Field Trials for Controlling Mikania Infestation in Forest Plantations and Natural Forests in Kerala

(Final Report of the Research Project KFRI 333/'99)

K.V. Sankaran
R.C. Pandalai

Kerala Forest Research Institute
An Institution of Kerala State Council for Science, Technology and Environment (KSCSTE)
Peechi - 680 653, Kerala, India

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K.V. Sankaran
Forest Protection Division

R.C. Pandalai
SNPFM Division

KFRI

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Abstract of the project proposal

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Abstract

Mikania micrantha H.B.K. (mikania), the perennial invasive weed of neotropical origin, is a menace in natural forests, forest plantations and agricultural systems in Kerala. The apparent negative impacts of the weed include reduction in yield of subsistence and cash crops, loss of native biodiversity and prevention of forest regeneration. An ecological survey conducted during 1999-2002 in the State revealed that the weed is widespread in Kerala and is still expanding its range. The spread of the weed to the neighbouring States, where it is currently absent, appears imminent.

A total of 402 different localities (including natural forests, forest plantations and agricultural systems) were surveyed in Kerala for the occurrence and severity of infestation by the weed. Of these, 244 (61%) were with various levels of infestation. The invasion was the most severe in the central zone of the State (72%) compared to southern, northern and high range zones. Spread of the weed was observed in all the districts except Kasaragod. The survey showed that mikania infested sites were more in the moist deciduous forests (64%) compared to evergreen (54%) and semi-evergreen forests (58%). Shola forests and grasslands were free from infestation.

Of the forest plantations surveyed, teak had the maximum number of plantations infested (78%). Young (1-to 3-yr-old) plantations of teak were particularly heavily affected. In agricultural systems, although 65 per cent of the surveyed sites were infested, only a few were severely affected. The major agricultural crops susceptible to the weed were pineapple, banana, coconut, cassava and ginger. The survey also revealed that highly disturbed forests are more prone to invasion than undisturbed/less disturbed. In evergreen forests, where canopy is more or less closed, infestation was either absent or scarce.

Herbicidal trials to control mikania were carried out in plantations of teak and eucalypt and a natural reed growing area. Of the herbicides tested, triclopyr + picloram @ 1.75 – 3.5 l/ha and triclopyr @ 0.5 – 1 l/ha showed the highest weed control efficacy (WCE) compared to the other herbicides. Glyphosate @ 2.5 – 5 l/ha and diuron @ 1 – 1.5 kg/ha were also effective in controlling the weed. Since the former two herbicides are not yet available in the Indian market, use of glyphosate or diuron at the given concentrations is recommended for mikania control in forest plantations and natural reed growing areas in the State. The herbicidal applications need preferably be done before flowering/seed setting stage of the weed (August-September) for maximum efficacy. Though a single application of either of the herbicides will provide long-term control of the weed, repeated yearly applications may be necessary wherever re- invasion is a problem through wind-borne seeds.

The efficacy of paraquat and 2,4-D is apparently short-lived and hence may not be suitable for control of mikania. Also, animal toxicity of 2,4-D and its long and persistent residual action preclude use in any environment. Addition of adjuvants viz., ammonium sulphate and urea improved WCE of both glyphosate and diuron. Likewise, combinations of glyphosate/ paraquat/diuron exhibited higher WCE

compared to application of each herbicide individually.

Mechanical weeding (knife weeding) of mikania in forest plantations and natural forest areas is more labour intensive and expensive compared to a single application of the recommended herbicides. However, it is cautioned that continuous use of herbicides in any ecosystem is environmentally hazardous and may cause toxicity if used in food crops. Hence, the suggested herbicides may only be used as a short-term measure until alternative cost-effective and eco-friendly methods for mikania control are developed. Great caution is also warranted while using the herbicides; application may be avoided near settlements, cattle grazing areas and water bodies.

1. Introduction

Invasion by exotic weeds has been identified as one of the greatest threats to biodiversity around the globe (Singh, 2001). Due to their inherent efficacy in nutrient uptake and use, weeds easily invade degraded and disturbed lands adversely affecting ecosystems. The negative impacts of weeds include competition with indigenous flora and fauna, changes in nutrient cycling and hydrology and damage to agricultural and forestry crops. Some of the world's worst weeds have been present in India for over a century. Of these, *Lantana camara* L., *Chromolaena odorata* (L.) K.&R., *Parthenium hysterophorus* L., *Eichhornia crassipes* (C. Martius) Solms-Laub. and *Salvinia molesta* D. Mitch., are ill-reputed for their adverse effect on various crop plants and ecosystems. *Mikania micrantha* H.B.K. (common name- mikania) happens to be one of the most recent additions to this group. It is a fast growing perennial creeper belonging to the family Asteraceae. Mikania is commonly called 'mile-a-minute weed' because of the exceptionally fast growth rate and spreading nature (Choudhury, 1972).

The native range of mikania lies in the tropical and sub-tropical zones of north, central and south America (Holm *et al.*, 1977). Though, it is only of minor importance as a weed in its native habitats, outside these, mikania can rapidly produce huge amount of biomass and smother even large trees, which results in significant loss in natural forests, plantations and agricultural systems (Sankaran *et al.*, 2001). Mikania is currently considered as a major menace in the moist tropical zones of south and south-east Asia and the Pacific where the weed is still expanding its range (Waterhouse, 1994).

Mikania has vigorous vegetative and sexual reproductive capacity (Saxena and Ramakrishnan, 1984). Seeds are dispersed over long distances by wind and the plant can grow vegetatively from the nodes and very small segments of the stem (Holm *et al.*, 1977). Growth of young plant is extremely fast (8-9 cm in 24 h). Areas free from the weed get colonized within a few days through wind borne seeds (Choudhury, 1972).

Mikania is reported to be intentionally introduced into north-eastern India during the Second World War as a ground cover for tea plantations (Parker, 1972). Thereafter, it got spread very fast increasing the range particularly in the moist tropical zones of south-west and north-east India (Choudhury, 1972; Muniappan and Viraktamath, 1993; Sankaran *et al.*, 2001). In Kerala, the occurrence of mikania was first recorded in 1968 in a rubber plantation in Kottayam District (Nair, 1968). It has emerged as a major problem in natural forests and plantations in the 1980's. Infestation by mikania causes significant loss in teak (*Tectona grandis* L.), eucalypts (*Eucalyptus tereticornis* Sm.), *Ailanthus triphysa* (Dennst.) Alston and *Acacia auriculiformis* Cunn. Ex G. Don. plantations in the State (Sankaran *et al.*, 2001). It is also a big menace in commercial and homestead crops like tea (*Camellia sinensis* (L.) Kuntze), coffee (*Coffea arabica* L.), pineapple (*Ananas comosus* (L.) Merr.), banana (*Musa paradisiaca* L.) and ginger (*Zingiber officinale* Roscoe) (Sankaran and Sreenivasan, 2001). Invasion of natural forests is known from south-west and north-east India (Sen Sarma and Mishra, 1986 ; Sankaran *et al.*, 2001).

The harmful effects of mikania on soil properties and crop yield are well-known (Watson *et al.*, 1964). Since the weed can smother, penetrate crowns, choke and pull over plants it is considered as one of the worst enemies of crop plants. Reduction in the yield of rubber (*Hevea brasiliensis* (A. Juss.) Muell.), oil palm (*Elaeis guinensis* Jacq.) and cacao (*Theobroma cacao* L.) plantations due to mikania invasion is reported from Malaysia (Watson *et al.*, 1964). In Kerala, mikania infestation causes both cost escalation and income reduction in forest plantations and agricultural systems (Sankaran *et al.*, 2001). In Indonesia, coconut (*Cocoa nucifera* L.), rubber, teak and pine plantations are under threat due to mikania (Suharti and Sudjud, 1978). Apart from the adverse effect on crop yield, mikania makes harvesting cumbersome due to its twining and creeping habit. For example, in natural forests of Kerala, harvesting of non- wood forest products like reeds has been more labour intensive due to the weed which has negatively impacted on the livelihood of tribal people in the forests (Sankaran *et al.*, 2001).

Control of mikania in India and elsewhere was attempted from time to time using cultural, mechanical, biological and chemical methods (Murphy, 2001). Sickle weeding, uprooting and digging were some of the mechanical methods used. These were, however, labour intensive, expensive and effective only for a short duration (Sen Sharma and Mishra, 1986). Likewise, cultural control, which is widely practiced in north-east India, is also ineffective and uneconomical (Gogoi, 2001). Chemical control based on 2,4-D compounds was attempted in several countries including Malaysia and Indonesia but with inconsistent results (Suharti and Sudjud, 1978; Palit, 1981; Teoh *et al.*, 1985). Glyphosate was found effective in a good number of cases but its high cost and non-selectivity have restricted wider use (Hee *et al.*, 1993; Ipor and Price, 1994; Gogoi, 2001). Contact herbicides like Paraquat provide short-term control but vigorous re-growth was observed after a few months of application (Seth, 1971; Lam *et al.*, 1993). In short, none of these methods has resulted in any substantial impact on either the distribution or abundance of mikania in India or other countries.

Biological control of mikania was attempted in Solomon Islands and Malaysia using a natural insect enemy viz., *Liothrips mikaniae* (Priesner) (Thysanoptera, Phlacothripidae) (Cock *et al.*, 1999). But, unfortunately, successful establishment of the insect was not achieved apparently due to predation. A number of fungal pathogens of mikania with potential for biocontrol have been recorded by Barreto and Evans (1995) from Brazil. In Kerala, the insect *Spilosoma oblique* (Diacrisia), tea mosquitoes, certain aphids, mealy bugs and jassids are reported as natural enemies of the weed (KAU, 1993). But, the damage due to these herbivores appeared negligible. Likewise, although 10 fungal pathogens have been recorded on mikania from Kerala, none appears to have the potential for bio-control (Sreenivasan and Sankaran, 2001). Recent studies by Ellison (2001) proved that a highly damaging, microcyclic, auteocious rust viz., *Puccinia spegazzinii* De Toni which occurs naturally in the neotropics has great potential as a biological control agent against mikania. Its efficacy against the weed is being tested and attempts are currently underway to introduce it into north-east and south-west India. However, the fungus, if successfully introduced, is sure to take a few years before showing any impact on the distribution and spread of mikania. It is in this context that the present project was envisaged. It is aimed at (a) assessing the distribution, spread and severity of infestation of mikania in various ecosystems in the State of Kerala, and (b) developing, in the short-term, chemical methods to control mikania infestation in forest plantations and natural forests in the State.

2. Materials and Methods

2.1. Study area

Kerala State is situated in the south-western part of Peninsular India between 8°18′ and 12°48′ North latitude and between 74°52′ and 77°22′ East longitude. The State is sprawled over an area of 38,863 km^2. Of this, about 9,400 km^2 constitutes either natural forests or forest plantations (Forest Statistics, Kerala Forest Department, 2000). Natural forests in the State occupy an area of 7,609 km^2. The major types of natural forests are southern tropical wet evergreen and semi-evergreen (3,299 km^2), southern tropical moist deciduous (4,100 km^2), tropical dry deciduous (100km^2) and montane subtropical (70 km^2). Teak (760 km^2), eucalypt (245 km^2) and acacia are the important species grown under plantations in the State. The agricultural cropping pattern of the State varies with different physiographic zones due to differences in water availability, soil properties, climatic conditions, etc. In the high altitude areas, coffee, tea and cardamom are the principal crops. The midland area is an intensive cultivation zone of cashew, coconut, areca, paddy, ginger, black pepper and vegetables. Coconut, paddy and areca are the major crops in low land areas.

On the basis of topographic and physiographic features, the State can be divided into four major zones viz., southern, central, northern and high altitude zones (Sankar and Chandrashekara, 2002) (Fig.1). The southern zone includes five districts viz., Kollam, Thiruvananthapuram, Kottayam, Pathanamthitta and Alappuzha. Ernakulam, Thrissur and part of Palakkad district form the central zone. Malappuram, Kozhikode, Kannur and Kasaragod districts constitute the northern zone. The high altitudinal region (700-2695 m asl) includes Wayanad, Idukki and part of Palakkad district.

2.2. Climate

The State has a tropical, warm, humid monsoonal climate. There are two main monsoons, the south-west (June-September) and the north-east (October- January). The summer season is from March to May. The average rainfall is 3,000 mm (ranges from 2,200-3,600 mm) spread over 120 rainy days. Mean atmospheric temperature is 27°C and relative humidity ranges between 64 (February-March) and 93 per cent (June-July), (Menon and Rajan, 1989).

2.3. Survey for the occurrence and distribution of mikania in Kerala

Comprehensive ecological surveys for the distribution of mikania were carried out in all the districts of the State during 1999-2002. Simple random sample survey method was used in the study. Within each district, sites were chosen at random to represent natural forest areas, forest plantations and agricultural systems at different eco-climatic regions and altitudes (Table 1). The number of localities surveyed under each category (natural forests and plantations) was based on the proportion of area available under each in the State. At each locality, a 100 m x 100 m (1 ha) plot was selected at random and 10m x 10 m grids were marked. In each grid, five, 1m x 1m quadrats were laid randomly and number of individual mikania plants (stalks) enumerated. Mean number of stalks in the quadrats was worked out and total number/ha estimated from this data. These were assigned a grade based on

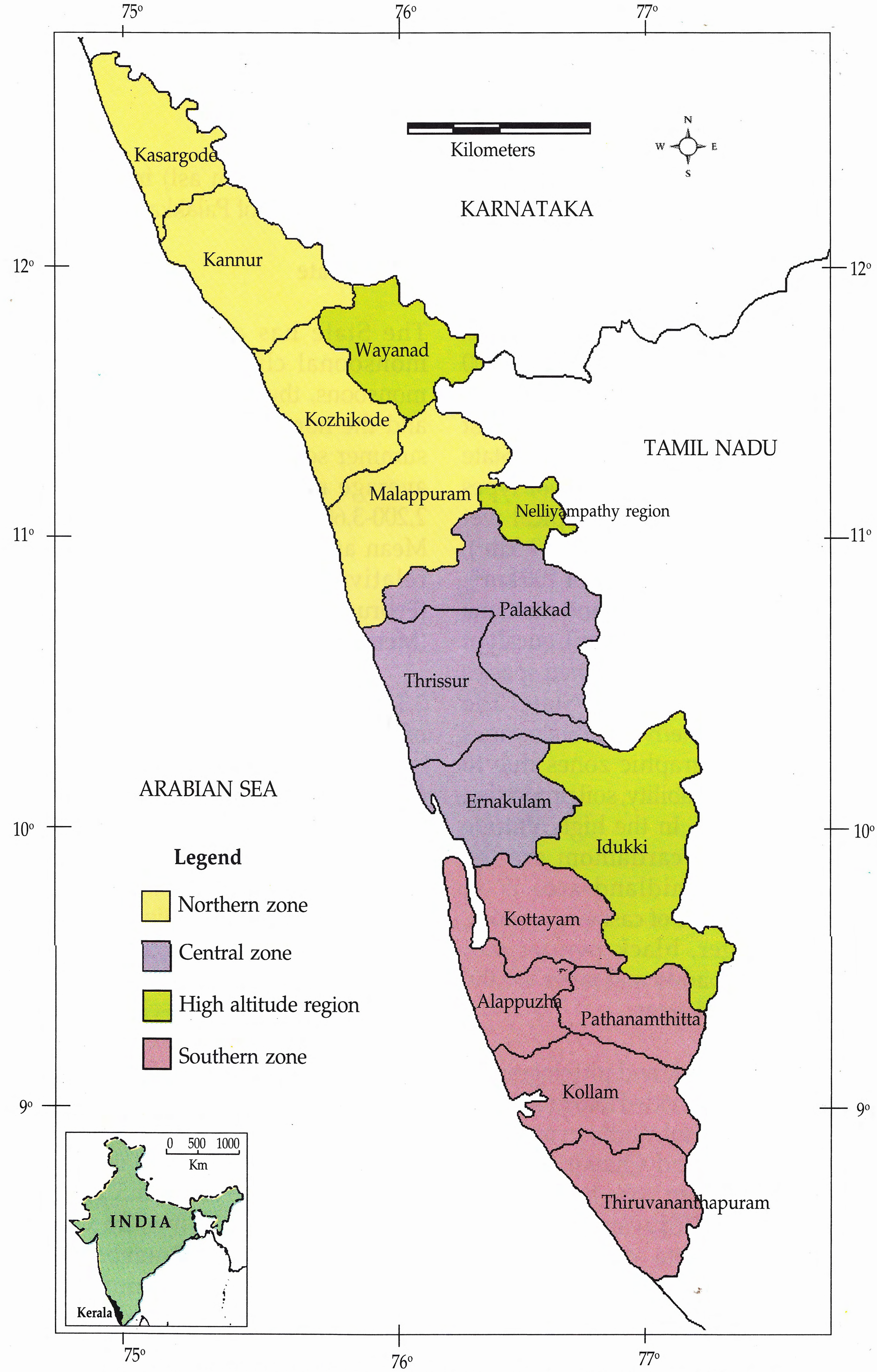

Fig. 1. Kerala State- North, Central, South and High altitude (roughly) zones

the number of stalks per ha and intensity of infestation noted (Table 2). The characteristics of the sites like altitude, availability of water (any water bodies nearby), disturbance (different grades), etc. were recoded. The total number of localities surveyed for the distribution of mikania during the tenure of this project was 288 (Appendix 1). Data from 114 localities surveyed earlier under another study (Sankaran *et al.*, 2001) were also added to the present data (total number of sites 402) for a better understanding of the distribution and spread of mikania in the State.

