



# Weed Biomass and Seedling Emergence Patterns as Affected by Different Ground Cover Management Systems in Coconut Plantations of Asian Humid Tropics Sri Lanka

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**Abstract** – Weeds are a perennial problem in coconut plantations and causes significant losses in terms of nut yield. The occurrence of weeds also causes difficulties in its eradication. The influence of different management systems were evaluated in terms of their impact on weed seedling emergence patterns in coconut plantations in Sri Lanka. Treatments imposed were application of glyphosate (N-(phosphonomethyl)-glycine) (T<sub>1</sub>), cover cropping with *Pueraria phaseoloides* (T<sub>2</sub>), tractor harrowing (T<sub>3</sub>), tractor slashing (T<sub>4</sub>) and tractor ploughing (T<sub>5</sub>). All treatments were applied twice a year except for the (T<sub>2</sub>). Based on a reduction in weed biomass, application of glyphosate (T<sub>1</sub>) and cover cropping (T<sub>2</sub>) practices were very efficient methods to reduce the weed population. Chemical weeding and cover cropping were the best methods to reduce weed seedling emergence density in the field. The effectiveness of slashing in reducing weed seedling emergence density was lower than cover cropping and chemical weeding methods. The monocotyledonous, dicotyledonous and total weed seedling emergence densities were almost similar in ploughed and harrowed plots. The seed depth of emerged seedling of all the weed species was very high in harrowed and ploughed treatments when compared to other treatments. This indicated that loosening the soil creates more favorable environment for the germination of weed seeds buried in soil. Therefore, it can be argued that the elimination of weed seeds in the top 2cm or 4cm in the soil seed bank by any means is likely to reduce the level of weed infestation by about 60% to 95%.

**Keywords** – Coconut, Cover Crop, Glyphosate, Seedling Emergence.

## I. INTRODUCTION

Coconut (*Cocos nucifera* L) is the most extensively cultivated major plantation crop in Sri Lanka. It is a tropical perennial plantation crop and its canopy structure requires a wide spacing between palms, which permits abundant sunlight to the understory. As a result, the unutilized space beneath the plantation is invaded by a wide range of perennial and annual weed species [9]. Such weeds invariably compete with coconut for soil moisture and nutrients, affecting growth and yield and obstructing routine management practices [16]. Management of the understory weed growth is, therefore, considered an essential step in maintaining the plantation. In fact, the cost of weeding (20% of the total cost of production of the plantation) accounts for a substantial proportion of the total recurrent expenditure for

maintenance. Therefore, weeds in coconut plantations in Sri Lanka not only reduce yield due to crop weed competition but also add to the production cost. Therefore, there is an acute need to introduce effective and economically viable weed control strategies for coconut growers in Sri Lanka.

In integrated weed management, all available strategies are used to reduce weed seeds in the soil, to prevent weed emergence from the seed bank and to minimise competition from weeds [6], [18], [19] and [8]. This implies that any successful long term weed management programme requires the control of seedlings arising from the soil. Further, unpredictable emergence of weed seedlings from dormant seeds makes weed management a more difficult and costly operation in arable lands [2]. Therefore, manipulation of environmental conditions to reduce emergence of undesirable species in the planted crop or at least to optimize the establishment of desirable species is an effective and economical strategy for weed management.

In order to develop a sustainable integrated weed management strategy, a detailed understanding of the seed bank is required, incorporating germination characteristics of weed seeds and factors that regulate emergence and establishment of seedlings in the field. Although there are many studies on weed biology, weed competition and herbicide technology, little attention has been paid to investigating the regulation of weed seedling emergence in coconut lands, which is the focus of this study. Therefore, the objective of this study was to evaluate the effect of different practices for weed management on the seedling emerging pattern and emerged seedling population under field condition.

## II. MATERIALS AND METHODS

This experiment was carried out at the Pallama Seed Garden, Sub Station of the Coconut Research Institute, in the Low country Dry Zone of North Western province of Sri Lanka from August 2009 to May 2012. The area is characterized by bi-modal pattern of rain fall with an annual mean precipitation of 1200 mm. Approximately 65% of the annual rainfall is received from September to February (Maha rain season).

