea fields should essentially be an eco-friendly and non-chemical strategy. In other word, all manual, cultural/ecological and biological methods as discussed above could be utilized. Particularly selective weeding, which is more environmentally friendly and economically viable, could be practiced in organic tea fields.

Chemical weeding

Chemical weeding using various herbicides, is the most convenient and effective method among various weed management techniques. In contrast to manual weeding by means of tools, chemical weeding could minimize soil erosion and eliminate loss of plant nutrients, which are carried away with the weeds removed from the fields (Sivapalan, 1983). For more safe and effective use of herbicides, there should be good understanding about the mode of action and properties of herbicides, correct use of herbicides and spraying equipments etc., possible hazards to the crop, human being and the environment *i.e.* soil, water and air, correct time of application and the type of weed spp present in the field and so on.

Current use of herbicides in Tea

Recommendation of herbicides

The TRI, from time to time, makes recommendations on the use of various herbicides. Following herbicide samples are received from the respective company with prior approval of the Registrar of Pesticides (ROP), a series of screening trials are carried out at different tea growing regions. Thus, recommendation of any herbicide is based on the weed controlling efficacy, weed species resistance to the herbicide and the suitability for tea lands in terms of phytotoxicity of the given herbicide on tea and the possible residue level in made tea.

TRI has so far recommended number of herbicides for weed control in tea, accordingly. Those are gramoxone (20% a. i), diuron (80% wp), oxyfluorfen (24% a.i.), 2, 4-D (73% a. i), MCPA 40% & 60%, glyphosate (36% w/v and 41% w/w), glufosinate ammonium (15% a.i.). The choice of the herbicide would largely depend on the weed species present and the current price of the given herbicide.

Some issues related to herbicide use

As far as the herbicide use in tea cultivation is concerned, resorting to a single herbicide rather than application of different herbicides in rotation is becoming a major threat to our tea industry. Under the present financial crisis that has been faced by some plantation companies they have been compelled to use a single herbicide.

The regular use of a single herbicide over the years, at a rate of 4-5 rounds/year has resulted in reduced plant growth and lower yield of tea, compared to untreated control due to phytotoxic effects on tea (Table 3). Thus, the manifestation of adverse effects on the growth and productivity of tea is seen to be on the increase. Other major issue is the possible risk of development of resistance in some weeds for herbicides which are applied on regular basis. Unavailability of range of selective herbicides and high cost of suitable herbicides may be another reasons for depending on a single herbicide.

Phytotoxicity in tea

Glyphosate, a broad spectrum, non-selective and translocated herbicide, which is available in the market under different trade names, has been indiscriminately used for the control of weeds particularly in tea estates of the corporate sector. Thus, herbicide drifts which come into contact with tea leaves have resulted in chlorosis, browning in leaf, enhanced leaf senescence, leaf wilting, rosetting, multiple bud formation, deformed leaves and defoliation particularly with higher dosages (Ekanayake & Prematilake, Per. Commun; Prematilake, 1997).

Risk of accumulation of residues in made tea

Glyphosate 36% [N-(Phosphonomethyl) Glycine] was initially recommended mainly for the control of Couch grass in tea fields as a 2% {1 l in 50 l of water} solution and later the lower rates of application (0.25-0.5%) to control a broad-spectrum of weeds. Investigations on residue analysis have shown that the amount of glyphosate present in the end product (black tea) is above the Maximum Residual Limit (MRL) of 0.5 ppm, when tea was harvested 7 days after application (DAA) of glyphosate at the rate of 0.5%-2.0% (i.e 2.8-11 litres in 550 l of water).

Table 3: Effect of different methods of weed management on the growth and yield of tea.

Treatment	Made tea yield (kg MT ha^{-1})		Girth at the base (cm)	Pruning weight (mt ha^{-1})	Tipping weight (mt ha^{-1})
	Annual^{+}	Cycle*			
T1 MW every month	3657 a	3380 a	18.1 a	12.0 a	1.59 a
T2 MW every 2 months	3307 ab	3136 ab	17.4 b	11.6 ab	1.50 ab
T3 MW every 3 months	3206 abc	3146 ab	16.7 bc	11.0 abc	1.48 ab
T4 CW-paraquat (1.1 l ha^{-1})	3151 abc	2987 b	16.2 cd	10.8 abc	1.32 bc
T5 CW-glyphosate (1.7 l ha^{-1})	2673 cd	2920 b	15.5 e	9.2 cd	1.12 cd
T6 CW-sulphosate (1.7 l ha^{-1})	2626 cd	2800 b	15.2 e	8.0 d	0.95 d
T7 CW-paraquat (1.1 l ha^{-1}) + 2, 4-D (1.5 kg ha^{-1})	3163 abc	3086 ab	16.2 cd	10.1abcd	1.37 abc
T8 CW- paraquat (1.1 l ha^{-1})+ 2, 4-D (1.5 kg ha^{-1}) + diuron (1.2 kg ha^{-1})	2573 d	2904 b	15.5 de	9.4 abc	1.33 abc
T9 Slash weeding	2735 bcd	3150 ab	17.0 b	9.9 abcd	1.44 ab