2.3.1. Monitoring natural spread of mikania within the State

To assess the natural spread of mikania in the northern parts of Kerala, 1000 m long x 10 m wide permanent transects (10 numbers of 100 m x 10 m continuous quadrats) were laid in the southern and northern banks of the Valapattanam River and its tributary, the Koottupuzha River during 1999-2000 and 2000-2001. These sites were selected because in the previous survey (1997-1999) it was found that the distribution of the weed was restricted to the southern banks of these two rivers. Biomass samples were collected from the transects each year using 3, 1 m x 1 m quadrats laid at random at 100 m interval along each transect. The samples were dried at 70° C for 48 h and oven dry weight (kg/ ha) determined.

Table 1. Number of localities surveyed for mikania infestation in Kerala

Production System		Number of localities surveyed
Natural forest	Moist deciduous forest	87
	Evergreen	24
	Semi-evergreen	31
	Shola	18
	Grassland	21
	Dry deciduous	5
Plantation	Teak	37
	Eucalyptus	42
	Miscellaneous (*Acacia*, *Albizia*, *Casuarina*, etc.)	32
Agricultural system (Coconut, banana, areca nut, cassava, pineapple, etc.)		66
Non-production systems (roadside, dam site, etc.)		39
Total localities surveyed		402

Table 2. Severity scale for quantification of level of infestation by mikania

No. of stalks of mikania per ha	Level (grade)
0	Not present (-)
1- 100	Isolated (0)
101 - 250	Scattered (1)
251 - 500	Low (2)
501 - 750	Moderate (3)
751 - 1,000	Medium (4)
>1,000	High (5)

2.3.2. Survey for the distribution of mikania in degraded/disturbed forests

Degree of disturbance in each forest ecosystem was graded based on visual methods (Rapoport, 1991) and an arbitrary i to v scale depicting level of disturbance was developed (Table 3). Surveys were conducted for mikania infestation in these forests (Table 1) as per the methodology described in 2.3. to make out whether degradation of the forests influenced mikania infestation.

2.4. Herbicidal trials to control mikania infestation in forest plantations and natural reed growing areas

2.4.1. Study sites

The sites used for herbicidal applications are given in Table 4. These sites were heavily

Table 3. Disturbance regimes in the forest ecosystems

Disturbance	Main cause of disturbance	Level of disturbance
>75	Areas clearfelled, high level of Non-Wood Forest Products (NWFP) gathering, grazing and browsing	v
50–75	Area selection felled, NWFP gathering, grazing and browsing at medium level	iv
25–50	NWFP gathering and small scale grazing and browsing	iii
1-25	Only NWFP gathering	ii
Undisturbed	No major external interventions	i

infested by mikania at the time of the herbicidal trials.

2.4.2. Selection of herbicides

Six herbicides namely, (1) glyphosate (trade name Roundup, Glycel) (2) triclopyr (Garlon 600), (3) triclopyr + picloram (Grazon DS), (4) 2,4-D (Fernoxone), (5) diuron (Klass) and (6) Paraquat (Gramoxone) were used in the study (Table 5).

Table 4. Localities of herbicidal trials

Forest Division	Forest Range	Locality	Species & age of plantation (yr)	Date of herbicidal application
1. Vazhachal	Kollathirumedu	Thavalakkuzhippara	Teak (5)	9 Nov. 2000
2. Vazhachal	Kollathirumedu	Choozhimedu	Reed	11 Nov. 2000
3. Malayattoor	Kuttampuzha	Kottappara (1)	*Eucalyptus tereticornis* (7)	6 Nov. 2000
4. Malayattoor	Kuttampuzha	Kottappara (2)	-do- (7)	3 Jan. 2002
5. Vazhachal	Kollathirumedu	Pothupara	Teak (7)	10 Feb. 2002
6. Malayattoor	Kuttampuzha	Kottappara (3)	*E.tereticornis* (7)	1 Sep. 2002

2.4.3. Application of herbicides

In all cases, plots for herbicidal application were laid down in a completely randomized block design. Each plot was 10 m x 10 m in size separated from the adjacent by a 0.5 m wide strip. Each treatment (different concentration of herbicides, herbicides added with adjuvants and combination of herbicides) and respective controls were replicated thrice. The concentration of herbicides and adjuvants are given in Tables 6-9.

The specific concentration and quantity of herbicides (in 5 l water per plot) was sprayed evenly in individual plots using compressed system knapsack sprayers (Aspee, India) fitted with high volume flood jet nozzles (Figure 2). Low volume sprays were not attempted since our previous studies have indicated that these were not as effective as high volume sprays. The surfactant Plantowet was added (1 ml/l of herbicide) in all treatments as a sticker to reduce washing off of the herbicides in dew or rain. During the spray, care was taken to cover the entire growth of mikania with the herbicide and avoid the herbicide falling on the leaves

Table 5. Herbicides used for mikania control in forest plantations and natural reed growing areas

1. Gyphosate	
Chemical name	N-(Phosphonomethyl) glycine
Chemical family	Phosphate compounds
Trade name	Roundup (Monsanto), Glycel (Excel)
Type	Post-emergence, non selective and systemic
Active ingredient	41%; 68% (Glycel)
LD_{50}	4,320 mg/kg
Visible symptoms	Appeared after 7-15 days; wilting, browning and defoliation
2. Triclopyr	
Chemical name	Triclopyr (3,5,6 tricloro-2-pyridloxyacetic acid)
Chemical family	Phenoxy compound
Trade name	Garlon 600
Type	Selective, systemic, pre/post emergence
Active ingredient	86%
LD_{50}	375 mg/kg
Visible symptoms	Appeared after 7 days; desiccation, browning and defoliation
3. Triclopyr + Picloram	
Chemical name	Triclopyr (3,5,6 trichloro-2-pyridyloxyacetic acid) + Picloram (4- amino-3,5,6-trichloropyridine-2-carboxylic acid)
Chemical family	Heterocyclic nitrogen derivatives and phenoxy compounds
Trade name	Grazon DS
Type	Selective, systemic
Active ingredient	42.8% + 19.2%
LD_{50}	4,568 mg/kg
Visible symptoms	Appeared after 7 days; desiccation, browning and defoliation
4. 2,4-D	
Chemical name	2-4-Dichlorophenoxy acetic acid
Chemical family	Phenoxy compound
Trade name	Fernoxone
Type	Non selective, post/pre-emergence, systemic
Active ingredient	80%
LD_{50}	375 mg/kg
Visible symptoms	Appeared after 9 days; yellowing and weathering
5. Diuron	
Chemical name	3-(3,4-dichlorophenyl)-1, 1-dimethyl urea
Chemical family	Urea compound
Trade name	Klass
Type	Selective, pre-post emergence, systemic
Active ingredient	80%
Visible symptoms	Appeared after the 6th day – desiccation and weathering
6. Paraquat	
Chemical name	1,1-Dimethyl-4, 4-bipyridinium dichloride
Chemical family	Heterocyclic nitrogen derivatives
Trade name	Gramoxone
Type	Non selective contact and pre-emergence
Active ingredient	29.1%
Visible symptoms	Appeared after second day, chlorosis and weathering

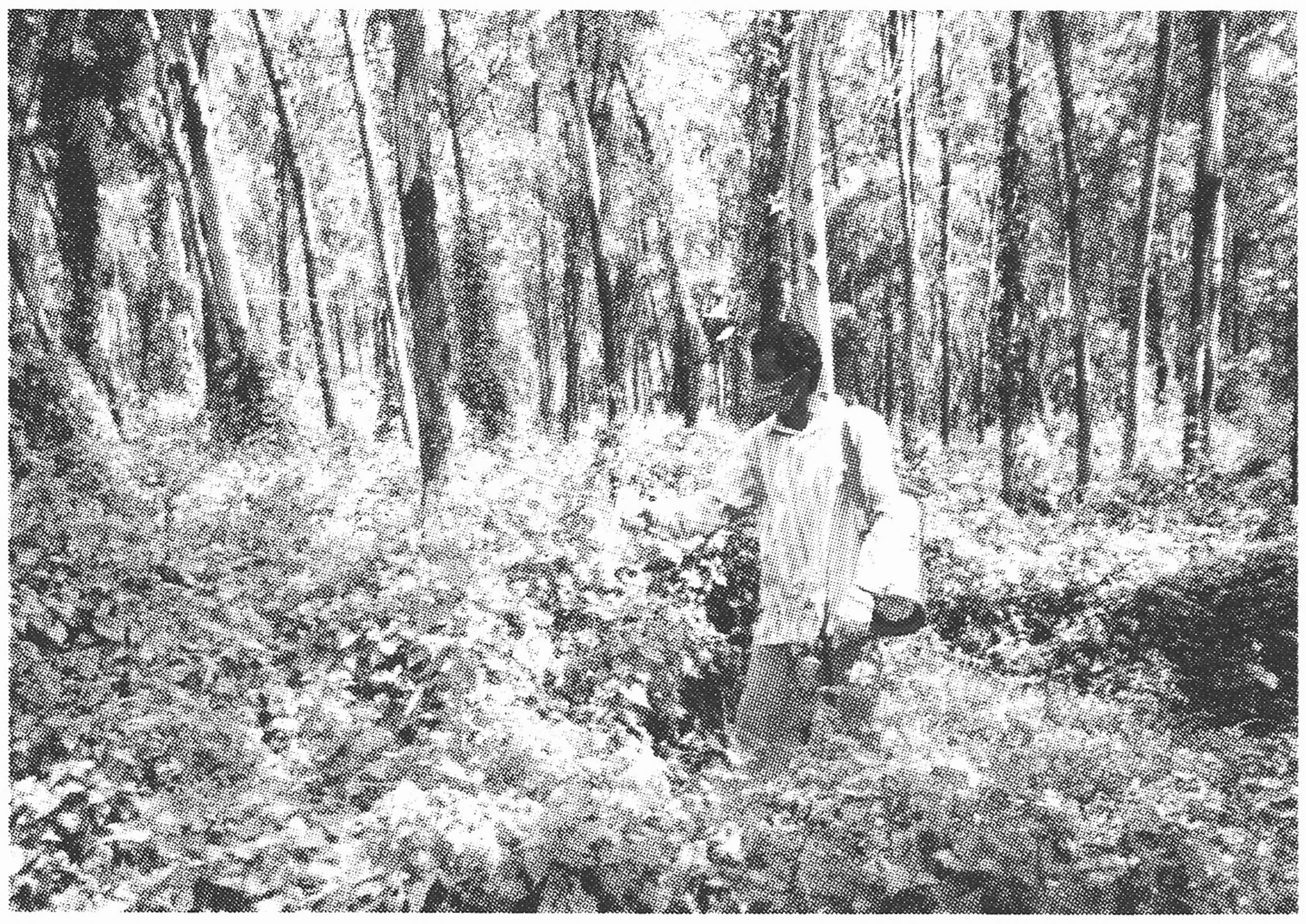

Fig. 2. Herbicidal spray using knapsack sprayers

of the plantation species. Unsprayed plots and plots sprayed with herbicides without adjuvants served as control.

Spraying trials were carried out during pre-flowering (September) and post flowering (November) stage of the weed and during early summer (January-February) when mikania starts drying up. The efficacy of each treatment was determined by estimating biomass of the weed at periodic intervals (30, 60, 120, 180, 240 and 300 days after the spray). Biomass was collected from three, 1m x 1m quadrats from each plot at each collection time and dried in a hot air oven at 70° C for 48 h and dry weight (kg/ha) determined. Using this data, weed control efficacy-WCE (% reduction of biomass of the weed over control) of each herbicide concentrations was assessed.

2.5. Statistical analyses

Chi-square test (SPSS Version 6) was used to test the significance of differences in the distribution of mikania in different ecosystems and disturbance regimes. Efficacy of various herbicides and their concentrations in controlling mikania was compared using Duncan's Multiple Range Test (DMRT).

Table 6. Concentration of different herbicides used at Thavalakkuzhippara (teak), Choozhimdeu (reed) and Kottappara (eucalypt) during November 2000

Herbicides	Concentration of herbicides/l of water		
	I	II	III
Triclopyr +Picloram	3.5 ml (1.75 l/ha)*	7 ml (3.5 l/ha)	10.5 ml (7 l/ha)
Triclopyr	1 ml (500 ml/ha)	2 ml (1 l/ha)	4 ml (2 l/ha)
Diuron	2 g (1 kg/ha)	3 g (1.5 kg/ha)	4 g (2 kg/ha)
Glyphosate	5 ml (2.5 l/ha)	10 ml (5 l/ha)	20 ml (10 l/ha)
2,4-D	1 g (500 g/ha)	2 g (1 kg/ha)	3 g (1.5 kg/ha)
Paraquat	2 ml (1 l/ha)	4 ml (2 l/ha)	6 ml (3 l/ha)

*High volume spray applied at the rate of 5 l (water + herbicide) per 10 x 10 m plot.

Table 7a. Concentration of herbicides used at Kottappara eucalypt plantation (2)

Herbicides	Concentration of herbicides/l of water (amount/ha in parentheses)		
	I	II	III
Diuron	2 g (1 kg/ha)*	10 g (5 kg/ha)	20 g (10 kg/ha)
Glyphosate (Roundup)	7.5 ml (3.75 l/ha)	12.5 ml (6.25 l/ha)	15 ml (7.5 l/ha)
Glyphosate (Glycel)	5 ml (2.5 l/ha)	7.5 ml (3.75 l/ha)	10 ml (5 l/ha)
Paraquat	10 ml (5 l/ha)	12.5 ml (6.25 l/ha)	15 ml (7.5 l/ha)

*High volume spray applied at the rate of 5 l per 10 x 10 m plot.

Table 7b. Concentration of herbicides and adjuvants used at Kottappara eucalypt plantation (2)

Herbicide and concentration	Adjuvants	Concentration/l
Glyphosate (Roundup) 7.5 g/l of water (3.75 l/ha)	Ammonium sulphate	5 g, 10 g
	Ammonium chloride	8 g, 16 g
	Urea	5 g, 10 g

Table 7c. Concentration of combination of herbicides used at Kottappara eucalypt plantation (2)

Herbicide/ l of water	Combination herbicide (conc./l of water)	
	Paraquat	Diuron
Glyphosate 3.75 ml , 6.25 ml	5 ml , 2.5 ml	5 g , 1 g

Table 8a. Concentration of different herbicides used at Pothupara teak plantation

Herbicides*	Concentration of herbicides/l of water (amount/ha in parentheses)		
	I	II	III
Diuron	2.5 g (1.25 kg)	7.5 g (3.75 kg)	12.5 g (6.25 kg)
Glyphosate (Roundup)	2.5 ml (1.25 l)	5 ml (2.5 l)	10 ml (5 l)
Glyphosate (Glycel)	5 ml (2.5 l)	7.5 ml (3.75 l)	10 ml (5 l)
Paraquat	3 ml (1.5 l)	4 ml (2 l)	7 ml (3.5 l)

*Except for paraquat, the same concentrations of the other herbicides were also applied after knife weeding of mikania in separate plots at Pothupara

Table 8b. Combinations of herbicides and adjuvants used for the control of mikania at Pothupara teak plantation

Herbicide and concentration	Adjuvants	Conc. of adjuvants/ l of herbicide
Diuron 2.5 g/l of water (1.25 kg/ha)	Ammonium sulphate	5 g, 10 g
	Ammonium chloride	8 g, 16 g
	Urea	5 g, 10 g

Table 8c. Combination of herbicides used at Pothupara eucalypt plantation

Herbicide/ l of water	Combination herbicide (conc./l of water)	
	Roundup	Paraquat
Diuron 2.5 g, 12.5 g	5 ml, 2.5 ml	3 ml, 7 ml

*These combinations of herbicides were also applied after knife weeding of mikania in separate (adjacent) plots at Pothupara.

Table 9. Concentrations of herbicides used at Kottappara eucalypt plantation (3)

Herbicide	Conc. used/l of water	
	I	II
Glyphosate (Roundup)	10 ml	20 ml
Diuron (in combination with Roundup 10 ml/l)	5 g	3 g

3. Results and Discussion

3.1. Distribution of mikania in Kerala

Of the 402 localities surveyed for mikania infestation in the State, 244 (60.7%) showed various levels of infestation; the rest of the sites (158) were free from invasion (Table 10, Fig.3). The highest level of infestation (Grade 5) was recorded from 71 localities (18%). Medium and moderate infestations were recorded from 28 (7%) and 39 (10%) localities respectively. A zone-wise analysis for the distribution of the weed in the State revealed that the central zone had maximum proportion of the localities infested (72% of the total) compared to southern (70.3%), northern (46.4%) and high altitudinal zones (47.8%) (Table 11). The proportion of sites infested varied significantly between different zones ($P < 0.05$). Of the total localities surveyed in each district, Ernakulam District (central zone) had the highest number of localities (92%) infested with the weed (Fig.2). Mikania infested areas were also high in Pathanamthitta (85%), Alappuzha (76.9%) and Kottayam (68.8%) districts in the southern zone. Kasaragod District was free from infestation. The infestation was restricted to the northern boundary of Valapattanam River and southern boundary of its tributary, the Koottupuzha River in Kannur District.