The soil at the site is a predominantly well-drained Red Yellow Podzolic (RYP) soil with soft or hard laterite (70-90%) [4]. Surface soil is brown in colour with a sandy



loam texture. Structure development is moderate due to presence of sand in the surface soil. Sub surface soil is dark to yellowish brown in colour with prominent mottles. Texture of the subsoil is sandy loam to sandy clay loam. Reaction of the soil is strongly acidic (pH 5.0 – 5.5). Base saturation of the subsurface soil is greater than 35%. Organic carbon content in the surface soil is generally less than 1% under natural conditions [10]. The experimental design was a Randomized Complete Block design with three replicates and plot size was four coconut squares (the spacing of the square planting system of coconut is 8.2m x 8.2m).

*The treatments of the experiment were as follows.*

Five different weed control treatments

T<sub>1</sub>. Chemical weeding (Application of Glyphosate 1.44 kg a.i. per hectare)

T<sub>2</sub>. Establishment of cover crop (*Pueraria phaseoloides*)

T<sub>3</sub>. Tractor harrowing (once in six month) (0cm - 15cm depth)

T<sub>4</sub>. Tractor slashing (once in six month)

T<sub>5</sub>. Tractor ploughing (once in six months) (0cm - 45cm depth)

T<sub>6</sub>. Unweeded (Control)

The different weeding methods were applied to control weeds according to the schedule. In the chemically weeded plots glyphosate (1.44 ai kg /ha) was applied at 6 monthly intervals, at the latter part of the rainy season using a knapsack sprayer in the morning. Generally there was no rain for five to six hours after applying glyphosate. The cover crop was established to control weeds and the over grown conditions of cover crop was managed to overcome competition by harrowing once a year. Tractor harrowing, slashing and ploughing were done at the latter part of the rain season at six monthly intervals.

*The data collected was as follows*

*Weed biomass*

The weed biomass within 0.5m x 0.5m quadrates was collected from four random points per plot. Weed samples were dried at 80°C for five days and weighed. The dry weight of weeds was measured separately every two months from February 2009 to May 2011.

*Emergence of weed seedlings in the field*

In this study, four permanent quadrates (0.5m x 0.5m) were fixed randomly in each plot to monitor emergence of weeds. The emerging seedling count was taken before and after applying all treatments. The weeds which emerged around a 30cm border area outside each quadrate were removed frequently while the remaining area had free weed growth. The emerged seedlings within each quadrate were identified, counted and removed weekly for 16 weeks after applying the treatments. Estimation of average seedling density was obtained by summing the seedling count over the experimental period from February 2009 to May 2011.

*The seed depth of emerging weed seedlings in the field*

This study was done in 2009 Maha rain season (September – October), 2010 Yala rain season (April – May), 2010 Maha rain season (September – October) and 2011 Yala rain season (May – June). During the rainy

season ten common weed species, (two grass species and eight broad leaved) were selected for the study. The selected weed species were namely *Panicum maximum*, *Pennisetum polystachion*, *Chromoleana odorata*, *Euphorbia hirta*, *Urena lobata*, *Croton hirtus*, *Allmania nodiflora*, *Mitracarpus villosus*, *Tephrosia purpurea* and *Hyptis suaveolens*. The germination and emergence of seeds at different depths in the soil was measured in the field. The study used 30 plants from each species. The weed seedlings were marked at ground level with Indian ink and each seedling was excavated to the depth of its caryopsis and the length for the caryopsis to the ink mark of each seedling was measured as described [20]. Estimation of average seedling emergence depth was calculated by measuring the seedling emergence depth over the four rain seasons.

