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Management of Prosopis juliflora through Chemicals: A Case Study in India

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Abstract
Prosopis juliflora is popularly known as Honey Mesquite in the western world, commonly known as mesquite in India and popularly known as Bellary Jali in Karnataka. *Prosopis* is fast growing, salt-tolerant and drought-tolerant trees that can grow in an areas receiving as little as 50 mm of rainfall per year. This is a rhizomatous perennial weed dominating an important part of productive agricultural lands in most of the developing countries including India. It tolerates traditional methods of weed control such as soil solarisation and mechanical methods. This study was carried out to manage this weed with the available herbicides on cultivated land at the Main Agricultural Research Station, University of Agricultural Sciences Campus, Raichur in Karnataka State in southern India during 2009 to 2011. Several easily available herbicides were used including Mera – 71 (Glyphosate), Paraquat, 2, 4-D amine and ester, Diuron, Keroscene and Coaltar as individual chemicals with different concentrations and combination of chemicals were also tried. The study results reveal that all treatments except diuron / keroscene / coaltar conmbinations reduced growth and development of *Prosopis juliflora.* Mera-71, 2, 4-D ester followed by paraquat were the best in affecting weed recovery. Results also indicates that the control of regrowth of *Prosopis juliflora* is effectively achieved by two times applications of systemic translocated herbicides such as Mera-71 (Glyphosate) and 2,4- found better as compared to paraquat, diuron and other farmer practices.
Keywords: *Prosopis juliflora*, Mangement, Glyphosate, 2,4-D, Paraquat, Diuron, Keroscene

Introduction

Exotic plant species have been purposely and/or accidentally introduced throughout the world due to their economic, environmental or aesthetic values. Nonetheless, introduction of new species is not always a success and brings about the possibility of invasiveness of the species which in turn result in negative impacts (economic, environmental and social). Encroachment of rangelands by invasive species, reduction of crop yield, genetic erosion of biodiversity, disruption of water flow, poisoning of livestock, formation of impenetrable thickets, etc are some of the impacts of invasive species across a wide range of agro-ecologies.

There are many species in the genus Prosopis like *Prosopis juliflora, Prosopis pallida, Prosopis chilensis, Prosopis alba, Prosopis pubescens* and *Prosopis tamarugo* are all species that are native to the America, but have now become established in arid and semiarid Australia, Africa and Asia. *Prosopis cinerarium is* native to India, while *Prosopis africana* is native to the Sahelian belt of Africa (Ahmed *et al.*, 2009). *Prosopis* is a fast growing, salt-tolerant and drought-tolerant tree that can grow in an areas receiving as little as 50 mm of rainfall per year. There is great controversy surrounding *Prosopis juliflora*, if it is unmanaged, it often colonizes, eroded and over-grazed lands, forming dense impenetrable thickets. Thickets of *Prosopis juliflora* have become established in grazing lands, crop lands and along river courses, alarming pastoralists, farmers and conservationists. There is a great concern on the impacts of the tree on biodiversity of native plants and on the amount of water in dryland streams. *Prosopis* species have been declared noxious weeds in many countries, including Argentina, Australia, South Africa, Pakistan and Sudan (Al-Sherif, 2007) and *P. juliflora* is now one of the top global invasive plant species according to the International Union for Conservation of Nature (IUCN). On the other hand, *Prosopis juliflora* has proved useful in restoring degraded and saline lands, producing a variety of useful products for the local populations. *Prosopis juliflora* has potential as a source of fuel wood, timber, honey and animal forage. *Prosopis juliflora* was introduced in India in the last century and was thought to be a very promising species for aforestation of dry and degraded land. However, its environmental benefits and economic potential are increasingly overshadowed by some of its undesirable properties. But it cannot be kept uncontrolled as it occupied the cultivable area if not properly controlled, thereby giving a big threat to the Indian agriculture. The experiences from other countries shows that control of *Prosopis* is extremely difficult and costly to eradicate once it take root. Hence, it is an urgent need to find out the ways and means of controlling this menace. In this direction, a research study was conducted at the Main Agriculture Research Station, University of Agricultural Sciences, Raichur, Karnataka to know the effect of selective herbicides on *Prosopis juliflora.*

Material and methods

Experiments were conducted during 2009 to 2011 at MARS, UAS Raichur (Figure 1) on medium to deep black cotton soils (vertisols). The different stem thickness of *Prosopis juliflora* plants have been selected in three different sites as per the technical programme. Four different available herbicides namely glyphosate, 2, 4-D, paraquat and diuron were sprayed with different concentration as well as smeared the cut portion of the *Prosopis juliflora* with the help of cotton web. Apart from this the farmer practices like spraying kerosene, hot salt water and burning the plant and applying the coaltar to the cut portion of the plant were also tried.