Table 10. Localities surveyed for mikania infestation in Kerala State arranged according to severity levels

Sl. No.	Grade of infestation	Status	No. of localities with/without mikania	% of Mikania infested localities	
1	-	Absent	158	39.30	39.30
2	0	Isolated	8	2.00	60.70
3	1	Scattered	50	12.43	
4	2	Low	48	11.94	
5	3	Moderate	39	9.70	
6	4	Medium	28	6.97	
7	5	High	71	17.66	
Total			402		100.00

Table 11. Zone-wise distribution of mikania in Kerala

Zone	Grade of infestation (based on abundance)							Total localities surveyed*	% of localities infested
	Absent	0	1	2	3	4	5		
Southern	30	4	11	17	11	4	24	101	70.29
Central	35	4	4	13	20	18	31	125	72.00
Northern	45	-	15	11	4	3	6	84	46.43
High range	48	-	20	7	4	3	10	92	47.83

$\chi^2 = 78.11$ at 5% level of significance *Total localities surveyed in each zone was proportionate to the area available for survey under each in the state

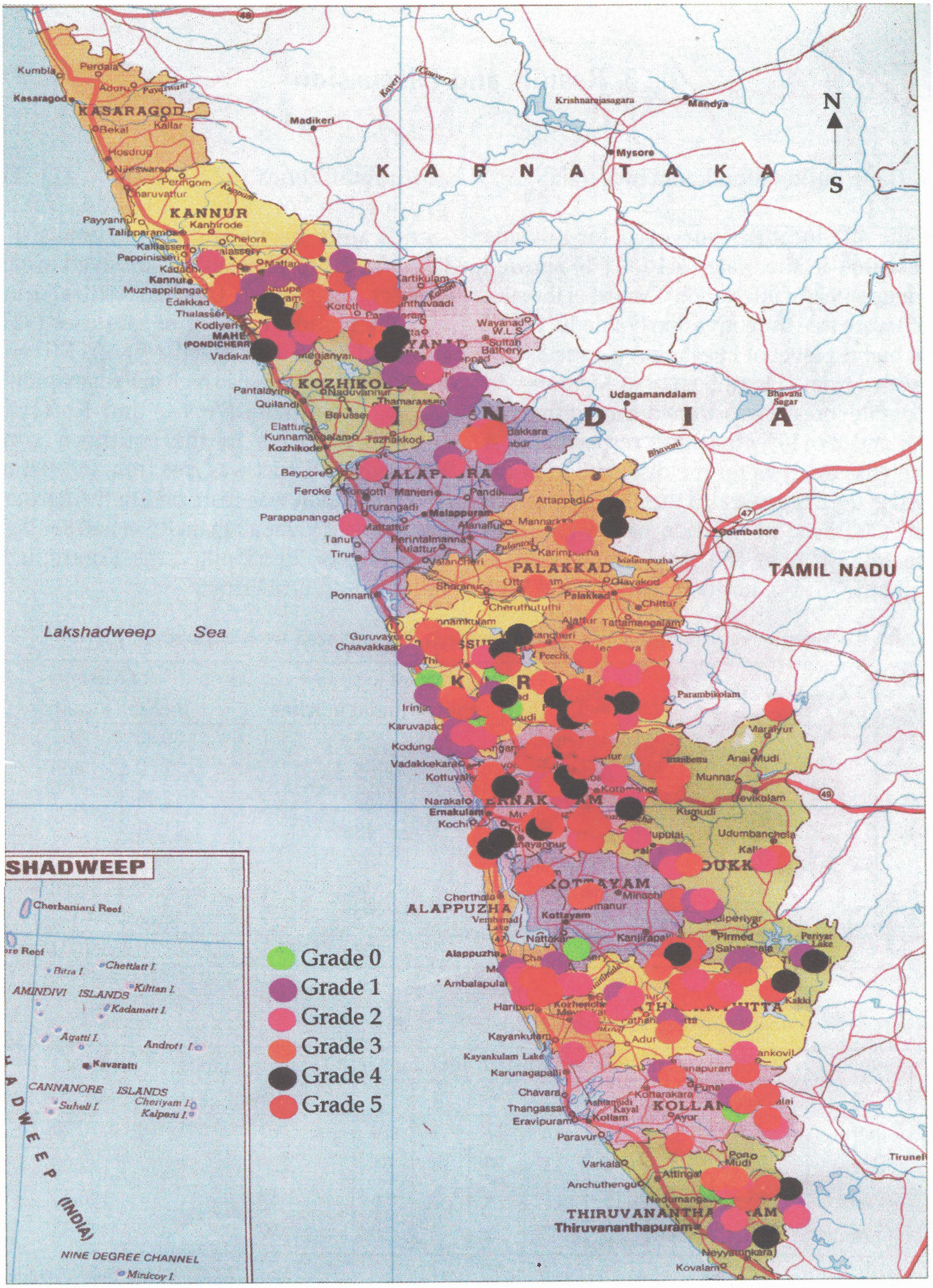

Fig. 3. Distribution of mikania in Kerala state - different severity levels are indicated as grades

Among the different types of natural forests surveyed, the highest proportion of mikania infested localities was in the moist deciduous forests (64.4%) (Table 12, Fig. 4). Of these, 44.6 per cent of the localities showed the highest level of infestation (Grade 5). About 58.1 per cent of semi-evergreen and 54.2 per cent of evergreen forests surveyed were infested with the weed at various levels. None of the Shola forests and grasslands surveyed were infested with the weed.

Data on mikania infestation in forest plantations showed that 78 per cent of teak plantations surveyed were infested. Of these, over 69 per cent showed highest level (Grade 5) of infestation (Table 12). Among other plantations, 38 per cent of eucalypt and 88 per

Fig. 4. Mikania infestation in degraded moist deciduous forest at Vazhachal

Table 12. Severity of mikania infestation in different production and non-production systems in Kerala part of the Western Ghats

Production system		Grade of infestation							Total no. of localities surveyed	% of localities infested
		Absent	0	1	2	3	4	5		
Natural forests	Moist deciduous	31	-	-	14	7	10	25	87	64.37
	Evergreen	11	-	3	4	3	1	2	24	54.17
	Semi-evergreen	13	-	6	2	3	2	5	31	58.06
	Shola	18	-	-	-	-	-	-	18	0
	Grassland	21	-	-	-	-	-	-	21	0
Plantations	Dry deciduous	3	-	-	1	-	1	-	5	40
	Teak	8	-	1	3	1	4	20	37	78.38
	Eucalypts	26	-	3	6	1	3	3	42	38.10
	Miscellaneous (*Acacia, Albizia, Casuarina*, etc.)	4	-	12	3	3	1	9	32	87.50
Agricultural systems (coconut, banana, areca, cassava, pineapple, etc.)		23	8	14	10	6	3	2	66	65.15
Non-productive areas (road side, dam site, etc.).		-	-	11	5	15	3	5	39	100

$\chi^2 = 237.74$ at 5% level of significance

** Total number of areas surveyed under each category was broadly based on the proportion of the area available under each in the State cent of miscellaneous plantations were under mikania attack. The proportion of highly infested plantations was lower in eucalypts (18.8 %) (Fig.5) and miscellaneous (32.1%) plantations compared to teak. In agricultural systems, 65 per cent of the surveyed localities were under various levels of mikania attack. Of these, 4.7 per cent of the areas were highly infested. Distribution of mikania in agricultural areas was rather sparse or scattered probably due to intensive management of the system by the farmers (Fig. 6). Proportion of localities (in relation to total localities surveyed) infested with mikania varied significantly between natural forests, forest plantations and agricultural systems ($P < 0.05$).

Fig. 5. Smothering of eucalypt tree by mikania at Kottappara

3.1.1. Range expansion of mikania in the northern parts of Kerala

During the first survey (1999-2000) in the northern parts of Kerala (Kannur District), infestation by the weed was found limited to and scattered on the southern bank of the Valapattanam River and its tributary, the Koottupuzha River (the localities surveyed were about 50 km apart) ; mean biomass of the weed being 7.8 and 4.9 kg/ha at the two sites respectively (Table 13). Beyond that, towards north and north-east of the State, mikania

Table 13. Biomass (dry weight kg ha^{-1}) of mikania on the southern and northern banks of Valapattanam (VR) and Koottupuzha Rivers (KR) in the northern part of Kerala (during 1999-2000 and 2000-2001)

Conti-nuous plots (100 x 10 m)	Biomass (kg ha^{-1}) 1999-2000 (first survey)		Biomass (kg ha^{-1}) 2000-2001 (second survey)		Biomass (kg ha^{-1}) 1999-2000 (first survey)		Biomass (kg ha^{-1}) 2000-2001 (second survey)	
	Southern bank of VR	Northern bank of VR	Southern bank of VR	Northern bank of VR	Southern bank of KR	Northern bank of KR	Southern bank of KR	Northern bank of KR
1	7.26 (0.64)	*0	11.04 (2.30)	4.63 (1.21)	13.69 (1.81)	0	15.07 (4.35)	0
2	8.14 (1.46)	0	14.71 (0.57)	0	8.83 (0.41)	0	8.05 (0.94)	0
3	8.09 (0.31)	0	13.25 (0.55)	7.15 (1.14)	4.02 (1.16)	0	5.82 (1.45)	0
4	*R	0	R	3.21(0.69)	3.16 (0.31)	0	3.57 (0.18)	0
5	R	0	R	0	2.25 (0.66)	0	2.75 (0.76)	0
6	R	0	R	0	1.33 (0.20)	0	2.06 (0.30)	0
7	R	0	R	1.60 (0.13)	1.33 (0.13)	0	1.61 (0.31)	0
8	R	0	R	0	0	0	0	0
9	R	0	R	0	0	0	0	0
10	R	0	R	0	0	0	0	0

Standard deviation in parenthesis ; R - Removed; 0 - Not present

Fig. 6. Infestation of mikania in agricultural systems at Muttikadavu (Malappuram Dt.)

infestation was absent in all ecosystems. During the subsequent survey (2000-2001), the mean biomass of the weed showed an increase on the two river banks (13.0 and 5.6 kg/ha on the banks of Valapattanam and Koottupuzha river, respectively). Moreover, the weed had also spread to the northern bank of the Valapattanam river (average biomass in 4 plots 4.1 kg/ha) and found spreading fast northwards. However, it is yet to cross the Koottupuzha River which may end up in invasion of areas in the Karnataka State.

3.1.2 Severity of mikania infestation in degraded/disturbed natural forests

A total of 186 natural forest sites under varying level of disturbance regimes were surveyed in the State to assess the severity of mikania attack. Of these, 92 sites (49.5%) showed some level of infestation by the weed. Interestingly, 87 per cent of the highly degraded sites (Grade v) surveyed were affected and 41.4 per cent among these were heavily infested (Grade 5) (Table 14). In undisturbed and areas under low disturbance, mikania growth was scarce or negligible. The biomass of mikania increased proportionately with increased disturbance levels. The number of localities infested by the weed differed significantly between forests under different disturbance regimes ($P < 0.05$).

Invasive weeds, in general, are rapid colonizers with high reproductive capacity and dispersal rates. Their habitat requirements are very flexible and with fast growth rates, they out compete indigenous flora. Since *M. micrantha* is only a minor and harmless species in its native range, absence of co-evolved natural enemies and ecological analogues can be considered as the main factors for the rapid spread and colonization of mikania in the moist tropics.

In Kerala State, mikania is widespread in the central and southern zones (around 70% of the surveyed localities infested) but scattered in distribution in the northern and High Range zones. While low atmospheric temperature and short light period may be one of the factors limiting growth of mikania in the High Ranges, in the northern zone, it could be attributed to the poor nutrient status (lateritic soils which is a poor reservoir of nutrients and with high toxicity of iron and manganese) of the soil (Varghese and Byju, 1993). Low water holding capacity of soils and the limited area under natural forests and plantations, where the weed can proliferate, are other probable reasons. The tropical humid conditions with highly leached soils of Kerala are similar to the Latin American home of mikania. The isoclimatic conditions in the native and exotic ranges may have promoted the growth and establishment of mikania in new geographical zones (Holdgate, 1986). Mikania now occurs widely in the moist tropical zones of south-east Asia and the Pacific posing serious threat to agricultural systems, forest plantations and natural forests (Waterhouse, 1994).

In Kerala, occurrence of mikania was first recorded in 1968. Since the weed was recorded from north-east India as early as 1900's, it was assumed that the spread to Kerala was from the north-east. However, molecular studies (AFLP) on populations *M. micrantha* from its native and exotic ranges indicated that there may have been separate introductions of the weed into the north-east and south-west India (Murphy , 2001). There is a hypothesis that the weed was introduced into Kerala through imported wood from the Neotropics (Sankaran *et al*., 2001). This is supported by the fact that since the Government of India banned clear felling in natural forests, importing wood to Kerala and other States began around this time (Mammen, 1993).

In confirmation with our earlier studies (Sankaran *et al*., 2001), the moist deciduous forests are found more vulnerable to mikania infestation since the highest proportion (65%) of infested localities were recorded from these forests compared to other types of forests. This can be ascribed to the thin canopy, poor stand density of trees and frequent disturbances like grazing and browsing, fire, illicit felling of trees, unsustainable gathering of minor forest products, etc. Moreover, most of the trees in these forests shed leaves seasonally, which facilitates luxuriant growth of the weed in open canopy areas. Mikania, a photophilic plant, easily encroaches such degraded lands (Sen Sarma and Mishra, 1986). In semi-evergreen and evergreen forests, weed colonization was limited to the fringes of the forests where canopy is thin due to biotic interferences and subsequent degradation. Core areas of these forests were generally unaffected since mikania is intolerant of dense shade (Holm *et al*., 1977). In dry deciduous forests, colonization is sparse due to limited moisture content of the soil.

Based on the results of an earlier survey in the Western Ghats, Sankaran *et al*. (2001) have reported that forest plantations in the State face serious threat due to colonization by mikania. They also reported that young plantations of teak are the worst affected by the weed. The results of the present study support this observation. Of the plantations surveyed, teak had 78 per cent of the plantations infested, with young plantations (2 to 3-yr-old) severely affected (Fig. 7). The high vulnerability of teak plantations is ascribed to the thin canopy and favorable micro and macro climatic conditions in the plantations (Sankaran *et al*., 2001). The weed also seriously affects plantations of *Acacia auriculiformis, Paraserianthes falcataria, Casuarina equisetifolia* and bamboo. Typically, the weed will entangle the crown of saplings or trees, smother them and ultimately pull them down due to the heavy weight of the infested crown. As reported earlier (Sankaran *et al*., 2001), eucalypt plantations are comparatively less affected probably due to the low moisture content of the soil and allelopathic effect of the leaves. To combat the mikania menace, the

Table 14. Distribution of mikania under different disturbance regimes

Disturbance level	Disturbance grade	Grade of infestation							Total localities infested	Total localities surveyed
		Absent	0	1	2	3	4	5		
Undisturbed	i	34	-	-	1	1	-	2	4	38
<25	ii	21	-	2	1	-	1	2	6	27
25-50	iii	16	-	-	5	-	1	1	7	23
50-75	iv	14	-	2	7	1	4	3	17	31
>75	v	9	-	4	8	14	8	24	58	67

$\chi^2 = 95.29$ at 5% level of significance

Fig. 7. Smothering of young teak trees by mikania at Vazhachal

State Forest Department carries out periodic weeding in young plantations of teak and eucalypts. A highly infested plantation will have to be weeded 2-3 times in a year to keep the weed growth under check.

In agricultural systems, though 65 per cent of the localities surveyed were infested, highly affected areas were only a few compared to the other ecosystems. It was noticed that the small landholders opt for intensive management of the weed in their farming systems by complete weeding, round weeding or even uprooting at regular intervals. Though such operations are neither practical nor economical for large landholders, they still carry out small-scale weeding (Muraleedharan and Anitha, 2000). The low infestation in agricultural systems is thus due to the intensive management and the frequent agricultural operations (Harley and Forno, 1992). However, Abraham and Abraham (1999a, b) have reported that mikania infestation is one of the reasons for the low productivity of pineapple (Fig. 8), cassava, ginger, turmeric and plantain in Kerala. The current survey also revealed that in central and south Kerala mikania has emerged as a big threat to banana, cassava, pineapple, ginger and paddy.

Forestry operations like clear felling and burning cause disturbance to natural forests creating favorable micro sites for mikania invasion. Regeneration of native species would be insignificant in these nutrient poor sites, which again set stage for weed invasion (Saxena, 1991). Saxena and Ramakrishnan (1984) reported that in slash and burn agriculture in north-east India, invasion by mikania was under check when disturbance to the site was less frequent. Gogoi (2001) has reported that heavy grazing and browsing caused structural and functional modification of micro sites that promoted invasion by mikania in the foothills of Assam and Meghalaya. The current study has also shown that invasion by mikania is more in highly disturbed forests.