*Data analysis:*

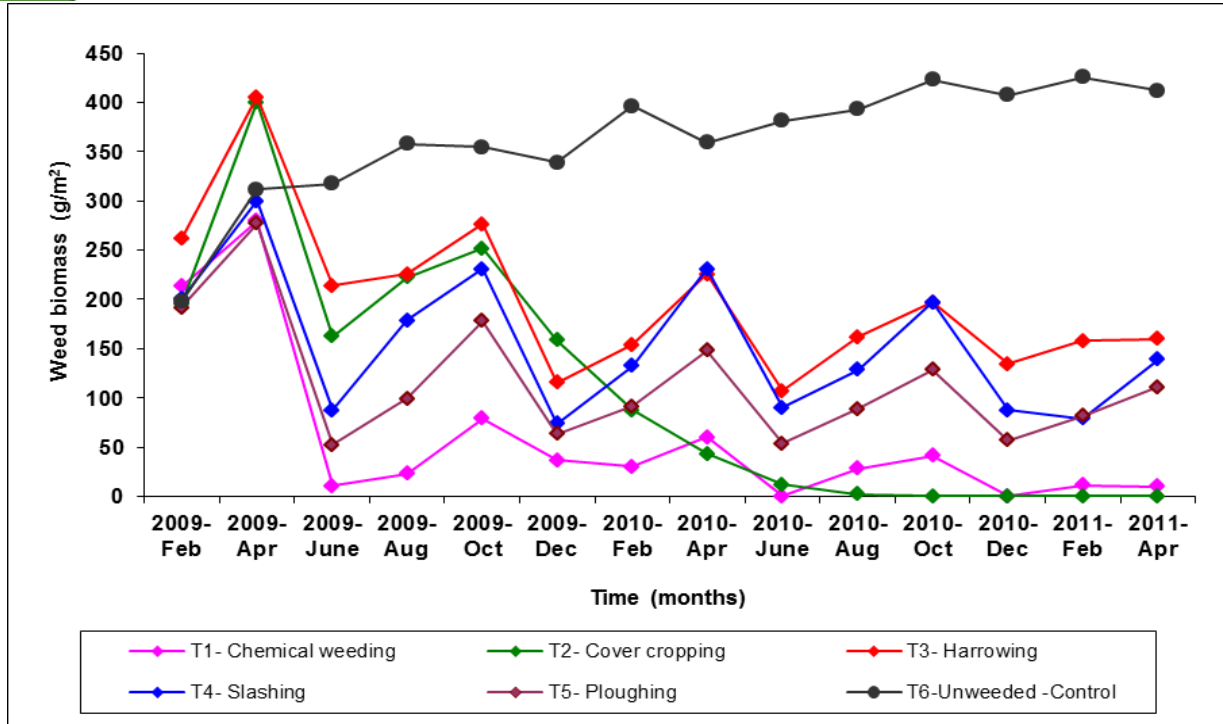
Data were analysed statistically by the Procedure of Analysis of Variance and means were separated using the Least Significant Difference test at the 0.05 significance level. Statistical program was the Statistical Analysis System [15].

### III. RESULTS AND DISCUSSION

*Effect of different weed control treatments on weed biomass*

The lowest total weed biomass was recorded in glyphosate applied plots at a concentration of 1.44 kg a.i. /ha and in plots with a *Pueraria phaseoloides* cover crop (Figures 1). When glyphosate was applied, the weed biomass was reduced and weed seeds in the soil seed bank initiated germination with the onset of rainy season. Most of the new emerging weeds were annual dicotyledonous species and the emergence of monocotyledonous weed species was comparatively low.

Initially *Pueraria phaseoloides* took several months to establish a good ground cover. The weed biomass (monocotyledonous and dicotyledonous) was very high at the initial stages in cover cropped plots which declined gradually later. With time *Pueraria* regenerated with seeds and formed a good ground cover, thereby suppressing weed populations (Figure 1). However, with time, cover crop management was essential to avoid possible competition between coconut palms and cover crops which suppressed the growth of weeds. The three mechanical weeding treatments (tractor harrowing, tractor ploughing and tractor slashing) suppressed weed growth initially, but rapid re-growth was observed in the monocot weeds when compared to the dicotyledonous weeds. Generally slashing damaged the aerial parts of the weeds but with no damage to the root system or underground plant parts such as stolons and rhizomes of the grass weed species. During favorable weather conditions, underground plant parts produced new shoots or new flushes. For example, the monocotyledonous weeds *Imperata cylindrica*, *Panicum maximum* and *Cynodon dactylon* and several dicotyledonous weeds *Lantana camara* and *Chromoleana odorata* produced a new flush within a few weeks of slashing. However, slashing



Treatments were applied in May 2009, October 2009, May 2010, October 2010 and May 2011.