Evaluations were conducted after nine months of first spray to allow sufficient time for herbicidal action to be completed and resprouting to occur. Within each spot 20 to 25 individual *Prosopis juliflora* plants were examined based on the stem girth size and grouped in to 3 stem size classes: < 1 cm = class I : 1-2 cm = class II and > 2 cm = class III. The number of basal supporting stems was counted for each plant. Stems were considered independent if branching occurred within 15 cm above ground level. Trees were grouped arbitrarily into 3 stem number categories for statistical analysis 1 to 2 stems = single stemmed; 3 to 5 stems = few-stemmed; and > 6 stems = many stemmed. After nine months of second application stem and root of *Prosopis juliflora* were studied to know the effect of the applied herbicides on the plant internal system. Some of the chemicals have shown effective results on xylem and phloem activities and also hinders the root system.

Data were processed by analysis of variance used percent plant mortality for each stem number class by stem thickness class and plot within a treatment as a data point. Percentage data were calculated (arcsin $\sqrt{x}$) and prior to analysis interactions were evaluated for stem number class x stem thickness class, stem number class X herbicide, and stem thickness class X herbicides, stem number class X Stem thickness class X herbicide, and each combination.

Results

Growth and development of *Prosopis juliflora* varied with different herbicides applications (Table 1 & 2). Mera-71 (Glyphosate and 2, 4- D) were almost twice as effective as paraquat and 3 times as effective as Diuron. Combination of herbicides (Mera-71 and 2, 4- D) controls the *Prosopis juliflora* growth better than the individual application.

Plant stem thickness (indirectly indicates age) of *Prosopis juliflora* also influenced by the different herbicides formulations. The higher concentrations of herbicides have more effective than the lower concentrations. Early stage plants (stem thickness size < 1 cm and 1-2 cm) are more susceptible to herbicides effect than the later stage plants (>2cm stem thickness)

Prosopis juliflora susceptibility to different herbicides was strongly influenced by individual tree stem number. Resistance increased proportionally with increasing stem numbers, averaging 46 - 60, 30 - 40 and 10 - 30 % for single, few and many stemmed trees. Among the herbicides Mera-71 @ 40 gm/ltr followed by 2,4-D @10 gm/ltr found to be effective than the paraquat @ 30 ml/ltr and diuron @ 5 gm/ltr across all stem thickness sizes (Table 3).

Among the methods of applications of herbicides, smearing the herbicide to cut portion of *Prosopis juliflora* found better than the spraying method especially in aged plants. But in early stage plants both methods found better. Similarly with in each stem thickness class by herbicides, resistance increased with increasing stem number, illustrating why interactions among herbicides, plant stem thickness and stem number were insignificant. Although efficacy for any particular herbicide fluctuated with the different tests, single stemmed trees were consistently more susceptible than either few or many stemmed plants of *Prosopis juliflora*.

After nine months of second spray stem and root internal systems were studied to know the effect of herbicides on the *Prosopis juliflora*. The observations confirms that the early stage (stem thickness <1cm and 1-2 cm) plants internal systems were collapsed (xylem and phloem cells of stem were died) due to the effect of these systemic herbicides. But the internal systems of later stage (stem thickness >2 cm) plants were partially functioning.

Apart from testing only herbicides, farmers' practices like spraying with kerosene, hot salt water followed by burning and smearing with coal tar were also tried. But the results of these treatments were not effective as that of herbicides.

Discussion

Chemical treatments involve the use of herbicides to kill trees, with the most effective being stem or aerial applications of systemic herbicides. Effectiveness is dependent upon chemical uptake, which in *Prosopis* is limited by the thick bark, woody stems and small leaves with a protective waxy outer layer. The choice of herbicides, the correct application method, dosage, time of application and follow-up actions are very important.