Fig. 8. Mikania overgrowing pineapple at Thodupuzha

Of the localities surveyed, mikania infestation was found to be more frequent in the altitudinal range of 100-500 m asl. The distribution of the weed was not recorded above 1,100 m asl in Kerala. This is at variance with the reports of Vaid (1973) who reported that mikania is distributed up to the elevation of 2,000 m in its native range. Barreto and Evans (1995) reported its occurrence at 3,000 m asl in Bolivia. However, Wirjahardja (1975) and Chiu and Chee (1998) recorded its presence up to an elevation of 800 m asl in Indonesia. In north-east India, the weed is distributed in the altitudinal zone of 100-1,330 m asl. In the high altitudinal zones in Kerala, the weed produces bushy and highly pubescent stem and leaves with reddish tinge and a highly toothed (serrate) margin. Such phenotypic plasticity is known to be one of the adaptability features of the weed to withstand extremes of climate in the high altitude regions (Bannister, 1980; Mercado, 1994). Choudhury (1972) has observed that the fluctuation of the microclimate and possibility of the existence of a hybrid as a result of natural cross-pollination may have contributed to the variation in morphology of mikania in the highlands.

In Kerala, the active growth of mikania is related to water availability and hence vigorous vegetative growth is observed during and after south-west monsoon (June-August). In north-east India, this is during March-November (Gogoi, 2001). Flowering phase of *Mikania micrantha* is September to October every year in Hong Kong (Hu and But, 2000). Long daylight and water availability favors blooming of the weed during August-January in the State; wherever water availability is

Table 15a. Biomass (oven dry weight – mean values in kg/ha) of mikania determined after different time intervals of herbicidal application in teak (5-yr-old) plantation at Thavalakuzhippara -

Herbicide/conc.	Biomass at different time intervals (days)					
	30	60	120	180	240	300
Triclopyr +Picloram 3.5 ml/l	2.60^{a}	1.10^{ab}	3.50^{a}	16.20^{abc}	18.90^{ab}	46.20^{ab}
Do - 7 ml/l	0.60^{a}	18.70^{d}	2.10^{a}	14.90^{ab}	28.40^{bcd}	36.90^{ab}
Do - 10.5 ml/l	0.00^{a}	33.10^{e}	38.30^{ef}	4.30^{a}	6.80^{a}	12.80^{a}
Triclopyr 1 ml/l	0.00^{a}	1.60^{ab}	7.40^{ab}	14.10^{ab}	18.60^{ab}	31.60^{ab}
Triclopyr 2 ml/l	1.80^{a}	1.10^{ab}	7.20^{ab}	11.80^{a}	14.60^{ab}	31.20^{ab}
Triclopyr 4 ml/l	0.30^{a}	1.10^{ab}	11.70^{ab}	18.30^{abc}	22.10^{abc}	29.50^{ab}
Diuron 2 g/l	110.40^{de}	1.60^{ab}	23.80^{bcde}	32.50^{cde}	42.10^{d}	71.50^{b}
Diuron 3 g/l	99.60^{d}	10.80^{bcd}	13.10^{abcd}	29.60^{bcd}	32.50^{bcd}	68.90^{b}
Diuron 4 g/l	45.10^{bc}	7.20^{abc}	9.10^{ab}	21.40^{abcd}	27.50^{bcd}	46.70^{ab}
Glyphosate 5 l/l	2.20^{ab}	6.30^{abc}	11.20^{abc}	7.30^{a}	29.60^{bcd}	49.10^{ab}
Glyphosate 10 ml/l	13.90^{ab}	3.20^{abc}	8.90^{ab}	5.60^{a}	28.30^{bcd}	46.10^{ab}
Glyphosate 20 ml/l	12.20^{ab}	1.50^{ab}	0.00^{a}	6.60^{a}	24.17^{abcd}	45.20^{ab}
2,4-D 1 g/l	56.60^{c}	16.90^{d}	14.40^{abcd}	82.80^{f}	116.60^{f}	192.50^{cd}
2,4-D 2 g/l	7.30^{a}	12.60^{cd}	27.60^{cde}	47.40^{e}	72.10^{e}	145.90^{c}
2,4-D 3 g/l	13.60^{ab}	5.50^{abc}	12.80^{abcd}	36.80^{de}	57.90^{d}	99.70^{c}
Paraquat 2 ml/l	145.10^{ef}	5.03^{abc}	49.90^{f}	172.40^{i}	196.40^{h}	202.90^{d}
Paraquat 4 ml/l	156.60^{f}	3.60^{abc}	114.60^{g}	142.90^{h}	162.53^{g}	143.47^{c}
Paraquat 6 ml/l	16.30^{ab}	2.70^{ab}	30.17^{de}	48.50^{e}	82.60^{e}	154.80^{c}
Control	250.70^{g}	154.00^{g}	165.60^{g}	118.70^{g}	197.50^{h}	238.90^{d}

* In a column, means followed by a common letter are not significant at 5% level (DMRT)

poor, mikania dries up during February-May. Thousands of seeds will be produced from one rampant clump of mikania. The high multiplication coefficient (high seed yield and ability for vegetative propagation) and the lightweight of seeds aid in spread and multiplication of the weed in its exotic range (Spahillari *et al.*, 1999).

To summarise, the survey revealed that the natural forests, forest plantations and agricultural systems in Kerala are highly infested by mikania. The infestation is widespread in the Western Ghats which are considered as one of the world's eleven hotspots of biodiversity (Nayar, 1980) harboring about 15,000 flowering plants (Sastry and Sharma, 1991). As already discussed, deforestation, grazing, plantation activities, fire and unsustainable use of forest products which cause disturbance to natural forests probably contributed to mikania invasion in the Western Ghats. Besides economic loss, of great concern is the threat that the weed poses to biodiversity in the Western Ghats. Hence, suitable methods need be developed urgently to manage mikania infestation in various ecosystems in the State.

3.2. Herbicidal control of mikania in forest plantations and reed growing areas

The results of various herbicidal trials are summarized in Tables 15-20.

3.2.1. Teak plantation at Thavalakkuzhippara

The results indicate that there is a significant decrease in biomass production of mikania compared to controls as a result of the various

Table 15b. Weed control efficacy (%) of herbicides applied on mikania after different time intervals of application (Thavalakuzhippara teak plantation)

Herbicide/conc.	WCE (%) at different time interval (days)					
	After 30	60	120	180	240	300
Triclopyr +Picloram 3.5 ml/l	98.96	99.29	97.89	86.35	90.43	80.66
Do - 7 ml/l	99.76	87.86	98.73	87.45	85.62	84.55
Do - 10.5 ml/l	100.00	78.51	76.87	96.38	96.56	94.64
Triclopyr 600 1 ml/l	100.00	98.96	95.53	88.12	90.58	86.77
Triclopyr 600 2 ml/l	99.28	99.29	95.65	90.06	92.61	86.94
Triclopyr 600 4 ml/l	99.88	99.29	92.93	84.58	88.81	77.73
Diuron 2 g/l	55.96	98.96	85.63	72.62	78.68	70.07
Diuron 3 g/l	60.27	92.99	92.09	75.06	83.54	71.16
Diuron 4 g/l	82.01	95.32	94.50	81.97	86.08	80.45
Glyphosate 5 ml/l	99.12	95.91	93.24	93.85	85.01	79.45
Glyphosate 10 ml/l	94.46	97.92	94.63	95.28	85.67	80.70
Glyphosate 20 ml/l	95.13	99.03	100.00	94.44	87.76	81.08
2,4-D 1 g/l	77.42	89.03	91.30	30.24	40.96	19.42
2,4-D 2 g/l	97.09	91.82	83.33	60.07	63.49	38.93
2,4-D 3 g/l	94.58	96.43	92.27	69.00	77.00	58.26
Paraquat 2 ml/l	42.12	90.69	69.87	0.00	0.56	15.07
Paraquat 4 ml/l	37.53	97.66	30.80	0.00	17.71	39.95
Paraquat 6 ml/l	93.50	98.25	81.78	59.14	58.18	35.20
Control	0.00	0.00	0.00	0.00	0.00	0.00

herbicidal applications. The weed control efficacy (WCE) of different herbicides and their concentrations also differed significantly (P< 0.05). The highest WCE (95-100) was observed after 30 days in most cases (Tables 15a and 15b and Fig. 9). The WCE showed a gradual decrease but was still high (70-95%) after 300 days in the case of triclopyr + picloram, triclopyr, glyphosate (Roundup) and diuron at different concentrations. 2-4,D showed high WCE till 120 days and then showed a decrease. This was also true for all concentrations of paraquat. By 300 days, the efficacy of these two herbicides was the least compared to the other herbicides. Of the four most effective herbicides viz., triclopyr + picloram, triclopyr, glyphosate (Roundup) and diuron, triclopyr + picloram at the concentration of 10.5 ml/l (5.25 l/h) gave maximum control even after 300 days of application. Of the rest, diuron @ 2 kg/h and glyphosate and triclopyr at all concentrations and triclopyr + picloram at lower concentrations were equally effective. At 300 days, there was no significant difference in the WCE of different concentrations of glyphosate and triclopyr.

3.2.2. Eucalypt plantation at Kottappara (1)

The trend of WCE of the herbicides triclopyr + picloram, triclopyr, diuron and glyphosate was similar to that observed for the teak plantation. Biomass of the weed was significantly lower at all concentrations of the different herbicides compared to control (P<0.05). Triclopyr + picloram @ 10.5 ml/l, triclopyr @ 4 ml/l, diuron @ 4 g/l and glyphosate @ 10 ml/l and 20 ml/l were highly effective in controlling the weed. WCE of the respective concentrations of the herbicides differed significantly from other concentrations used (P<0.05). Paraquat @ 4 ml and 6 ml/l were also effective but at a lower level compared to the other herbicides. The efficacy of 2,4- D lasted only for 120 days and thereafter a rapid re-growth of the weed was observed. Results are summarized in Tables 16a and 16b and Figure 10.

3.2.3. Natural reed growth at Choozhimedu

In general, results were similar to those observed for teak and eucalypt. The WCE of all herbicides

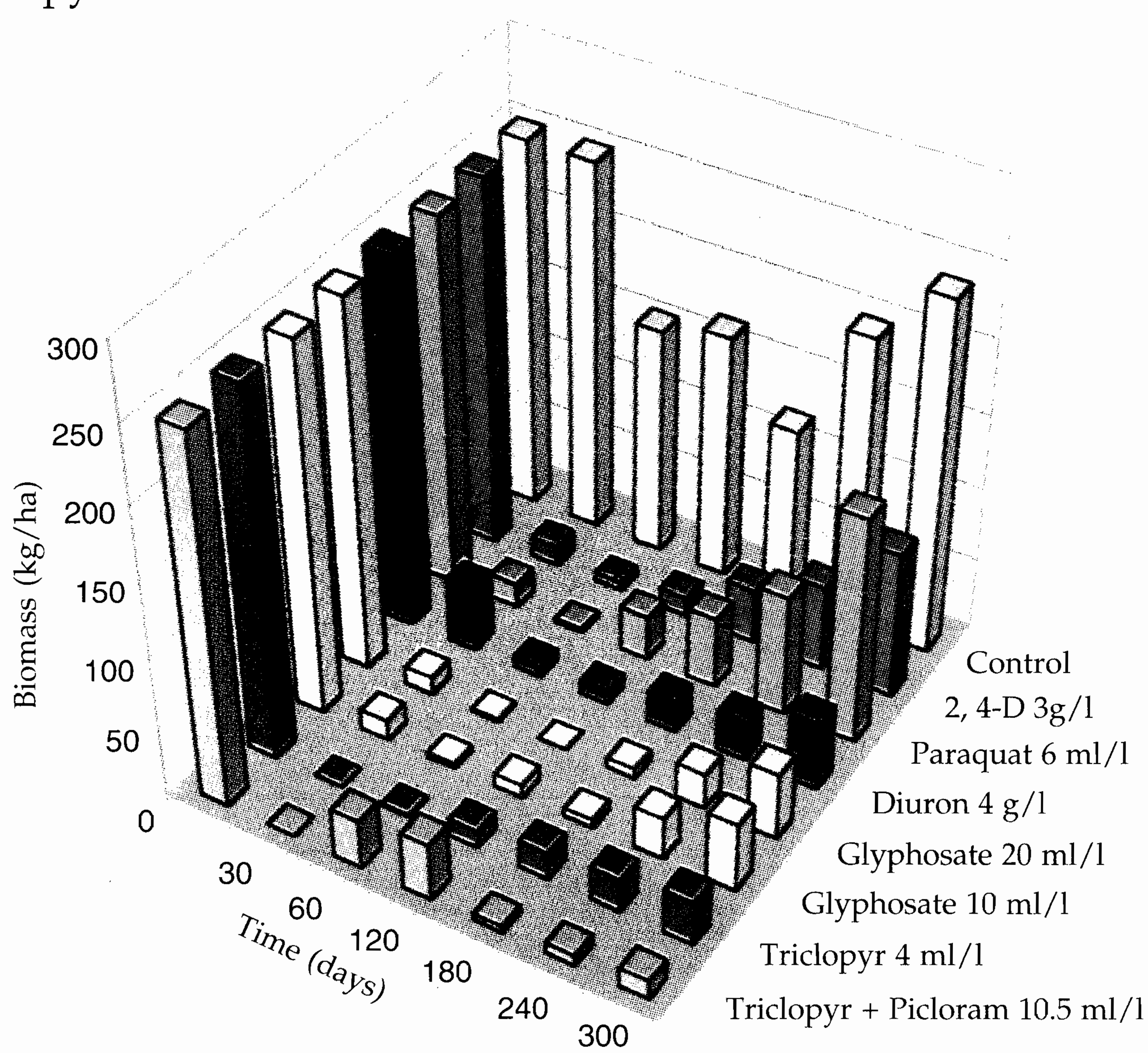

Fig.9. Biomass of mikania after different periods of herbicidal application at Thavalakkuzhippara.

Table 16a. Biomass (oven dry weight – mean values in kg/ha) of mikania determined after different time intervals of herbicidal application at Kottappara *Eucalyptus tereticornis* (10-yr-old) plantation

Herbicide/conc.	Biomass at different time interval (days)					
	30	60	120	180	240	300
Triclopyr +Picloram 3.5 ml/l	0.00[a]	5.00[cdef]	0.00[a]	21.60[ab]	31.70[a]	38.90[abcd]
Do - 7 ml/l	0.00[a]	18.00[h]	0.00[a]	7.90[ab]	11.70[a]	18.50[ab]
Do- 10.5 ml/l	0.00[a]	3.00[abcd]	0.00[a]	5.80[a]	7.30[a]	14.60[a]
Triclopyr 1 ml/l	0.00[a]	2.70[abcd]	0.00[a]	18.30[ab]	24.20[a]	28.60[ab]
Triclopyr 2 ml/l	0.00[a]	3.70[abcde]	0.00[a]	7.20[ab]	11.60[a]	18.60[ab]
Triclopyr 4 ml/l	0.00[a]	0.40[a]	0.00[a]	5.40[a]	7.90[a]	12.10[a]
Diuron 2 g/l	36.40[bcde]	8.10[fg]	14.90[c]	72.10[c]	114.00[b]	156.90[e]
Diuron 3 g/l	21.30[abcd]	4.50[bcde]	5.00[b]	36.30[b]	42.10[a]	59.20[cd]
Diuron 4 g/l	6.10[a]	4.50[bcde]	6.10[b]	24.80[ab]	32.10[a]	42.80[bcd]
Glyphosate 5 ml/l	41.80[cde]	1.10[ab]	24.20[e]	14.30[ab]	24.20[a]	35.40[abc]
Glyphosate 10 ml/l	0.40[a]	22.20[i]	0.00[a]	5.20[a]	12.10[a]	22.00[ab]
Glyphosate 20 ml/l	13.30[abc]	1.70[abc]	0.00[a]	4.80[a]	16.20[a]	18.60[ab]
2,4-D 1 g/l	42.50[de]	2.50[abcd]	31.20[f]	122.40[de]	122.80[b]	192.80[f]
2,4-D 2 g/l	51.30[e]	0.80[a]	18.70[d]	121.40[de]	122.10[b]	190.60[f]
2,4-D 3 g/l	26.40[abcde]	2.50[abcd]	5.60[b]	116.80[de]	121.50[b]	186.40[f]
Paraquat 2 ml/l	3.20[a]	6.00[def]	13.20[c]	99.40[d]	116.50[b]	142.70[e]
Paraquat 4 ml/l	8.50[ab]	6.80[ef]	4.60[b]	32.60[ab]	48.60[a]	62.90[d]
Paraquat 6 ml/l	4.10[a]	7.00[efg]	0.00[a]	23.40[ab]	32.40[a]	56.40[cd]
Control	167.80[f]	110.20[i]	131.30[g]	128.50[e]	122.80[b]	196.00[f]

* In a column, means followed by a common letter one not significant at 5% level (DMRT).