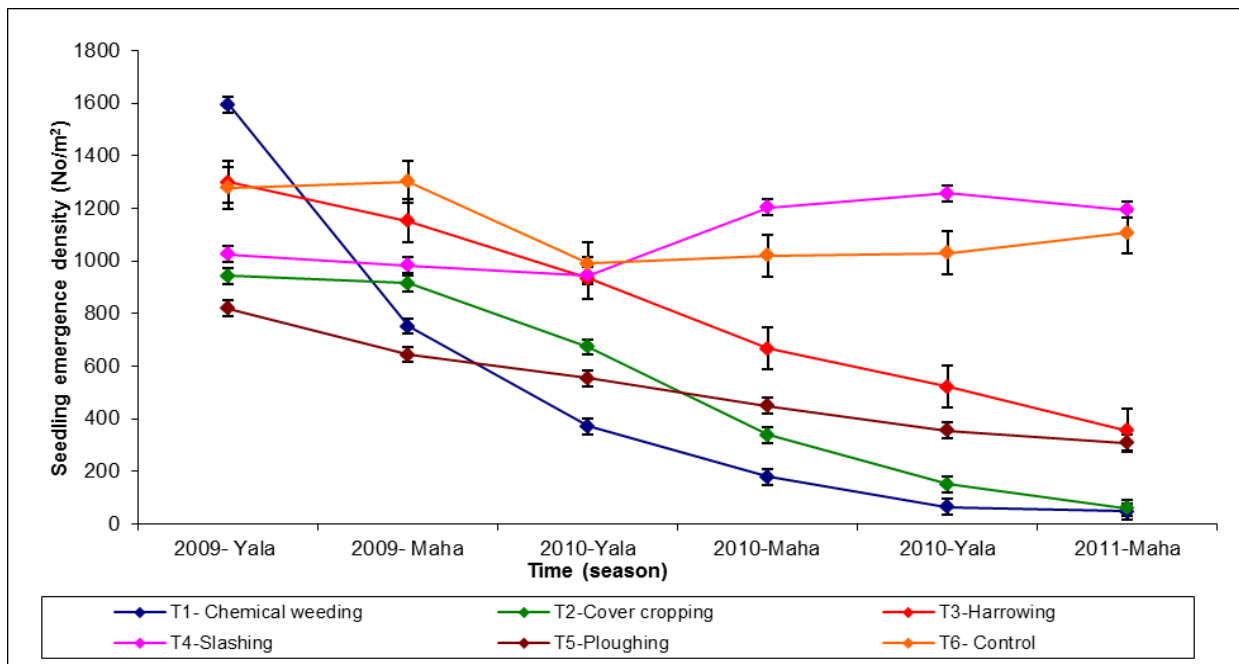
Fig.1. Effect of different ground cover management systems on total weed biomass from February 2009 to April 2011.

monocotyledonous grass weeds at shorter intervals in coconut lands may not be cost effective. Tractor harrowing and ploughing at six month intervals reduced the weed biomass significantly when compared to slashing. Both methods were helpful to bury weed seeds in deep layers, and thus reduce the growth of weed population on the surface. However, this practice loosens

the soil and which would create a suitable environment for the germination of some weed species seeds [16].

*Weed seedlings emergence density in the field*

The numbers of weed seedlings gradually decreased with time in all weeding treatments except in the control plots (Figures 2, 3 and 4). A high weed seedling density was observed on the surface in the control and slashing treatments.