The formulation and application of chemicals for trees of mixed ages and sizes within a stand is difficult. Many herbicides and herbicide mixtures have been tested, mostly on *Prosopis juliflora*. According to Our result, it was showed that Combination of herbicides (Mera-71 and 2, 4- D) controls the *Prosopis juliflora* growth and development better than the individual applications. However the management method was influenced by the thickness and number of stem per plant due to the fact that the bigger thickness and more number of stem were inspired more concentration of herbicide than the smaller ones.

In the 1980s, 2, 4, 5-T was the herbicide of choice in the USA (Jacoby and Ansley, 1991) and Australia (Csurhes, 1996). Although 2, 4-D provided excellent suppression of top growth, few trees were actually killed and such chemical treatments had to be applied periodically to ensure that forage yields were maintained. Infested sites often needed spraying every 5-7 years. The most effective chemical for high tree kill in the USA is clopyralid, but dicamba, picloram and triclopyr have also been successfully used, either alone or in combination (Jacoby and Ansley, 1991). In India, ammonium sulfamate was successful in killing *P. juliflora* trees and as a stump treatment (Panchal and Shetty, 1977). Our research result was also coincide with Waisel (1972) and Weinert and Sakri (1977) who reported the early stage plants internal systems were collapsed (xylem and phloem cells of stem were died) due to the effect of these systemic herbicides. But the internal systems of later stage plants were partially functioning.

The basal bark and cut-stump techniques used with an appropriate registered herbicide are effective on mature trees. Basal bark treatment (spraying around the entire stem up to 750 mm from the ground) should be used during the growing season (approximately October to April, depending on species and location). The cut-stump technique, where herbicide is immediately applied to a stump that has been cut horizontally very close to the ground, is effective year round. Seedlings can be controlled by spraying foliar herbicide over the entire plant. This is particularly effective for dealing with actively growing, dense stands of mesquite up to 1.5 m tall Geesing *et al*. (2004).

Conclusion

Prosopis juliflora infests almost all kinds of land in India. Either it is agriculture, industries, roads, reservoirs, streams/nalas etc., it competes for light, soil moisture and nutrients with the neighboring plant species apart from destroying the beauty of the surrounding environment. As the mechanical methods often control only the top growth and allow the *Prosopis juliflora* to resprout as a multi-stemmed plant. Controlling *Prosopis juliflora* through chemicals at early stages is very effective than the later stages. Double application of herbicides seems to be effective than the single application irrespective of the chemicals. In this scenario controlling the *Prosopis juliflora* by spraying or smearing with locally available chemicals like Glyphosate and 2, 4- D ester seems to be better options than the other chemicals.

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Table 1: Effect of single application of different herbicides on *Prosopis juliflora* plants and their regrowth

Sl. No.	Sub Treatments (Factor-B)	Visual Observations Made (90 Days after first time chemical spray)	Number of Side Shoots Observed (90 Days after first time chemical spray) (Factor-A)		
			< 1 cm stem thickness	1-2 cm stem thickness	>2cm stem thickness
1	Mera -71 @ 20 g/ltr	Plants appears dried	0.88 (0)	1.05 (1)	1.35 (1)
2	Mera -71 @ 30 g/ltr	Plants completely dried	0.70 (0)	0.70 (0)	1.05 (1)
3	Mera -71 @ 40 g/ltr	Plants completely dried	0.70 (0)	0.70 (0)	0.88 (0)
4	2,4- D @ 5 g/ltr	Plants appears dried	0.88 (0)	1.05 (1)	2.04 (4)
5	2,4- D @ 10 g/ltr	Plants appears dried	1.05 (1)	1.44 (2)	1.56 (2)
6	Paraquat @ 10 ml/ltr	Plants appears dried	1.46 (2)	1.81 (1)	1.35 (1)
7	Paraquat @ 20 ml/ltr	Plants partially dried	1.86 (3)	2.60 (6)	3.24 (10)
8	Paraquat @ 30 ml/ltr	Plants partially dried	1.86 (3)	2.19 (4)	2.74 (7)
9	Diuron (Klass) @ 2.5 g/ltr	Plants are green	2.11 (4)	3.28 (10)	3.06 (9)
10	Diuron (Klass) @ 5 g/ltr	Plants are green	1.89 (3)	2.79 (7)	2.84 (8)
11	Mera-71 @ 30 g/ltr + 2,4- D 5 g/ltr	Plants appears dried	0.88 (0)	1.05 (1)	1.56 (2)
12	Mera-71 @ 40 g/ltr + 2,4- D 10 g/ltr	Plants completely dried	0.70 (0)	0.88 (0)	1.68 (2)
13	Mera-71 @ 20 g/ltr + paraquat 10 ml/ltr	Plants completely dried	0.70 (0)	0.70 (0)	1.77 (3)
14	Mera–71 @ 30 g/ltr + paraquat 20 ml/ltr	Plants completely dried	1.18 (1)	1.35 (1)	1.86 (3)
15	Mera-71 @ 40 g/ltr + paraquat 30 ml/ltr	Plants completely dried	0.88 (0)	1.35 (1)	1.86 (3)