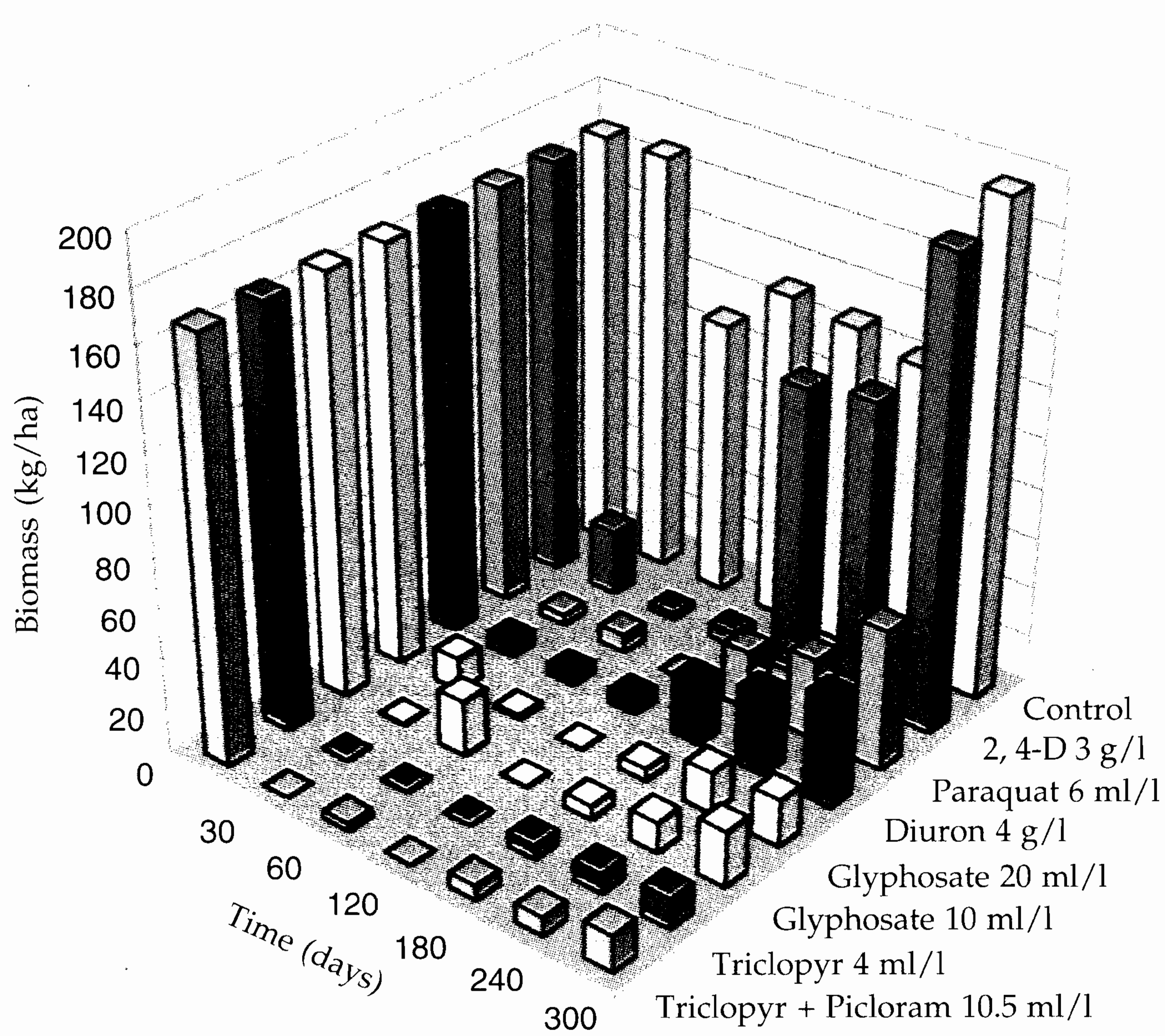

Fig.10. Biomass of mikania after different periods of herbicidal application in eucalypt plantation at Kottappara.

Table 16b. Weed control efficacy (%) of herbicides after different time intervals of application Kottappara *Eucalyptus tereticornis* plantation (1).

Herbicide/conc.	WCE (%) at different time interval (days)					
	30	60	120	180	240	300
Triclopyr +Picloram 3.5 ml/l	100.00	95.40	100.00	83.19	74.19	80.15
Do- DS 7 ml/l	100.00	75.90	100.00	93.85	90.47	90.56
Do- DS 10.5 ml/l	100.00	97.20	100.00	95.49	94.06	92.55
Triclopyr 1 ml/l	100.00	97.50	100.00	85.76	80.29	85.41
Triclopyr 2 ml/l	100.00	96.60	100.00	94.40	90.55	90.51
Triclopyr 4 ml/l	100.00	99.60	100.00	95.80	93.57	93.83
Diuron 2 g/l	78.31	92.60	88.60	43.89	7.17	19.95
Diuron 3 g/l	87.31	95.90	96.10	71.75	65.72	69.80
Diuron 4 g/l	96.36	95.90	95.40	80.70	73.86	78.16
Glyphosate 5 ml/l	75.09	99.00	81.50	88.87	80.29	81.94
Glyphosate 10 ml/l	99.76	80.00	100.00	95.95	90.15	88.78
Glyphosate 20 ml/l	92.07	98.50	100.00	96.26	86.81	90.51
2,4-D 1 g/l	74.67	97.70	76.20	4.75	0.00	1.63
2,4-D 2 g/l	69.43	99.20	85.70	5.53	0.57	2.76
2,4-D 3 g/l	84.27	97.70	95.70	9.11	1.06	4.90
Paraquat 2 ml/l	98.09	94.50	90.00	22.65	5.13	27.19
Paraquat 4 ml/l	94.93	93.80	94.80	74.63	60.42	67.91
Paraquat 6 ml/l	97.56	93.60	100.00	81.78	73.60	71.20
Control	0.00	0.00	0.00	0.00	0.00	0.00

showed a gradual decrease from 30 to 300 days. However, the efficacy of triclopyr + picloram, triclopyr, diuron and glyphosate was still high (65-92%) at the end of 300 days. The highest concentrations of all the four herbicides showed significantly higher efficacy compared to the lower concentrations ($P< 0.05$). As for teak and eucalypt, WCE of 2,4-D and paraquat was significantly high only during the initial stages (30-120 days). Paraquat@ 6 ml/l was a better treatment in terms of WCE compared to other concentrations. Results are summarized in Tables 17a, 17b and Fig 11.

3.2.4. Eucalypt plantation at Kottappara (2)

Compared to the earlier treatments, in this trial, higher concentrations of diuron (except for 2 g/l) glyphosate (Roundup) (except for 15 ml/l) glyphosate (Glycel) and paraquat were used. However, the efficacy of all the treatments diminished significantly by 180 days (Table 18a).

The higher efficacy of diuron, glyphosate (R) and glyphosate (G) compared to paraquat was still evident. WCE of glyphosate (R) (15 ml/l) was significantly higher than other herbicides and lower concentrations of glyphosate itself. The results pertaining to application of herbicides after knife weeding showed inconsistent results. There was an initial significant increase ($P<0.05$) in WCE in all cases except for Glycel @ 7.5 ml/l. But by 60 days this trend diminished and the WCE was equal to or lower than those recorded for un treated

Table 17a. Biomass (oven dry weight – mean values in kg/ha) of mikania determined after different time intervals of herbicidal application at natural reed growing area- Choozhimedu

Herbicide/conc.	Biomass at different time interval (days)					
	30	60	120	180	240	300
Triclopyr + Picloram 3.5 ml/l	13.20[a]	1.90[a]	0.00[a]	16.40[a]	24.70[ab]	36.90[abc]
Do - 7 ml/l	0.00[a]	2.40[a]	0.00[a]	12.30[a]	24.20[ab]	36.40[abc]
Do - 10.5 ml/l	0.00[a]	0.70[a]	0.00[a]	6.80[a]	14.30[a]	25.80 [a]
Triclopyr 1 ml/l	0.00[a]	4.30[a]	15.80[ab]	26.50[a]	39.70[ab]	53.80[abcd]
Triclopyr 2 ml/l	0.90[a]	3.20[a]	7.60[a]	21.60[a]	28.60[ab]	39.80[abc]
Triclopyr 4 ml/l	1.40[a]	1.00[a]	0.00[a]	9.50[a]	16.80[a]	24.80[a]
Diuron 2 g/l	7.20[ab]	10.70[abc]	35.00[bc]	42.10[a]	53.40[b]	96.00[e]
Diuron 3 g/l	11.40[ab]	18.40[c]	20.60[ab]	37.70[a]	42.70[ab]	72.10[cde]
Diuron 4 g/l	11.50[ab]	5.00[a]	9.90[a]	22.50[a]	25.40[ab]	48.70[abc]
Glyphosate 5 ml/l	27.60 [ab]	1.40[a]	0.00[a]	39.60[a]	42.80[ab]	85.60[de]
Glyphosate 10 ml/l	14.40[ab]	1.60[a]	0.00[a]	14.20[a]	25.70[ab]	29.40[ab]
Glyphosate 20 ml/l	17.90[ab]	4.00[a]	0.00[a]	7.40[a]	11.70[a]	21.00[a]
2,4-D 1 g/l	17.70[ab]	11.10[abc]	75.30[de]	149.30[e]	198.40[e]	252.90[h]
2,4-D 2 g/l	0.50[a]	1.50[a]	84.20[e]	172.40[cd]	179.40[de]	269.80[hi]
2,4-D 3 g/l	0.00[a]	7.90[ab]	53.00[cd]	112.60[b]	153.50[d]	254.70[h]
Paraquat 2 ml/l	27.00[b]	28.10[d]	150.90[g]	112.60[b]	124.20[c]	198.60[g]
Paraquat 4 ml/l	3.50[a]	14.90[bc]	107.30[f]	82.60[b]	96.80[c]	128.90[f]
Paraquat 6 ml/l	53.30[ab]	33.70[de]	9.50[a]	46.80[a]	52.50[ab]	104.20[e]
Control	94.10[c]	39.30[e]	151.70[g]	187.20[d]	188.60[e]	288.60[i]

* In a column, means followed by a common letter are not significant at 5% level (DMRT).

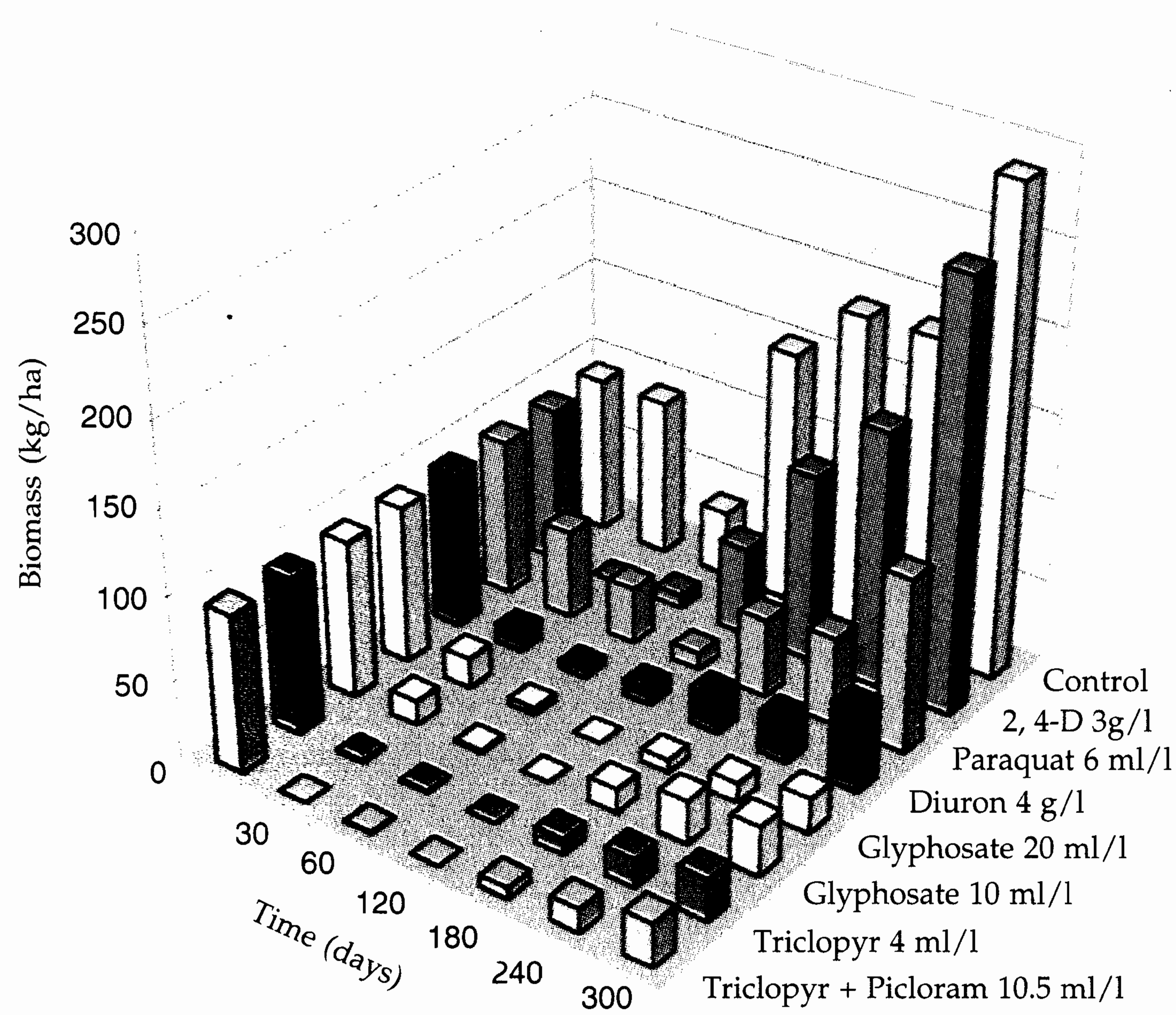

Fig.11. Biomass of mikania after different time intervals of herbicidal application in natural reed growth at Choozhimedu.

Table 17b. Weed control efficacy (%) of herbicides after different time intervals of application (Choozhimedu natural reed growing area)

Herbicide/conc.	WCE (%) at different time interval (days)					
	After 30	60	120	180	240	300
Triclopyr +Picloram 3.5 ml/l	85.97	95.17	100.00	91.24	86.90	87.21
Do - 7 ml/l	100.00	93.89	100.00	93.43	87.17	87.39
Do - 10.5 ml/l	100.00	98.22	100.00	96.37	92.42	91.06
Triclopyr 1 ml/l	100.00	89.06	89.58	85.84	78.95	81.36
Triclopyr 2 ml/l	99.04	91.86	94.99	88.46	84.84	86.21
Triclopyr 4 ml/l	98.51	97.46	100.00	94.93	91.09	91.41
Diuron 2 g/l	92.35	72.77	76.93	77.51	71.69	66.74
Diuron 3 g/l	87.89	53.18	86.42	79.86	77.36	75.02
Diuron 4 g/l	87.78	87.28	93.47	87.98	86.53	83.13
Glyphosate 5 ml/l	70.67	96.44	100.00	78.85	77.31	70.34
Glytphosate 10 ml/l	84.70	95.93	100.00	92.41	86.37	89.81
Glyphosate 20 ml/l	80.98	89.82	100.00	96.05	93.80	92.72
2,4-D 1 g/l	81.19	71.76	50.36	20.25	0.00	12.37
2,4-D 2 g/l	99.47	96.18	44.50	7.91	4.88	6.51
2,4-D 3 g/l	100.00	79.90	65.06	39.85	18.61	11.75
Paraquat 2 ml/l	71.31	28.50	0.53	39.85	34.15	31.19
Paraquat 4 ml/l	96.28	62.09	29.27	55.88	48.67	55.34
Paraquat 6 ml/l	43.36	14.25	93.74	75.00	72.20	63.90
Control	0.00	0.00	0.00	0.00	0.00	0.00

plots. This trend continued till 180 days when the last samples were drawn. The data collected from knife weeded plots (without herbicide application) showed that the biomass of the weed attained pre weeded status in 180 days. The WCE was 23 per cent by 60 days which was significantly lower than all the herbicide treated plots.

The data for the efficacy of glyphosate when added with different adjuvants (Table 18b) showed that this fungicide (@ 7.5 ml/l) in combination with ammonium sulphate @ 5 gm/l gave better control compared to ammonium chloride and urea ($P< 0.05$). In trials with different combinations of herbicides, glyphosate @ 3.75 ml added with paraquat @ 5 ml/l gave the highest WCE till sixty days ($P< 0.05$) (Table 18b).