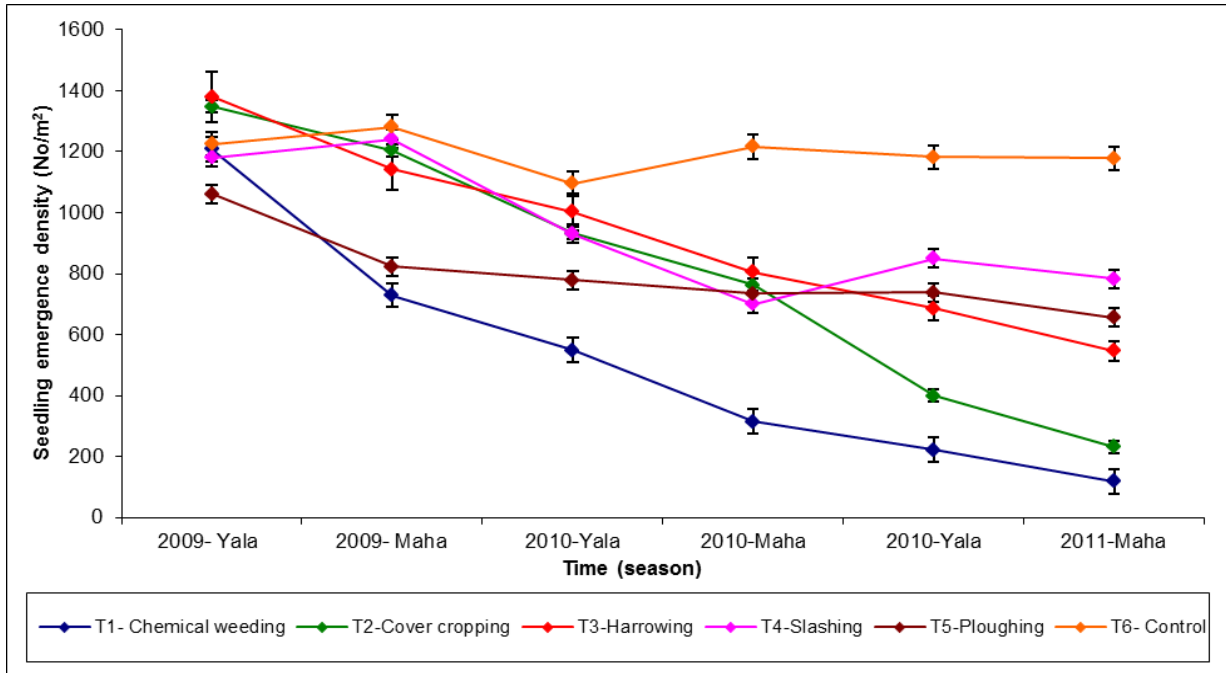
Treatments were applied in May 2009, October 2009, May 2010, October 2010 and May 2011.

Fig.2. Effect of different ground cover management systems on average monocotyledonous weed seedling emergence density from 2009 to 2011.



The seedling emergence density was significantly low ( $P < 0.05$ ) in chemical and cover cropping treatments. The densities of emerged monocotyledonous, dicotyledonous and total weed seedlings were almost similar in the chemically treated and cover cropped plots. The use of

herbicides can also influence the species composition of the seed bank, seedling emergence density and may increase or decrease it, depending on the chemicals used [1] and can also cause specific shifts in weed populations [13].