Sub Treatments (Factor-B means)	
Sl. No	Average
Treatment 1	1.097 (0.7)
Treatment 2	0.821 (0.3)
Treatment 3	0.766 (0.0)
Treatment 4	1.322 (1.3)
Treatment 5	1.354 (1.7)
Treatment 6	1.326 (1.3)
Treatment 7	2.563 (6.3)
Treatment 8	2.256 (4.7)
Treatment 9	2.816 (7.7)
Treatment 10	2.509 (6.0)
Treatment 11	1.165 (1.0)
Treatment 12	1.081 (0.7)
Treatment 13	1.068 (1.0)
Treatment 14	1.454 (1.7)
Treatment 15	1.363 (1.3)

Main (Factor-A means)	
Sl. No	Average
Treatment 1	1.188 (1.1)
Treatment 2	1.487 (2.3)
Treatment 3	1.925 (3.7)

Critical Difference Values		
-	CD 5%	CV (%)
Factor A	0.116	17.72
Factor B	0.251	
Treatments/ (A X B)	0.441	

Table 2: Effect of double application of different herbicides on *Prosopis juliflora* plants and their regrowth

Sl. No.	Treatments (Factor-B)	Visual Observations Made (90 Days after second time chemical spray)	Number of Side Shoots Observed (90 Days after second time chemical spray)		
			< 1 cm stem thickness	1-2 cm stem thickness	>2 cm stem thickness
1	Mera -71 @ 20 g/ltr	Plants appears dried	0.70 (0)	0.88 (0)	1.18 (1)
2	Mera -71 @ 30 g/ltr	Plants completely dried	0.70 (0)	0.70 (0)	0.70 (0)
3	Mera -71 @ 40 g/ltr	Plants completely dried	0.70 (0)	0.70 (0)	0.70 (0)
4	2,4- D @ 5 g/ltr	Plants appears dried	0.88 (0)	0.88 (0)	0.88 (0)
5	2,4- D @ 10 g/ltr	Plants appears dried	0.70 (0)	0.88 (0)	0.70 (0)
6	Paraquat @ 10 ml/ltr	Plants appears dried	1.86 (3)	2.28 (5)	2.47 (6)
7	Paraquat @ 20 ml/ltr	Plants partially dried	1.46 (2)	2.19 (4)	2.47 (6)
8	Paraquat @ 30 ml/ltr	Plants partially dried	0.88 (0)	1.05 (1)	1.46 (2)
9	Diuron (Klass) @ 2.5 g/ltr	Plants are green	2.26 (5)	2.02 (4)	2.97 (8)
10	Diuron (Klass) @ 5 g/ltr	Plants are green	1.95 (3)	1.56 (2)	2.48 (6)
11	Mera-71@ 30 g/ltr + 2,4- D 5 g/lt	Plants appears dried	0.70 (0)	0.88 (0)	1.35 (1)
12	Mera-71@ 40 g/ltr + 2,4- D 10 g/ltr	Plants completely dried	0.70 (0)	0.70 (0)	1.23 (1)
13	Mera-71@ 20 g/ltr + paraquat 10 ml/ltr	Plants completely dried	1.05 (1)	1.35 (1)	1.35 (1)
14	Mera–71@ 30 g/ltr + paraquat 20 ml/ltr	Plants completely dried	1.05 (1)	1.18 (1)	1.05 (1)
15	Mera-71 @ 40 g/ltr + paraquat 30 ml/ltr	Plants completely dried	0.88 (0)	1.35 (1)	1.05 (1)