3.2.5. Teak plantation at Pothupara

Unlike the earlier trial in a teak plantation at Thavalakkuzhippara, the efficacy of various herbicides used in this trial did not last for even 120 days (Table 19a). This is apparently due to the frequent pre-monsoon showers experienced in the area soon after herbicidal trial which promoted growth of new saplings, from wind carried seeds, in the treated plots. However, data after 30 days of herbicidal application again proved the efficacy of diuron, glyphosate (R) and glyphosate (G) in controlling mikania. The WCE of higher concentrations of these

Table 18a. Biomass of mikania (oven dry weight – mean values in kg/ha) and weed control efficacy (%) of herbicides after different time intervals of application in *Eucalyptus tereticornis* (9-yr-old) plantation at Kottappara

Herbicide/conc.	Biomass (I) and weed control efficacy (%) (II) at different time intervals (days)					
	30		60		180	
	I	II	I	II	I	II
Diuron 2 g/l	142.70[e]	47.04	87.20[abc]	62.80	184.50[bc]	27.96
Diuron 10 g/l	140.30[de]	47.93	116.80[bcde]	50.18	166.47[abc]	35.00
Diuron 15 g/l	73.60[abcde]	72.68	62.87[ab]	73.18	156.30[abc]	38.97
Glyphosate (R) 7.5 ml/l	116.80[bcde]	56.65	124.80[bcde]	46.76	146.77[abc]	42.69
Do - 12.5 ml/l	68.50[abcde]	74.58	116.30[bcde]	50.39	129.33[ab]	49.50
Do - 15 ml/l	53.40[abc]	80.18	23.70[a]	89.89	124.20[ab]	51.51
Glyphosate (G) 5 ml/l	122.70[cde]	54.46	132.70[bcde]	43.39	144.17[abc]	43.71
Do- 7.5 ml/l	119.07[bcde]	55.81	128.50[bcde]	45.19	129.60[abc]	49.40
Do- 10 ml/l	81.83[bcde]	69.63	98.30[abcde]	58.07	101.40[ab]	60.41
Paraquat 10 ml/l	216.10[f]	19.79	119.30[bcde]	49.10	184.53[bc]	27.95
Paraquat 12.5 ml/l	213.40[f]	20.80	118.60[bcde]	49.41	195.87[c]	23.52
Paraquat 15 ml/l	116.30[bcde]	56.83	101.60[abcde]	56.60	156.80[abc]	38.78
Knife weeding followed by direct application of herbicide						
Diuron 2 g/l	96.30[abcde]	64.26	88.50[abcd]	62.25	169.50[abc]	33.82
Diuron 10 g/l	96.80[abcde]	64.07	115.40[bcde]	50.77	129.60[abc]	49.40
Diuron 15 g/l	32.30[a]	88.01	69.70[abcd]	70.27	145.80[abc]	43.07
Glyphosate (R) 7.5 ml/l	97.30[abcde]	63.89	114.50[bcde]	51.16	156.83[abc]	38.77
Do - 12.5 ml/l	43.20[ab]	83.97	116.80[bcde]	50.18	125.50[ab]	51.00
Do - 15 ml/l	28.40[a]	89.46	132.97[bcde]	43.28	114.50[a]	55.29
Glyphosate (G) l 5 ml/l	112.50[bcde]	58.25	158.63[cdef]	32.33	158.10[abc]	38.27
Do - 7.5 ml/l	120.57[bcde]	55.25	99.70[abcde]	57.47	143.50[abc]	43.97
Do - 10 ml/l	96.30[abcde]	64.26	111.80[bcde]	52.31	128.70[ab]	49.75
Paraquat 10 ml/l	91.60[abcde]	66.00	128.40[bcde]	45.23	199.70[abc]	22.03
Paraquat 12.5 ml/l	116.30[bcde]	56.83	126.50[f]	46.00	184.30[bc]	28.04
Paraquat 15 ml/l	96.40[abcde]	64.22	153.20[cde]	34.65	199.70[abc]	33.74
Complete weeding						
Knife weeding	75.27[abcde]	72.06	180.23[f]	23.12	250.80[f]	2.08
Control	269.40[f]	0.00	234.43[f]	0.00	256.12	0.00

* In a column, means followed by a common letter are not significant at 5% level (DMRT).
Glyphosate (R) - Roundup; Glyphosate (G) - Glycel

Table 18b. Biomass of mikania and weed control efficacy (%) of different herbicides in combination and added with adjuvants after different time intervals of application in *Eucalyptus tereticornis* plantation at Kottappara

Herbicide/adjuvants	Biomass (I) and weed control efficacy (II) (%) at different time intervals (days)			
	30		60	
	I	II	I	II
Glyphosate (7.5 ml/l) + ammonium sulphate (5 g/l)	54.17[abc]	79.89	49.07[ab]	79.07
Glyphosate (7.5 ml/l) + ammonium chloride (8 g/l)	104.40[abcde]	61.25	86.20[abc]	63.23
Glyphosate (7.5 ml/l) + ammonium sulphate (10 g/l)	82.43[abcde]	69.41	115.63[bcde]	50.68
Glyphosate (7.5 ml/l) + ammonium chloride (16 g/l)	64.33[abcd]	76.12	93.17[abcde]	60.26
Glyphosate (7.5 ml/l) + urea (5 g/l)	92.07[abcde]	65.83	99.80[abcde]	57.43
Glyphosate (7.5 ml/l) + urea (10 g/l)	62.87[abcd]	76.67	82.77[abc]	64.69
Combination of herbicides				
Glyphosate + Paraquat (3.75+5 ml/l)	27.27[a]	89.88	43.83[ab]	81.30
Glyphosate + Paraquat (6.25+2.5 ml/l)	94.13[abcde]	65.06	103.60[abcde]	55.81
Glyphosate (6.25 ml/l)+ Diuron (1 g/l)	62.37[abcd]	76.85	119.00[bcde]	49.24
Glyphosate (3.75 ml/l)+ Diuron (5 g/l)	102.53[abcde]	61.95	123.77[bcde]	47.20
Control	269.43[f]	0.00	234.43[f]	0.00

herbicides (diuron – 12.5 g/l, glyphosate (R) – 10 ml/l and glyphosate (G) 7.5 ml and 10 ml/l) differed significantly from the lower concentrations used ($P< 0.05$). The WCE did not differ significantly when the same concentrations of diuron and glyphosate (G) were used after mechanical weeding.

In another trial, when different concentrations of the adjuvants, ammonium sulphate, ammonium chloride and urea were used in combination with diuron, the combination diuron @ 2.5 g/l plus urea @ 5 g/l and 10 g/l gave maximum control of the weed after 30 days compared to applications with out adjuvants (Table 19b.). Further observations from the plot were marred by fresh growth of mikania in the plots as indicated earlier. Also, when diuron @ 2.5 g and 12.5 g/l was used in combination with herbicides paraquat and glyphosate (G), the combination with paraquat @ 3 and 7 ml/l showed significantly higher WCE ($P< 0.05$). Manual weeding during the present trial indicated that the biomass of the weed regained the pre-weeding status in 4 months time.

3.2.6. Eucalypt plantation at Kottappara (3)

This herbicidal trial was carried out to evaluate the efficacy of glyphosate (R) and mixture of glyphosate (R) and diuron to control the weed when applied at the pre-flowering stage. Glyphosate (R) at the rate of 10 ml and 20 ml/l and diuron at the rate of 5 g and 10 g added with glyphosate (R) (10 ml/l) were equally effective in controlling the weed (Table 20). The WCE ranged between 93.6 – 96.4% after 120 days of treatment.

3.2.7. Efficacy of different herbicides in controlling mikania

The results of these herbicidal trials show that triclopyr + picloram @ 1.75 – 5.25 l/ha, triclopyr @ 500 ml – 2 l/ha, glyphosate (Roundup) @

Table. 19a. Biomass of mikania (oven dry weight – mean values in kg/ha) and weed control efficacy (%) of herbicides determined after different time intervals of application at Pothupara teak (7-yr-old) plantation.

Herbicide/conc.	Biomass(I) and weed control efficacy(II) at different time intervals (days)			
	30		120	
	I	II	I	II
Diuron 2.5 g/l	154.43[ab]	47.96	278.33[c]	0.00
Diuron 7.5 g/l	112.03[ab]	62.25	265.27[c]	1.20
Diuron 12.5 g/l	65.40[a]	72.38	212.80[c]	20.74
Glyphosate (R) 2.5 ml/l	204.93[bc]	30.95	265.87[c]	0.98
Glyphosate(R) 5 ml/l	144.67[ab]	51.25	247.87[c]	7.68
Glyphosate(R) 10 ml/l	74.03[a]	68.73	208.60[c]	22.31
Glyphosate (G) 5 ml/l	133.73[ab]	54.94	266.90[c]	0.60
Glyphosate (G) 7.5 ml/l	81.17[a]	72.65	269.80[c]	0.00
Glyphosate (G) 10 ml/l	77.17[a]	74.00	212.57[c]	20.83
Paraquat 4 ml/l	76.90[a]	74.09	298.80[c]	0.00
Paraquat 3 ml/l	105.97[ab]	64.29	265.20[c]	1.23
Paraquat 7 ml/l	69.93[a]	76.44	258.70[c]	3.65
Knife weeding followed by direct application of herbicide				
Diuron 2.5 g/l	70.07[a]	76.39	245.60[c]	8.53
Diuron 7.5 g/l	72.80[a]	75.47	247.80[c]	7.71
Diuron 12.5 g/l	60.97[a]	79.46	231.60[c]	13.74
Glyphosate (G) 5 ml/l	119.00[ab]	59.90	268.70[c]	0.00
Glyphosate (G) 7.5 ml/l	94.50[ab]	68.16	245.60[c]	8.53
Glyphosate (G) 10 ml/l	105.97[ab]	64.29	214.60[c]	20.07
Combination of weedicides after knife weeding				
Diuron (2.5 g/l) + Paraquat (3 ml/l)	119.10[ab]	59.87	214.50[c]	20.11
Diuron (12.5 g/l) + Paraquat (7 ml/l)	53.70[a]	77.32	156.50[c]	41.70
Diuron (2.5 g/l) + Glyphosate (R) (5 ml/l)	100.27[ab]	66.21	207.50[c]	22.72
Diuron (12.5 g/l) + Glyphosate (R) (2.5 ml/l)	134.80[a]	43.07	256.50[a]	4.47
Control	296.77[c]	0.00	268.50[a]	0.00

2.5 – 10 l/ha and diuron @ 1 – 2 kg/ha are highly efficient in controlling mikania in forest plantations and natural reed growing areas (Figures 9 - 11). No significant re-growth of the weed was observed in the treated plots even after a period of 300 days. The highest concentrations of each of these were the most efficient. But whether the highest concentrations need be used in the field depend on the gravity of the weed infestation in each ecosystem.

Table. 19b. Biomass of mikania and weed control efficacy (%) of herbicides after different time intervals of application at Pothupara teak plantation.

Herbicide/conc.	Biomass (I) and weed control efficacy (II) at different time intervals (days)			
	30		120	
	I	II	I	II
Diuron + ammonium sulphate (2.5+10 g/l)	166.13[ab]	44.02	254.30[c]	5.29
Diuron + ammonium sulphate (2.5+5 g/l)	168.33[ab]	43.28	268.47[c]	0.01
Diuron + ammonium chloride (2.5+8 g/l)	198.63[b]	33.07	247.80[c]	7.71
Diuron + ammonium chloride (2.5+16 g/l)	167.53[ab]	43.55	265.80[c]	1.01
Diuron + Urea (2.5+5 gm/l)	60.53[a]	79.60	147.80[b]	44.90
Diuron + Urea (2.5+10 gm/l)	70.43[a]	76.27	191.60[b]	28.60
Combination of herbicides				
Diuron (2.5 g/l)+ Paraquat (3 ml/l)	22.50[a]	92.42	202.67[c]	24.52
Diuron (12.5 g/l)+ Paraquat (7 ml/l)	18.27[a]	93.84	201.80[c]	24.84
Diuron (2.5 g/l)+ Glyphosate (R) (5 ml/l)	90.50[ab]	69.51	247.87[c]	7.68
Diuron (12.5 g/l)+Glyphosate (G) (2.5 ml/l)	109.20[ab]	63.20	264.20[c]	1.60
Complete weeding				
Sickle weeding	152.30[ab]	48.68	285.90[c]	0.00
Control	296.77[c]	0.00	268.50[c]	0.00

Table 20. Biomass of mikania (oven dry weight – mean values in kg/ha) and weed control efficacy of herbicides determined after different time intervals of application at Kottappara *Eucalypts tereticornis* plantation (3).

Herbicide/conc.	Biomass (I) and weed control efficacy (II) at different time intervals (days)							
	After 30 days		60		90		120	
	I	II	I	II	I	II	I	II
Glyphosate (R) 10 ml/l	70.66[b]	46.54	18.94[a]	86.98	12.54[a]	91.83	7.78[a]	93.67
Glyphosate (R) 20 ml/l	55.21[a]	58.23	10.24[a]	92.96	8.96[a]	94.17	4.38[a]	96.44
Diuron (5 g/l) +								
Glyphosate (R) (10 ml/l)	66.78[ab]	49.48	13.83[a]	90.49	11.09[a]	92.78	6.98[a]	94.32
Diuron (7.5 g/l) +								
Glyphosate (R) (10 ml/l)	60.39[ab]	54.31	11.99[a]	91.76	9.38[a]	93.89	5.13[a]	95.82
Control	132.18[c]	0.00	145.49[b]	0.00	153.57[b]	0.00	122.87[b]	0.00

For most purposes, a lower concentration, for eg., triclopyr + picloram @ 1.75 l, triclopyr 500 ml, glyphosate 2.5 – 5 l and diuron 1.5 – 2 kg/ha would be sufficient to control the menace as far as efficacy is concerned. As discussed earlier, sparse growth of mikania may occur in some of the treated plots through wind borne seeds (especially if there are highly infested plots in the vicinity) during the next monsoon. Sen Sarma and Mishra (1986) have also reported that local effort to control mikania was prevented due to reinvasion through wind borne seeds.

Of the four herbicides, application of triclopyr in combination with picloram is the best option to control mikania followed by triclopyr alone or glyphosate/diuron (Figs. 12 & 13). However, since the triclopyr based herbicides are not yet available in the Indian markets, use of either glyphosate (Roundup) or diuron is recommended. The cost of glyphosate is around Rs. 340/l and diuron Rs. 875/kg. It would be necessary to employ two casual workers (@ Rs. 150/day for each) for a day to apply the herbicide in a 1 ha area. Thus the total cost of applying one of these herbicides in low to highly mikania infested areas would range between Rs. 1,150-2,000/ha. This is much lower than the cost required for a single and thorough mechanical weeding of a 1 ha plantation area. In a general sense, 2,4-D and paraquat were also efficient, though not equally, but the efficacy lasts at the most for 3-4 months (120 days) only which is almost the same as manual weeding. Of the two, paraquat when used at the highest concentration (3 l/ha) was the best with regard to efficacy and longevity of WCE. It should be noted that biomass of the control plots was always significantly high ($P< 0.001$) compared to plots applied with different concentrations of all the herbicides.

The results from the second set of trials (January-February 2002) need be treated with caution since rains soon after the herbicidal application obscured the efficacy of the herbicides. Nevertheless, the data do confirm the efficacy of diuron, glyphosate (Roundup) and paraquat in weed control. Glycel, another glyphosate based herbicide, appears more or less equally efficient as Roundup. The data from these studies also reveal that knife weeding before herbicidal application is neither useful nor economical since

Fig. 12. Plot treated with triclopyr @ 1.75 l ha^{-1} (after 180 days of spray)

the apparent initial benefits disappear in a few weeks. Experiments on mechanical weeding indicated that it may be effective only for a period of 4-5 months in plots with medium level of infestation. The herbicidal applications during January - February showed that herbicidal applications after seed dispersal of mikania may not be effective for long-term control.

Of the various treatments where adjuvants were used along with herbicides, glyphosate (R) @ 7.5 ml/l added with ammonium sulphate @ 5 g/l) and diuron @ 2.5 g added with either 5 or 10 g/l of urea controlled the weed more effectively than the other herbicide-adjuvant combinations ($P< 0.05$). The WCE of these combinations were also significantly higher than herbicides applied without adjuvants ($P< 0.05$). Likewise, when different herbicides were combined, paraquat @ 2.5 – 7 ml/l with glyphosate @ 3.75 – 6.25 ml/l or diuron @ 2.5 – 12.5 g turned out to be better options for mikania control than individual application of each herbicide ($P< 0.05$) . More over, both of these combinations are attractive in the sense that paraquat is a contact herbicide and the other two systemic in action. Though the range of concentration given for each herbicide is

Fig. 13. Plot treated with glyphosate (R) @5 l ha^{-1} (after 180 days of spray)

wide, even the combination of lower concentrations were found highly effective. It may also be noted that use of combination of herbicides is more economical than using higher concentration of a single expensive herbicide. In another trial, diuron @ 5–7.5 ml/l added with glyphosate @ 10 ml/l was found equally effective as glyphosate alone @ 10 ml or 20 ml/l.

In plots applied with triclopyr based herbicides, the weed showed symptoms of wilting on the second day of spraying. Terminal parts of the weed including young leaves started drying up and mature leaves showed yellowing. Wilting, defoliation and death occurred between 20-30 days. As regards glyphosate (both Roundup and Glycel) and diuron, initial symptoms such as chlorosis and discoloration of the tender stem appeared after 3 to 4 days. Death of the plants occurred almost at the same time as in plots treated with triclopyr. In plots applied with the other herbicides, especially 2,4-D, appearance of initial symptoms was further delayed (5-7 days). Treatment with the contact herbicide paraquat resulted in wilting in a couple of days.

The time of herbicidal application has significant implications for long-term control since application after seed setting may not be very effective. During the current study, applications before flowering (September) and before seed dispersal (November) were found very effective compared to application after seed dispersal (January-February). Ideally, applications should be done during the active growth period of mikania and before flowering and seed setting (June to early September in Kerala). This way, fresh invasion through seeds from the same plot was avoided. Patterson (1995) has observed that most of the herbicides will be effective when applied at the rapidly growing and actively metabolizing period of the plants, typically when they are free from environmental stresses. Applications before seed dispersal may be effective, but it depends on how thorough the application is since the target of the herbicides will also include the minute seeds. Sreenivasan (2003) has reported that application of herbicides before seed setting in mikania is more efficient in controlling the weed than applications after seed setting.

Use of picloram in controlling mikania is reported from Malaysia and Indonesia (Faiz, 1992). It is generally used either in combination with 2,4-D or glyphosate. Sabudin and Teng (1986) reported that the combination of glyphosate and picloram was the best for efficient control of mikania in Malaysia. With this combination, only 10% of the weed re-growth was observed after 2 months of herbicidal application. The present study has also proved the efficacy of picloram in controlling mikania. Grazon (combination of triclopyr and picloram) is known to have only low toxicity to aquatic animals and is easily degradable. It is a selective, post emergence, systemic herbicide widely used for the control of weeds in several countries.