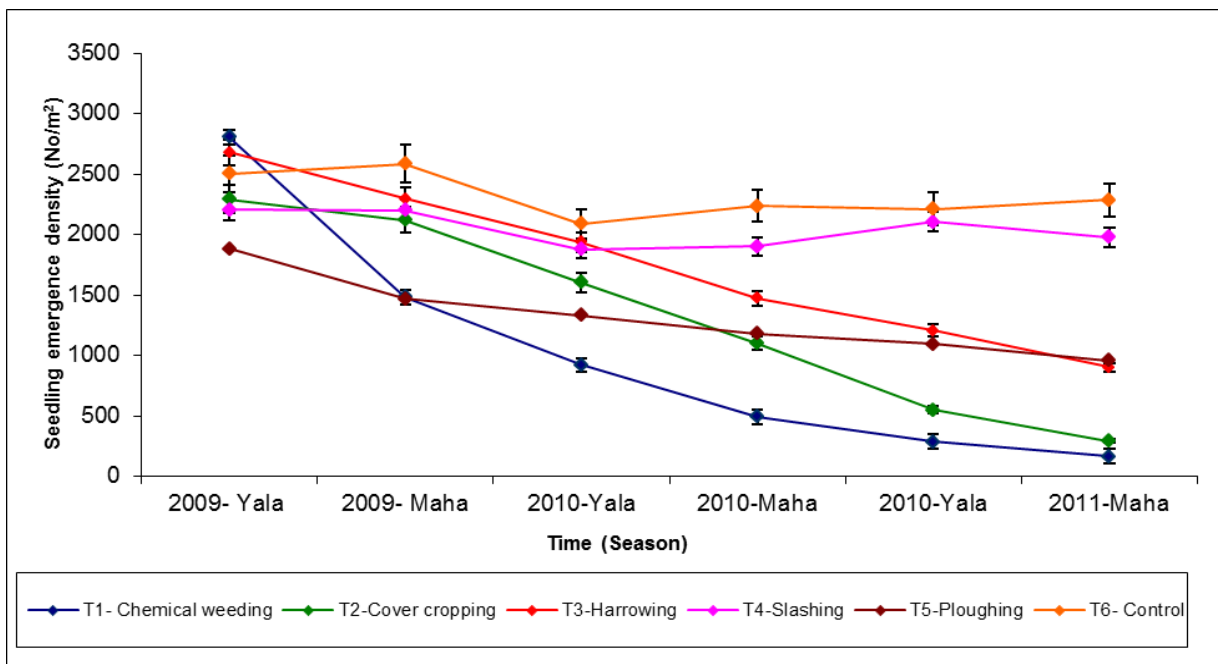


Treatments were applied in May 2009, October 2009, May 2010, October 2010 and May 2011.

Fig.3. Effect of different ground cover management systems on average dicotyledonous weed seedling emergence density from 2009 to 2011.

During the experimental period, more grass seedlings emerged than broad leaved seedlings in slashed plots, when compared to other weeding treatments, except in the

control plots. The effectiveness of slashing is low in controlling monocotyledonous weeds than cover cropping and chemical weeding methods.



Treatments were applied in May 2009, October 2009, May 2010, October 2010 and May 2011.

Fig.4. Effect of different ground cover management systems on average total weed seedling emergence density from 2009 to 2011.

The monocotyledonous, dicotyledonous and total weed seedling emergence densities were almost similar in ploughed and harrowed plots (Figures 2 and 3). Some weed species invaded a higher intensity of emergence in the no tillage planting than in the conventional tillage. The presence of seeds at the superficial layer of the soil and frequent cultivation, are factors that reduce the seed bank rapidly. This situation can facilitate seed loss by exposing seeds to variations in temperature and humidity, and breaking dormancy and finally reducing the seedling density in the field [17].

In this study, chemical weeding and cover cropping were the best methods to reduce weed seedling emergence density. This may depend on several factors, including the pattern of rain fall and the time of germination at a site, the timing of seed input (seed rain) into the seed bank and different agronomic practices [3] and seed and seed losses due to predators [5] and [12]. However, different weeding methods over the experimental period in different treatment plots produced dense stands of weeds and the

seed rain from these plants probably caused the seed bank changes observed in subsequent sampling occasions.

*The seed depth of emerged weed seedlings in the field*

The average depths from which seedlings of eight dicotyledonous weed and two monocotyledonous weed species emerged in the field are presented in Tables 1, 2 and 3. The seed depth of emerged weed seedling of all the weed species was very high in harrowed and ploughed weeding treatments when compared to other weeding treatments. The large number of seedlings of the two monocotyledonous weeds (*Panicum maximum* (71%) and *Pennisetum polystachion* (66%) in chemical weeding, cover cropping, slashing and control treatments were derived from the seeds in the top 1cm of the soil. In harrowing and ploughing plots, these two monocotyledonous weeds seedlings emerged from depths of 1.63cm and 1.05cm depths of the soil respectively.