Sub Treatments (Factor-B means)	
Sl. No	Average
Treatment 1	0.912 (0.3)
Treatment 2	0.701 (0)
Treatment 3	0.701 (0)
Treatment 4	0.931 (0.3)
Treatment 5	0.876 (0)
Treatment 6	0.766 (0)
Treatment 7	2.193 (4.7)
Treatment 8	2.035 (4.0)
Treatment 9	2.419 (5.7)
Treatment 10	1.992 (3.7)
Treatment 11	0.977 (0.3)
Treatment 12	0.876 (0.3)
Treatment 13	0.821 (0)
Treatment 14	1.244 (1.0)
Treatment 15	1.097 (1.0)

Main (Factor-A means)	
Sl. No	Average
Treatment 1	1.091 (1.0)
Treatment 2	1.204 (1.2)
Treatment 3	1.411 (2.1)

Critical Difference Values		
-	CD 5%	CV (%)
Factor A	0.105	19.96
Factor B	0.236	
Treatments/ (A X B)	0.401	

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Table 3: Effect of different herbicides on *Prosopis juliflora* plants and influence of stem number

Sl. No.	Stem no. class (Factor A)	Herbicide (Factor C)	Resistance to herbicide (in percentage) (90 Days after second time chemical spray)		
			Stem thickness class (Factor B)		
			< 1cm thickness	1-2 cm thickness	> 2 cm thickness
1	Single stemmed	Mera-71 @ 40 g /ltr	14.72 (8)	18.32 (10)	23.32 (16)
		2,4-D @ 10 g /ltr	22.73 (15)	30.94 (27)	32.80 (31)
		Paraquat @ 30 ml/ltr	47.91 (55)	51.10 (60)	66.55 (83)
		Diuron @ 5g/ltr	68.62 (84)	75.38 (92)	85.16 (100)
2	Few stemmed	Mera-71 @ 40 g/ltr	18.20 (10)	20.73 (13)	26.90 (21)
		2,4-D @ 10 g/ltr	26.76 (20)	29.27 (24)	42.86 (46)
		Paraquat @ 30 ml/ltr	55.01 (65)	55.42 (67)	73.04 (90)
		Diuron @ 5g/ltr	63.93 (82)	65.45 (82)	86.87 (100)
3	Many stemmed	Mera-71 @ 40 g/ltr	15.87 (8)	19.28 (11)	30.14 (25)
		2,4-D @ 10 g/ltr	29.70 (25)	27.78 (22)	48.08 (55)
		Paraquat @ 30 ml/ltr	56.77 (70)	50.51 (59)	73.65 (92)
		Diuron @ 5g/ltr	69.14 (85)	71.56 (88)	85.16 (100)

A x B Means	
Sl. No	Average
AB 1	38.49
AB 2	41.52
AB 3	42.87
AB 4	43.93
AB 5	42.71
AB 6	42.28
AB 7	49.75
AB 8	54.29
AB 9	56.27

A x C Means	
Sl. No	Average
AC 1	16.26
AC 2	26.40
AC 3	52.90
AC 4	67.23
AC 5	19.44
AC 6	29.32
AC 7	52.34
AC 8	70.79
AC 9	26.79
AC 10	41.24
AC 11	71.08
AC 12	75.34

B x C Means	
Sl. No	Average
BC 1	18.78
BC 2	28.82
BC 3	55.18
BC 4	72.57
BC 5	21.94
BC 6	32.96
BC 7	60.84
BC 8	69.16
BC 9	21.77
BC 10	32.39
BC 11	60.30
BC 12	72.06

Main (Factor-A means)	
Sl. No	Average
A1	40.92
A2	42.95
A3	53.43

Main (Factor-B means)	
Sl. No	Average
B1	43.96
B2	46.23
B3	47.10

Main (Factor-C means)	
Sl. No	Average
C1	20.80
C2	32.39
C3	58.62
C4	71.25

A x B x C Means	
S.No	**Average**
ABC 1	14.71
ABC 2	22.73
ABC 3	47.90
ABC 4	68.62
ABC 5	18.19
ABC 6	26.75
ABC 7	54.05
ABC 8	63.92
ABC 9	15.87
ABC 10	29.70
ABC 11	56.76
ABC 12	69.14
ABC 13	18.31
ABC 14	30.94
ABC 15	51.09
ABC 16	75.38
ABC 17	20.72
ABC 18	29.26
ABC 19	55.42
ABC 20	65.44
ABC 21	19.28
ABC 22	27.78
ABC 23	50.50
ABC 24	71.56
ABC 25	23.32
ABC 26	32.80
ABC 27	66.54
ABC 28	85.16
ABC 29	26.90
ABC 30	42.86
ABC 31	73.04
ABC 32	86.86
ABC 33	30.14
ABC 34	48.07
ABC 35	73.65
ABC 36	85.16