Glyphosate is extensively used for the long-term control of mikania in rubber, tea and oil palm plantations in many tropical and sub tropical countries (Wong, 1973; Parker, 1978; Ipor and Price, 1994). Earlier studies conducted in Kerala have also shown the efficacy of glyphosate in controlling mikania in rubber, eucalypt and teak plantations (Balasundaran, 1989; Abraham and Abraham, 1999a ; Sankaran *et al.*, 2001). According to Parker (1978), glyphosate at the rate 8 l/ha gave good control of the weed in Malaysia. The results of the prest study are in agreement with these reports. The dosage of glyphosate depended on the intensity of infestation and the number of applications required for effective control. Parker (1978) also reported that the action of glyphosate could be increased by the addition of the adjuvant ammonium sulphate. According to Hu and But (1994), glyphosate not only affect growth of mikania but also inhibit seed germination.

Paraquat is a commonly used post emergence contact herbicide for mikania management in rubber, tea and oil palm plantations (Seth, 1971; Parker, 1978; Teoh *et al.*, 1985; Ipor and Price, 1994). However, many workers found paraquat to be useful only for short-term control since vigorous re-growth was observed after a short while (Seth, 1971; Faiz *et al.*, 1982). In the current study, though efficacy of paraquat was found to last only for 3-4 months it showed higher WCE in combination with either glyphosate or diuron. According to Faiz *et al.* (1982), a combination of hexazinone and diuron (2 kg) mixed with 0.5 kg paraquat was more efficient in controlling mikania than paraquat and diuron separately. Likewise, a mixture of paraquat and glyphosate was also effective and gave good control of the weed in oil palm plantations in Malaysia (Lam *et al.*, 1993; Ipor and Price, 1994).

Ester and sodium salts of 2,4-D are widely used in several countries for controlling mikania (Seth, 1971; Palit, 1981; Caunter and Lee, 1996). Paraquat, 2,4-Damine, glyphosate and mixtures incorporating these are generally used for mikania management in Malaysia and Indonesia (Suharti and Sudjud, 1978; Teoh *et al.*, 1985). According to Abraham and Abraham (1999a), application of 2,4-D @ 0.50 and 1 kg/ha controlled mikania infestation in a pineapple and rubber plantation, respectively, in Kerala. Reports contrary to the efficacy of 2,4-D are also available in the literature, for eg., Balasundaran (1989) reported that 2,4-D is less effective than glyphosate in controlling mikania in the State. Moreover, Lam *et al.* (1993) have recorded that in Malaysia, the herbicidal action of 2,4-D amine and its salt combinations on mikania was not prolonged and high re-growth of the weed was observed after a while. Results of the present study have also shown the inefficacy of 2,4-D (sodium salt) in the long-term control of mikania compared to other herbicides including glyphosate and diuron (Fig. 14).

Wang *et al.* (1994) reported that 2,4-D is toxic to animal life and has relatively long and persistent residual action. Its volatilization is known to cause severe off-target damage. In Malaysia, since use of 2,4-D was found toxic to young oil palm, cocoa and coconut, its use has been restricted in such plantations (Teoh *et al.*, 1985). In the light of the above findings and the results of this study, it is suggested that use of 2,4-D compounds in controlling weeds in all ecosystems need be restricted or stopped.

Use of diuron at the rate of 1 kg/ha was found suitable for managing mikania growth in a pine apple plantation in Kerala (Abraham and Abraham 1999a). Results of the present study are in agreement with this report. Our results also show that addition of adjuvants with selected herbicides (glyphosate and diuron) enhanced activity of these herbicides. Parker

Fig. 14. Plot treated with 2,4-D (after 120 days of spray)

(1978) has reported the enhanced activity of glyphosate when added with ammonium sulphate in weed control in Malaysia. One advantage of the addition of adjuvants is that only a lower concentration of individual herbicides need be used for weed management. Gupta and Lamba (1978) have observed that the adjuvants do not act by increasing the innate activity of any herbicide but they aid in its availability in the region of the plant where it is most needed to produce best results. The mode of activity differed depending on the chemical that is used as adjuvant; e.g., some of the nitrogen fertilizers can break leaf cuticle and aid in the universal opening of the stomata. This facilitate easy entry of maximum amount of the herbicide into the weed facilitating quick action.

Manual weeding (knife weeding) of mikania commonly practiced by the State Forest Department and the farmers of Kerala appears to be more expensive compared to a single application of the herbicide glyphosate or diuron. A one time application of one of these herbicides at an appropriate concentration should take care of the mikania menace at least for one year. Since fresh growth may occur in the treated plots from wind - carried seeds, it may be necessary to repeat the application for a couple of years depending on the degree of re-infestation. Herbicidal applications should preferably be done before flowering/seed setting (August-September) and when the south-west monsoon rains have ceased. However, it should be noted that the continuous use of herbicides to control weeds is environmentally hazardous and cause toxicity problems if used in food crops. Moreover, they are unlikely to be useful as a long-term solution to the problem. Hence, suitable cost-effective and environmentally benign methods are to be developed urgently to combat the mikania menace.

4. Conclusions

- *Mikania micrantha*, the alien invasive weed widespread in Kerala, is expanding its range within the State and is likely to spread to the neighboring States in a short span of time. The invasion of the weed is recorded from almost all the ecosystems in the State including forest plantations, natural forests and agricultural systems.
- Level of infestation by mikania was higher in the central and southern zones than in the northern and high range zones in the State. Moist deciduous forests appear to be more vulnerable to infestation than other forest types. Intensity of infestation was high in disturbed forests; in undisturbed forests mikania was either scattered in distribution or absent. Sholas and grasslands in the high altitude areas are currently free from infestation.
- Among forest plantations, teak (especially 1 to 3-yr-old) was comparatively more heavily infested compared to eucalypts and acacia. In agricultural systems, level of infestation by mikania was negligible due to intensive management. However, the weed is a big menace in pineapple, banana, cassava and ginger gardens.
- Application of the herbicides glyphosate @ 2.5 – 5 l/ ha or diuron @ 1– 1.5 kg /ha (in 500 l water) is recommended for the control of mikania in forest plantations and natural reed growing areas. It is preferable to carry out the applications before flowering/seed setting of the weed (August-September). A single application of either of these herbicides, at the recommended dosage, may cost Rs. 1,150- 2,000/ha. The highest concentration need be used only in severely infested areas.
- Though a single application of the herbicide may keep the weed under control in a given area for a period of more than a year, re-growth may occur in certain areas through wind-borne seeds, especially at the beginning of the monsoon each year. It may therefore be necessary to repeat the annual application for next few years, depending on the severity of re-infestation.
- The efficacy of paraquat (1– 2 l /ha) and 2,4-D (0.5 – 1 kg/ ha) was short lived and hence may not be useful for the long- term control of the weed. Since 2,4-D is toxic to animal life and it has a relatively long and persistent residual action, it is suggested that the use of 2,4-D need be curbed in all ecosystems.
- Addition of the adjuvant ammonium sulphate @ 2.5 kg/ha with glyphosate @ 3.75 l/ha increased the weed control efficacy (WCE) of the herbicide. Likewise, combination of diuron @ 1.25 kg/ha with urea (adjuvant) @ 2.5 kg/ha was also better in controlling the weed as compared to the use of diuron alone.
- Combination of the herbicides *viz.*, glyphosate (3.75 l/ha) with paraquat (2.5 l/ha) and diuron (1.25 kg/ha) with paraquat (1.5 l/ha) increased the efficacy of all the three herbicides compared to individual applications.
- Manual weeding of mikania in forest plantations appears to be a more expensive option when compared to a single application (per yr) of glyphosate or diuron at the recommended concentrations. However, it is cautioned that repeated use of herbicides in any ecosystem will be environmentally damaging and may cause toxicity if used in food crops. The herbicidal applications recommended here may strictly be treated as a short-term solution for the mikania problem until a more cost-effective and environmentally benign method is developed.

5. Recommendations

This study shows that mikania infestation in forest plantations and natural forests in the State could be managed by herbicidal application. The cost of one herbicidal application (including cost of herbicides and labour charges) works out to about Rs. 1,150 - 2,000 per hectare. The following recommendations are made to manage mikania infestation.

1. Sites with low to moderate infestation of mikania may be treated with 2.5 l of glyphosate or 1 kg of diuron, mixed with 500 l of water per ha. A surfactant like Plantowet (100 ml) may be added to the solution and mixed thoroughly. This may be sprayed evenly to cover the entire growth of mikania using knapsack sprayers fitted with high volume flood jet nozzles.

2. Sites with very high infestation will have to be treated with a higher concentration of glyphosate (@ 4 - 5 l/ha) or diuron (1.5 kg/ha). Alternatively, use of glyphosate @ 3.75 l/ha added with 2.5 kg of ammonium sulphate or diuron @ 1.25 kg/ha added with 2.5 kg of urea will also give adequate control.

3. Herbicidal application should preferably be carried out during the months of August-September before the initiation of flowering/seed setting of mikania. Applications should be carried out on non-rainy days since rainfall within 48 hr of herbicidal spray will reduce the efficacy of the herbicides.

4. Though a single application of the proposed herbicide/s at the given concentrations will provide long-term control, repeated yearly applications may be necessary, at least for a few years, wherever reinvasion (especially after the monsoon) is a problem through wind-borne seeds.

5. Extreme care should be taken to avoid the herbicide solution falling on stem/leaves of plantation/non-target species.

6. Care should be taken to avoid skin and eye contact and inhalation of spray mist while applying the herbicides. Also, care should be taken to avoid contamination of fertilizers, seed, feed, foodstuff or water by storage or disposal of the herbicides.

The herbicidal applications recommended in this report may strictly be treated as a short-term solution for mikania control until alternative cost-effective and eco-friendly methods are developed.

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Appendix 1

Localities surveyed for the occurrence and severity of infestation by *Mikania micrantha* in Kerala during the project period (1999-2003). (A complete list of the localities surveyed (402) is available with the authors.)

Sl No	District	Forest Division	Forest Range	Place surveyed	Production system	Grade of infes-tation
1	Alapuzha	-	-	Kuthiyathodu	Agriculture	5
2	Alapuzha	-	-	Kainakari	Agriculture	5
3	Alapuzha	-	-	Ponga	Agriculture	5
4	Alapuzha	-	-	Purakkad	Agriculture	0
5	Alapuzha	-	-	Ramankavu	Agriculture	5
6	Alapuzha	-	-	Plakkary	Agriculture	2
7	Alapuzha	-	-	Ayodu	Agriculture	5
8	Alapuzha	-	-	Nedumudi	Agriculture	4
9	Ernakulam	Malayattur	Kaladi	Mallana	Teak	5
10	Ernakulam	Kothamangalam	Kothamangalam	Thalikulam	Teak	5
11	Ernakulam	Kothamangalam	Mullaringad	Mullaringad	Moist deciduous	4
12	Ernakulam	Malayattur	Kodanadu	Panali Section	Moist deciduous	5
13	Ernakulam	Malayattur	Kodanadu	Bhagavathykulam	Teak	5
14	Ernakulam	Malayattur	Thundathil	Edamalayar	Moist deciduous	4
15	Ernakulam	Malayattur	Thundathil	Thalumkandam	Medicinal garden	1
16	Ernakulam	Malayattur	Thundathil	Thundathil	Teak	4
17	Ernakulam	Malayattur	Thundathil	Sakthimedu	Teak	4
18	Ernakulam	Malayattur	Thundathil	Thali section	Semi-evergreen	5
19	Ernakulam	Malayattur	Thundathil	Edamalayar Dam	Semi-evergreen	5
20	Ernakulam	Malayattur	Thundathil	Edamalayar	Teak	5
21	Ernakulam	Malayattur	Kalady	FACT Campus	Industrial area	5
22	Ernakulam	Malayattur	Mullaringad	Thalakodu	Albizia	5
23	Ernakulam	Malayattur	Kuttampuzha	Kottappara	Eucalyptus	5
24	Ernakulam	Malayattur	Kuttampuzha	Kottappara	Moist deciduous	5
25	Ernakulam	Malayattur	Kuttampuzha	HNL plantation	Acacia	3
26	Ernakulam	Kothamangalam	Kaliyar	Pachila	Teak	5
27	Ernakulam	Kothamangalam	Kaliyar	Veloor	Teak	5
28	Ernakulam	-	-	N. Paravur	Agriculture	3
29	Ernakulam	-	-	Ayakkad	Agriculture	5
30	Ernakulam	-	-	Kottappady	Agriculture	5
31	Ernakulam	-	-	Nedugur	Agriculture	0
32	Ernakulam	-	-	Nellimattom	Agriculture	2

33	Ernakulam	-	-	Edappilly	Agriculture	2
34	Ernakulam	-	-	Kuvappadam	Agriculture	2
35	Ernakulam	Kothamangalam	Mullaringad	Perumbavoor	Eucalyptus	3
36	Ernakulam	Kothamangalam	Mullaringad	Kaladyplantation	Eucalyptus	5
37	Ernakulam	Kothamangalam	Mullaringad	Manjummal	Eucalyptus	5
38	Ernakulam	Malayattur	Kuttampuzha	Anapuzha	Eucalyptus	2
39	Ernakulam	-	-	Vyttila	Agriculture	3
40	Ernakulam	-	-	Welligton Island	Agriculture	1
41	Ernakulam	Kothamangalam	Mullaringad	Kappakkadu	Moist deciduous	3
42	Ernakulam	Kothamangalam	Mullaringad	Thappanikkadu	Moist deciduous	4
43	Ernakulam	Kothamangalam	Mullaringad	Kuttichira	Moist deciduous	5
44	Ernakulam	Kothamangalam	Mullaringad	Aruvimedu	Moist deciduous	5
45	Ernakulam	Kothamangalam	Kuttampuzha	Mullil	Moist deciduous	3
46	Ernakulam	Kothamangalam	Kuttampuzha	Meloor	Moist deciduous	2
47	Ernakulam	Kothamangalam	Thundathil	Maravathur	Moist deciduous	3
48	Idukki	Munnar	Adimali	Machiplavu	Teak	5
49	Idukki	Munnar	Adimali	200 Acre	Teak	3
50	Idukki	Munnar	Adimali	Pullakandam	Eucalyptus	4
51	Idukki	Munnar	Devikolam	Surianelli	Eucalyptus	0
52	Idukki	Munnar	Devikolam	Kacheriland	Eucalyptus	0
53	Idukki	Munnar	Chinnar	Chullipetty	Dry deciduous	5
54	Idukki	Munnar	Marayoor	Marayoor	Semi- evergreen	0
55	Idukki	Munnar	Neriyamangalam	Villingia	Moist deciduous	5
56	Idukki	Munnar	Marayoor	Vattavada	Eucalyptus	0
57	Idukki	Munnar	Marayoor	Vattavada	Shola	0
58	Idukki	Munnar	Adimali	Valara	Moist deciduous	5
59	Idukki	Munnar	Munnar	Mattupetty	Eucalyptus	0
60	Idukki	Munnar	Devikolam	Kolukkumalai	Eucalyptus	0
61	Idukki	Munnar	Devikolam	Kundala Dam	Eucalyptus	0
62	Idukki	Munnar	Marayoor	Top station	Eucalyptus	0
63	Idukki	Munnar	Adimali	Mayiladumpara	Eucalyptus	2
64	Idukki	Munnar	Adimali	Cherutoni	Eucalyptus	0
65	Idukki	Munnar	Marayoor	Vattavada	Grass land	0
66	Idukki	Munnar	Marayoor	Valsapetty	Grass land	0
67	Idukki	Munnar	Devikolam	Chokkanad	Eucalyptus	0
68	Idukki	Munnar	Devikolam	Idallimotta	Grassland	0
69	Idukki	Munnar	Devikolam	Kolukkumalai	Grassland	0
70	Idukki	Munnar	Marayoor	Pudhukkudishola	Shola	0
71	Idukki	Munnar	Chinnar	Nallala	Dam site	0
72	Idukki	Munnar	Marayur	Marayur	Sandal	0
73	Idukki	Munnar	Eravikulam NP	Rajamala	Shola	0
74	Idukki	Munnar	Neriyamangalam	Neriyamangalam	Teak	5
75	Kannur	-	-	Edakkad	Agriculture	2
76	Kannur	-	-	Mattanur	Agriculture	1