MW= Manual weeding, CW= Chemical weeding, + Total of 5th year * Cycle average
Souce: Anonymous (2001)

However, residues were not detected when tea was harvested 14 DAA. Whereas, glyphosate residues were not detected at all when the rate of glyphosate was below 0.5% (Anonymous, 1995, '96, Ekanayake and Prematilake, Personal Communication).

Risk of development of resistance in some weeds

The risk of development of resistance in some weeds for any herbicide, which is regularly applied on weeds, has become a serious issue. Marambe *et al* (2002 & 2003) proved that *Erigeron sumatrensis* and *Crassocephalum crepidiodes* found in the upcountry tea growing area that has been exposed to paraquat for the last two decades has developed resistance to paraquat. Hence, it is more appropriate to use different herbicides in rotation with other weed management techniques in order to avoid such incidence of resistance development.

Weed shift and increasing trend on the outbreak of Problem weeds

Passali kody (*Anredera cordifolia*): Passali kody has alarmed the tea plantations at higher elevation of above 1000 m, in the districts of Nuwara Eliya, Badulla and it has moderately infested in the mid country tea lands as it prefers the cooler climate. Further, weed is tolerant for many of the herbicides and it grows climbing through the tea bush thereby weed has been escaped having more chances to widespread within tea crop. Due to the aggressive growth of Passali kody through the tea bushtea growth is adversely affected and plucking is interrupted. Thus, consequences of high cost of weeding and lowering of the plucking efficiency are in turn the high cost of production of made tea. The weed is mainly propagated by bulbils like vegetative propagules, which are produced on each node of the stem. These bulbils drop off at mature phase and start to germinate very rapidly on the litter with the onset of rains.

The weed species such as *Caladium hortulanum* (fancy-leaved Habarala) and *C. humboldtii* (white colored leaves), *Syngonium podophyllum* (Wel kohila) in low-grown tea have raised their heads in the areas such as Ratnapura, Kahawatte, Nivitigala, Horana and Kalutara. This is also due to escape of the weeds after herbicide application as a result of some morphological characteristics such as waxy cuticular layer of leaves.

Spermacoce hispida (Getakola) and other related species of Hedyotis in up and mid-grown tea have been widespread as they found to be partially resistance to the recommended dosages of glyphosate herbicide i. e 1.7-2.8 l ha in 550 l of water or 0.3-0.5%. This may be due to its morphological characteristics such as semi woody stem and coarse leaves at mature phase. Thus, the emergence of such weeds may presumably be due to the regular use of glyphosate as the weed gets more favourable conditions for proliferation and spread in the absence of any other common weeds. Further, manual removal of such weed species is really an arduous and laborious task. Weed is also spread very fast due to its high fecundity rate. As a result, Getakola weed has been invaded in all vacant patches of old tea fields and abandoned lands, road sides in the up and mid country and some of the tea lands in the low country (Prematilake and Gamage, 2002).

Commelina species (Paccha Amalai): A new *Commelina* spp has been reported in the upcountry estate at 1800 m AMSL from very recently. The stem and pale green leaves of the weed are more succulent. It grows very aggressively covering the primary frame of the tea bush. If not control at this stage its shoots climb through the tea bush and cover the tea canopy. It was not able to identify the species name yet as the weed starts to flower occasionally. The weed is readily propagated by its vegetative cuttings. The danger is that the workers, who collect the weed, are used to carry them away to feed their livestock and to use them for compost making incorporating with cow dung. With such practice some weeds could escape and spread very fast as they do not pay proper attention to avoid such threat (Prematilake, personal communication). Special investigations using various cocktail mixtures of herbicides and surfactants are now underway to mitigate this weed menace.

Arunadevi (*Wedelia trilobata*): Although Arunadevi has been introduced to lands as a cover crop it has now been widespread not only in tea growing areas but also in none-tea areas of the other districts. Moreover, it is spreading everywhere invading the other weeds floras (Prematilake, 2002). Therefore, the Ministry of forestry and environment has named Arunadevi as an invasive weed in Sri Lanka in 1999.