Critical Difference Values		
-	**CD 5%**	**CV (%)**
Factor - A	3.63	13.92
Factor - B	3.63	
Factor - C	4.20	
A x B	6.30	
A x C	7.27	
B x C	7.27	
A x B x C	11.57	

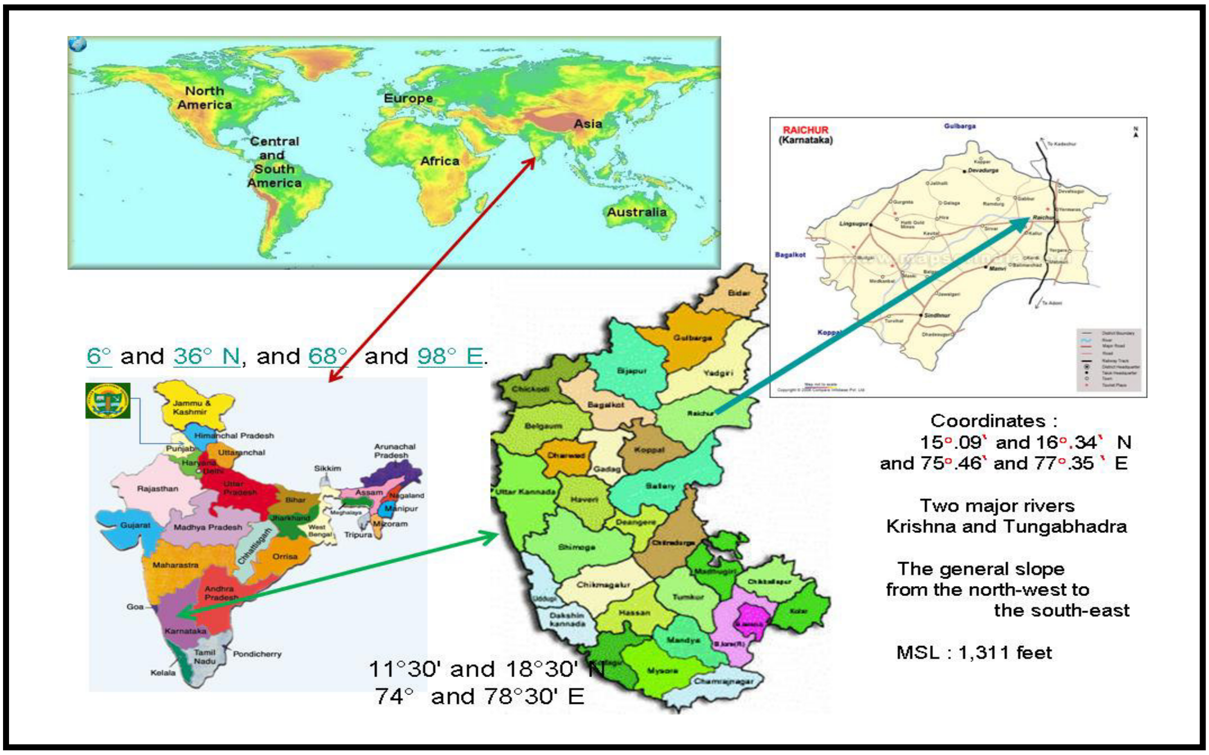

Figure 1: Location map of the study area Main Agricultural Research Station, UAS, Raichur, Karnataka State

Plate 1. Before chemical spray

Plate 2. 90 Days after chemical spray (Mera – 71 @ 40 g/ltr)

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Plate 3. Before Chemical Spray

Plate 4. 90 Days after chemical spray (Mera – 71 @ 40 g/ltr + 2,4- D 10 g/ltr)

Plate 5. Death of phloem and xylem cells in Mera– 71@ 40gm /ltr and 2,4- D 10 g/ltr

Plate 6. Root system study with different chemicals