77	Kannur	-	-	Sreekandapuram	Agriculture	3
78	Kannur	Kannur	-	Kalliassery	Agriculture	0
79	Kannur	Kannur	-	Aralam farm	Agriculture	5
80	Kannur	-	-	Thandiyil	Agriculture	2
81	Kannur	Kannur	Aralam	Chettamparamba	Evergreen	3
82	Kannur	Kannur	Aralam	Adakkathodu	Evergreen	3
83	Kannur	Kannur	Kottiyur	Perappara	Evergreen	0
84	Kannur	Kannur	Kannavam	Kommery	Semi evergreen	0
85	Kannur	-	-	Pappinisseri	Agriculture	5
86	Kannur	Kannur	Talipparamba	Pariyaram	Acacia	0
87	Kannur	Kannur	Kasaragod	Ezhimala'	Casuarina	0
88	Kannur	Kannur	Periya	Periya	Cashew	0
89	Kannur	Kannur	Periya	Makki	Moist deciduous	2
90	Kannur	Kannur	Periya	Palikkara	Agriculture	0
91	Kannur	-	-	Chalode	Agriculture	5
92	Kannur	-	-	Chooliyad	Agriculture	0
93	Kannur	-	-	Irikkur	Agriculture	2
94	Kannur	-	-	Narath	Agriculture	3
95	Kannur	-	-	Puthiyedam	Agriculture	3
96	Kannur	Kannur	Kottiyur	Kottiyur	Semi-evergreen	2
97	Kannur	Kannur	Kottiyur	Chathirurmala	Semi-evergreen	0
98	Kannur	Kannur	Thaliparamba	Paithalmala	Semi-evergreen	0
99	Kannur	Kannur	Kannvam	Kannvam	Semi-evergreen	1
100	Kannur	Kannur	Aralam	Thullal	Moist deciduous	2
101	Kannur	Kannur	Kannvam	Kolayad	Semi-evergreen	5
102	Kannur	Kannur	Kottiyur	Palchuram	Semi-evergreen	1
103	Kasaragod	Kannur	Kasaragod	Payyannur	Casuarina	0
104	Kasaragod	Kannur	Kasaragod	Bella	Casuarina	0
105	Kasaragod	Kannur	Kasaragod	Nileshwaram	Agriculture	0
106	Kasaragod	-	-	Pakkam	Agriculture	0
107	Kasaragod	-	-	Pallikkara	Agriculture	0
108	Kasaragod	Kannur	Kasaragod	Bonikkanam	Casuarina	0
109	Kasaragod	Kannur	Kasaragod	Mundinkunnu	Semi-evergreen	0
110	Kasaragod	Kannur	Kasaragod	Minnakulam	Semi-evergreen	0
111	Kasaragod	Kannur	Kasaragod	Parappara	Semi-evergreen	0
112	Kasaragod	Kannur	Kasaragod	Iriyanni	Moist deciduous	0
113	Kasaragod	Kannur	Kanhngad	Chemmattamvayal	Acacia	0
114	Kasaragod	Kannur	Kasaragod	Peroor	Cashew	0
115	Kasaragod	Kannur	Kanhngad	Anandashramam	Cashew	0
116	Kasaragod	Kannur	Kanhngad	Chammattam vayal	Casuarina	0
117	Kasaragod	Kannur	Kanhngad	Ramnagar	Acacia	0
118	Kasaragod	-	-	Uduma	Agriculture	0
119	Kollam	Punalur	Pathanapuram	Pookulanji	Eucalyptus	1
120	Kollam	Punalur	Pathanapuram	Karavoor	Eucalyptus	3

121	Kollam	Punalur	Pathanapuram	Piravanthur	Eucalyptus	0
122	Kollam	Punalur	Pathanapuram	Vilakkuvattam	Eucalyptus	0
123	Kollam	Punalur	Pathanapuram	Kadakkamon	Eucalyptus	1
124	Kollam	Punalur	Anchal	Chandanakavu	Moist deciduous	3
125	Kollam	Punalur	Anchal	Vattaman	Eucalyptus	0
126	Kollam	-	-	Kundara	Agriculture	5
127	Kollam	-	-	Nannanthodu	Agriculture	2
128	Kollam	Achankovil	Kallar	Kallar	Moist deciduous	2
129	Kollam	Thenmala	Shendhurny	Shendhurny	Moist deciduous	2
130	Kollam	Punalur	Pathanapuram	Chagarappara	Moist deciduous	5
131	Kollam	Thenmala	Thenmala	Thenmala	Moist deciduous	5
132	Kollam	Achankovil	Achankovil	Achankovil	Semi-evergreen	3
133	Kollam	Thenmala	Ariyankavu	Ariyankavu	Semi-evergreen	3
134	Kollam	-	-	Chavara	Sea shore	0
135	Kollam	-	-	Neendakara	Sea shore	0
136	Kottayam	Kottayam	Nagarampara	Nagarampara	Moist deciduous	5
137	Kottayam	Kottayam	Ayyappankovil	Mattuppally	Eucalyptus	1
138	Kottayam	-	-	Irattupetta	Agriculture	0
139	Kottayam	-	-	Pala	Agriculture	3
140	Kottayam	-	-	Thiruvalla	Agriculture	3
141	Kottayam	-	-	Kanjirapalli	Agriculture	1
142	Kottayam	Kottayam	Erumeli	Erumeli	Teak	5
143	Kottayam	Kottayam	Ayyappankovil	Ayamthodu	Moist deciduous	5
144	Kottayam	Kottayam	Ayyappankovil	Maradu	Moist deciduous	2
145	Kottayam	Kottayam	Ayyappankovil	Vallikayam	Moist deciduous	5
146	Kozhikode	Kozhikode	Kuttiyadi	Karavannur	Evergreen	1
147	Kozhikode	Kozhikode	Kuttiyadi	Nallalam	Evergreen	0
148	Kozhikode	Kozhikode	Kuttiyadi	Nettissery	Evergreen	2
149	Kozhikode	Kozhikode	Thamarassery	6th Hairpin	Evergreen	1
150	Kozhikode	Kozhikode	Thamarassery	Manavilangu	Evergreen	0
151	Kozhikode	Kozhikode	Thamarassery	Chengara	Evergreen	4
152	Kozhikode	Kozhikode	Peruvannamuzhi	Vadappathi	Evergreen	2
153	Kozhikode	Kozhikode	Peruvannamuzhi	Thenkara	Moist deciduous	2
154	Kozhikode	Kozhikode	Peruvannamuzhi	Tharakudi	Moist deciduous	0
155	Kozhikode	Kozhikode	Peruvannamuzhi	Thanissery	Moist deciduous	0
156	Kozhikode	Kozhikode	Peruvannamuzhi	Tiruvambadi	Moist deciduous	3
157	Kozhikode	Kozhikode	Peruvannamuzhi	Peruvannamoozhi	Moist deciduous	4
158	Kozhikode	Kozhikode	Kuttyadi	Kuttyadi	Moist deciduous	2
159	Malappuram	Nilambur	Edavanna	Mundanthodu	Moist deciduous	2
160	Malappuram	Nilambur	Karulai	Nedumkayam	Teak	0
161	Malappuram	Nilambur	Karulai	Puchenkolly	Moist deciduous	0
162	Malappuram	Nilambur	Karulai	Vattikkal	Moist deciduous	0
163	Malappuram	Nilambur	Kalikavu	Parayanmedu	Moist deciduous	0
164	Malappuram	Nilambur	-	Muttikadavu	Agriculture	2

165	Malappuram	Nilambur	Vazhikadavu	Nadukani	Semi-evergreen	0
166	Malappuram	-	-	Karimpuzha	Teak	1
167	Malappuram	-	-	Thengippalam	Agriculture	1
168	Malappuram	-	-	Kottakkal	Agriculture	2
169	Malappuram	-	-	Kuttippuram	Agriculture	0
170	Malappuram	-	-	Thavanur	Agriculture	0
171	Malappuram	Nilambur	Karulai	Karamthodu	Moist deciduous	2
172	Malappuram	Nilambur	Karulai	Naikkatty	Moist deciduous	0
173	Malappuram	Nilambur	Karulai	Pulikkotta	Moist deciduous	3
174	Malappuram	Nilambur	Karulai	Meenmutti	Moist deciduous	0
175	Malappuram	Nilambur	Edavanna	Pachakkanam	Semi-evergreen	1
176	Malappuram	Nilambur	Edavanna	Maruthanthodu	Semi-evergreen	1
177	Malappuram	Nilambur	Edavanna	Mannankuzhi	Semi- evergreen	2
178	Palakkad	Nemmara	Nelliampathi	Nelliampathi	Moist deciduous	3
179	Palakkad	Nemmara	Alattur	Odamthodu	Teak	0
180	Palakkad	-	-	Mambad	Wet land	2
181	Palakkad	Olavakod	Walayar	Nadampadam	Moist deciduous	0
182	Palakkad	Olavakkod	Walayar	Dhoni	Teak	0
183	Palakkad	Mannarkkad	Agali	Kalkandi	Acacia	0
184	Palakkad	Mannarkkad	Agali	Nadavu	Moist deciduous	2
185	Palakkad	Mannarkkad	Agali	Karimudi	Moist deciduous	3
186	Palakkad	Mannarkkad	Agali	Kattumala	Moist deciduous	2
187	Palakkad	Mannarkkad	Agali	Kurisadi	Moist deciduous	1
188	Palakkad	Mannarkkad	Agali	Karadippara	Moist deciduous	1
189	Palakkad	Parambikulam	Parambikulam	Kuriarkutti	Moist deciduous	5
190	Palakkad	Parambikulam	Parambikulam	Orukambil	Moist deciduous	5
191	Palakkad	Parambikulam	Parambikulam	Sunkam	Moist deciduous	4
192	Palakkad	Mannarkkad	Attappadi	Gottiyakandi	Moist deciduous	0
193	Palakkad	Mannarkkad	Attappadi	Chathanpara	Moist deciduous	0
194	Palakkad	Mannarkkad	Agali	Cholakkad	Semi-evergreen	0
195	Palakkad	Mannarkkad	Mannarkkad	Mannarkkad	Teak	2
196	Palakkad	Parambikulam	Parambikulam	Parambikulam	Teak	5
197	Palakkad	Parambikulam	Parambikulam	Sunkam	Teak	5
198	Pathanamthitta	Achankovil	Kanayar	Alakodi	Teak	5
199	Pathanamthitta	Achankovil	Kanayar	Pulikkayam	Teak	5
200	Pathanamthitta	Ranni	Vadasserikkara	Adukuzhi	Moist deciduous	5
201	Pathanamthitta	Ranni	Vadasserikkara	Chengara	Teak	5
202	Pathanamthitta	Ranni	Ranni	Ranni	Teak	5
203	Pathanamthitta	Ranni	Goodrickal	Chalakkayam	Moist deciduous	5
204	Pathanamthitta	Ranni	Goodrickal	Pookkavanam	Teak	5
205	Pathanamthitta	Ranni	Goodrickal	Pookkavanam	Moist deciduous	5
206	Pathanamthitta	Konni	Naduvathumuzi	Naduvathumuzi	Teak	5
207	Pathanamthitta	Konni	Konni	Konni	Teak	5
208	Pathanamthitta	Konni	Manappara	Manappara	Evergreen	3

209	Pathanamthitta	Ranni	Goodrickal	Muzhiyar	Evergreen	3
210	Pathanamthitta	Ranni	Goodrickal	Kakki	Evergreen	0
211	Pathanamthitta	-	-	Pathayamkundu	Agriculture	2
212	Pathanamthitta	-	-	Plamoodu	Agriculture	3
213	Pathanamthitta	-	-	Elinjipra	Agriculture	2
214	Pathanamthitta	-	-	Plakkal	Agriculture	2
215	Pathanamthitta	-	-	Nilakkal	Agriculture	1
216	Pathanamthitta	-	-	HarrisonMalayalam	Rubber	3
217	Pathanamthitta	Ranni	Vadasserikkara	Laha	Teak	3
218	Thiruvananthapuram	Thiruvananthapuram	Peppara WLS	Udayankulangara	Eucalyptus	3
219	Thiruvananthapuram	Thiruvananthapuram	Peppara WLS	Kazhakuttam	Eucalyptus	5
220	Thiruvananthapuram	Thiruvananthapuram	Peppara WLS	Pathi	Moist deciduous	5
221	Thiruvananthapuram	Thiruvananthapuram	Palod	Chuliamala	Eucalyptus	3
222	Thiruvananthapuram	Thiruvananthapuram	Palod	Peringamala	Eucalyptus	1
223	Thiruvananthapuram	Thiruvananthapuram	Kolathupuzha	Ponmudi	Grassland	0
224	Thiruvananthapuram	-	-	Vellayani	Agriculture	0
225	Thiruvananthapuram	-	-	Kattakkada	Agriculture	0
226	Thiruvananthapuram	-	-	Neyyattinkara	Agriculture	0
227	Thiruvananthapuram	-	-	Nedumangad	Agriculture	2
228	Thiruvananthapuram	-	-	Thirumala	Agriculture	2
229	Thrissur	Vazhachal	Athirappilly	Kadavu	Reed	3
230	Thrissur	Vazhachal	Athirappilly	Athirappilly	Reed	5
231	Thrissur	Vazhachal	Athirappilly	Ezhattumugham	Reed	4
232	Thrissur	Vazhachal	Athirappilly	Kadavu	Teak	5
233	Thrissur	Chalakudi SF	Chalakudi SF	Kannankuzhi	Reed	3
234	Thrissur	Chalakudi SF	Chalakudi SF	Nirappel	Reed	3
235	Thrissur	Chalakudi SF	Chalakudi SF	Samara block	Mixed plantation	5
236	Thrissur	Vazhachal	Charpa	Charpa fall	Reed	4
237	Thrissur	Vazhachal	Charpa	Charpa fall	Moist deciduous	5
238	Thrissur	Vazhachal	Charpa	Ponjanamkuthu	Teak	5
239	Thrissur	Vazhachal	Charpa	Charpathodu	Teak	5
240	Thrissur	Vazhachal	Charpa	Charpa	Moist deciduous	5
241	Thrissur	Vazhachal	Charpa	Nelliblock	Teak (1991)	5
242	Thrissur	Vazhachal	Charpa	Nelliblock	Teak (1985)	5
243	Thrissur	Vazhachal	Kollathirumedu	Choozhimedu	Reed	5
244	Thrissur	Vazhachal	Kollathirumedu	Palachuvadu	Teak	5
245	Thrissur	Vazhachal	Kollathirumedu	Choozhimedu	Mixed plantation	5
246	Thrissur	Vazhachal	Kollathirumedu	Amminipocket	Teak	4
247	Thrissur	Vazhachal	Kollathirumedu	Anamucku	Reed	4
248	Thrissur	Vazhachal	Kollathirumedu	Vachumaram	Reed	5
249	Thrissur	Vazhachal	Kollathirumedu	Puliyilappara	Teak	5
250	Thrissur	Vazhachal	Sholayar	Kummatti	Reed	5
251	Thrissur	Vazhachal	Sholayar	Kummatti	Reed	5
252	Thrissur	Vazhachal	Sholayar	Malakkappara	Reed	5

253	Thrissur	Vazhachal	Sholayar	Tunnel point	Reed	4
254	Thrissur	Vazhachal	Sholayar	Powerhouse	Reed	4
255	Thrissur	Vazhachal	Kollathirumedu	Thavalakuzhippara	Teak	5
256	Thrissur	Vazhachal	Vazhachal	Pokalappara	Reed	4
257	Thrissur	Vazhachal	Charpa	Poringal	Teak	4
258	Thrissur	Vazhachal	Charpa	Irumbupalam	Teak (1979)	5
259	Thrissur	Vazhachal	Charpa	Irumbupalam	Teak (1985)	5
260	Thrissur	Vazhachal	Charpa	Irumbupalam	Eucalyptus	5
261	Thrissur	Vazhachal	Charpa	Karamthodu	Acacia	5
262	Thrissur	Vazhachal	Vazhachal	Lakshmi	Bamboo	5
263	Thrissur	Vazhachal	Vazhachal	Lakshmi	Acacia	5
264	Thrissur	Vazhachal	Vazhachal	Anakkayam	Reed	3
265	Thrissur	Vazhachal	Kollathirumedu	Kollathirumedu	Eucalyptus	5
266	Thrissur	Vazhachal	Vazhachal	Lakshmi	Eucalyptus	5
267	Thrissur	Chalakudi	Pariyaram	Palappilli	Teak	4
268	Thrissur	Thrissur	Chimmony WLS	Chimmony	Teak	5
269	Thrissur	Thrissur	Chimmony WLS	Chimmony	Moist deciduous	5
270	Thrissur	Thrissur	Machad	Kayampoovam	Teak	0
271	Thrissur	Thrissur	Peechi-Vazhani	Peechi	Moist deciduous	3
272	Thrissur	Thrissur	Pattikkad	Vellanipacha	Moist deciduous	4
273	Thrissur	Thrissur	Pattikkad	Banasuramala	Moist deciduous	0
274	Wayanad	Wayanad	Muthanga	Nellurvayal	Moist deciduous	0
275	Wayanad	Wayanad	Muthanga	Muthanga	Eucalyptus	0
276	Wayanad	Wayanad	Sultanbathery	Sultanbathery	Moist deciduous	0
277	Wayanad	Wayanad	Chethalath	Kuppadi	Moist deciduous	0
278	Wayanad	Wayanad	Chethalath	Kuppadi	Eucalyptus	0
279	Wayanad	Wayanad	Begur	Begur	Moist deciduous	0
280	Wayanad	Wayanad	Begur	Begur	Teak	0
281	Wayanad	Wayanad	Tholpetty	Tholpetty	Moist deciduous	0
282	Wayanad	Wayanad	Tholpetty	Kutta	Teak	0
283	Wayanad	Wayanad	Tholpetty	Thirunelli	Eucalyptus	1
284	Wayanad	Wayanad	Tholpetty	Thirunelli	Semi-evergreen	0
285	Wayanad	Wayanad	Meppadi	Srambivalavu	Eucalyptus	0
286	Wayanad	Wayanad	Meppadi	Vallarpady	Moist deciduous	0
287	Wayanad	Wayanad	Kurichiyad	Kurichiyad	Moist deciduous	0
288	Wayanad	Wayanad	Kurichiyad	Kurichiyad	Teak	0