Management of problem weeds

Preventive measures

Adoption of preventive measures is the most appropriate method to manage problem weeds. The dissemination of Passali kody, new *Commelina* spp, *Caladium* spp and *Syngonium* spp and Arunadevi could largely be avoided through suspension of addition of compost or any litter to affected fields for few years, careful handling of removed yams or rhizomes or viable stems until they completely decay. Transporting of such materials to the unaffected areas from affected tea fields should also be banned. Although a costly operation, the only possible way to properly manage these weeds is to collect the bulbils/yams etc. from the litter on the ground and top soil layer. For passali and Commelina spp, this is an arduous job when the ground is fully covered by the tea canopy. Whereas, removal of passali bulbils can be undertaken more easily soon after pruning since many bulbils are visible with exposure of the ground and primary frame of tea bush (Prematilake, 2002). However, the most appropriate and safest way to manage such weeds is through a biological control agents, yet the information on this line of investigation are still lacking.

The spread of Getakola weed could be prevented by the use of herbicides at early stage of growth i.e before the weed becomes mature. Furthermore, infilling all vacant patches in tea fields with tea or another cover crop or green manure crop without delay will provide no room for Getakola. Also the maintenance of road sides, abandoned areas so on with free of weeds is another strategy to avoid the seed production thereby the weed (Prematilake and Ekanayake, *in press*).

Chemical methods

Management of above problematic or "hard-to-kill weeds" by manual methods or by normally recommended herbicides alone is a difficult task. As such an integrated approach would be more successful. In the case of usage of higher dosages of herbicides or their cocktail mixtures, there could be some phytotoxic effects in tea and contamination of made tea with herbicide residues. Therefore, some special precautions have to be followed as given below to minimise such adverse effects in tea.

- Such weeds should be treated in isolation as spot application.
- Use of a spray guard and a correct nozzle with a narrow swath is also important.
- If the weed is found within tea block plucking should be delayed at least for 2 weeks
- For Passali kody the use of some herbicides is possible only during seedling stage as they later climb through the tea bush to which herbicides cannot be applied without affecting the tea bush.
- Those weeds which grow over the tea bushes should not be treated with chemicals and they should be removed manually.

The higher dosages of glyphosate or gramoxone based cocktail mixtures in combination with Diuron, MCPA or 2,4-D and some surfactants have been found to be effective for the management of Caladium, Wel kohila and new *Commelina* spp and Getakola weeds.

Some integrated methods could also be practised to manage Getakola. Slash weeding followed by mulching with various materials such as Mana, Wild sun flower, *F. congesta* and use of herbicides incorporated with different tank-mixed surfactants or additives or cocktail mixtures of two herbicides could be used for successful control of Getakola (Prematilake and Gamage, 2002). However, the

application of mulches and the use of cocktail mixtures at mature phase of the weed cannot be afforded by many estates due to the unavailability of materials, high cost of labour and herbicides. Therefore, it is more appropriate to encourage planters at least to apply herbicides incorporated with surfactants at tender phase of Getakola.

Special precautions to be followed for safe and effective use of herbicides (Anonymous, 2003)

- Avoid use of contact or translocated (Systemic) herbicide on new clearing or young tea fields or during first 6 months after pruning in order to protect young tea shoots from phytotoxicity of herbicide.
- Use clean water to prepare herbicide spray solution.
- Minimize the number of applications of a single herbicide per annum (preferably twice per year). Also use a range of herbicides together with other cultural and manual methods in rotation without resorting to a single herbicide in order to avoid the risk of build-up of resistant weed species. Particularly, glyphosate should only be applied twice per year.
- Pre-emergence herbicides such as oxyfluorfen and diuron should be applied when the soil is bare and fairly moist i.e. before thatching.
- Use a knapsack sprayer after fixing a *polijet nozzle*, which produce quite larger droplets under a low pressure (1 Bar =14 psi) and use a spray guard to avoid spray drift coming in contact with tea branches.
- Creepers which grow over the tea bush should not be sprayed.
- Careful supervision of the entire operation is very necessary to make a success of chemical weed control. Training of supervisors and spray gangs for correct handling of equipments and herbicides.
- The decision making on the selection of aforesaid weed management techniques is based upon the cost factor, impact on the soil and environment and possible risk for the resistance development in weeds for herbicides. The climatic and weather pattern of a given area should also be taken in to account in the formulation of such programme.

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