Table 1: The average number of seedlings of monocotyledonous weeds species which merged at different soil depths in different ground cover management systems

| Species / treatments                  | Depths of emergence (cm) |                |               |        | Means emerged depth (mm) |
|---------------------------------------|--------------------------|----------------|---------------|--------|--------------------------|
|                                       | 0-2cm                    | 2- 4cm         | 4- 6cm        | 6-8 cm |                          |
| <b><i>Panicum maximum</i></b>         |                          |                |               |        |                          |
| T <sub>1</sub> . Chemical weeding     | 20                       | 10             | -             | -      | 09.58 <sup>b</sup>       |
| T <sub>2</sub> . Cover cropping       | 25                       | 5              | -             | -      | 06.26 <sup>c</sup>       |
| T <sub>3</sub> . Harrowing            | 18                       | 6              | 6             | -      | 16.38 <sup>a</sup>       |
| T <sub>4</sub> . Slashing             | 25                       | 5              | -             | -      | 04.70 <sup>c</sup>       |
| T <sub>5</sub> . Ploughing            | 15                       | 9              | 6             | -      | 10.51 <sup>b</sup>       |
| T <sub>6</sub> . Control              | 25                       | 4              | 1             | -      | 03.02 <sup>d</sup>       |
| <b>Total</b>                          | <b>128 (71%)</b>         | <b>39(22%)</b> | <b>13(7%)</b> |        |                          |
| <b><i>Pennisetum polystachion</i></b> |                          |                |               |        |                          |
| T <sub>1</sub> . Chemical weeding     | 18                       | 8              | 4             | -      | 07.58 <sup>c</sup>       |
| T <sub>2</sub> . Cover cropping       | 22                       | 6              | 2             | -      | 05.55 <sup>d</sup>       |
| T <sub>3</sub> . Harrowing            | 15                       | 10             | 5             | -      | 17.23 <sup>a</sup>       |
| T <sub>4</sub> . Slashing             | 21                       | 8              | 1             | -      | 05.11 <sup>ed</sup>      |
| T <sub>5</sub> . Ploughing            | 20                       | 8              | 2             | -      | 13.34 <sup>b</sup>       |
| T <sub>6</sub> . Control              | 24                       | 4              | 2             | -      | 03.62 <sup>e</sup>       |
| <b>Total</b>                          | <b>120 (67%)</b>         | <b>44(24%)</b> | <b>16(8%)</b> |        |                          |

- Values followed by the same letters are not different at P<0.05 in each treatment

Table 2: The average number of seedlings of dicotyledonous weeds species which emerged at different soil depths in different ground cover systems

| Species / treatments              | Depths of emergence (cm) |                |                |        | Means emerged depth (mm) |
|-----------------------------------|--------------------------|----------------|----------------|--------|--------------------------|
|                                   | 0-2cm                    | 2- 4cm         | 4- 6cm         | 6-8 cm |                          |
| <b><i>Urena lobata</i></b>        |                          |                |                |        |                          |
| T <sub>1</sub> . Chemical weeding | 12                       | 13             | 5              | -      | 21.95 <sup>b</sup>       |
| T <sub>2</sub> . Cover cropping   | 15                       | 12             | 3              | -      | 18.91 <sup>c</sup>       |
| T <sub>3</sub> . Harrowing        | 08                       | 16             | 5              | 1      | 29.55 <sup>a</sup>       |
| T <sub>4</sub> . Slashing         | 18                       | 08             | 4              | -      | 16.95 <sup>dc</sup>      |
| T <sub>5</sub> . Ploughing        | 12                       | 12             | 6              | -      | 24.02 <sup>b</sup>       |
| T <sub>6</sub> . Control          | 22                       | 06             | 2              | -      | 15.92 <sup>d</sup>       |
| <b>Total</b>                      | <b>87 (48%)</b>          | <b>67(37%)</b> | <b>25(14%)</b> |        |                          |

|                                   |                  |                 |                |              |                     |
|-----------------------------------|------------------|-----------------|----------------|--------------|---------------------|
| <b><i>Croton hirtus</i></b>       |                  |                 |                |              |                     |
| T <sub>1</sub> . Chemical weeding | 10               | 18              | 2              | -            | 26.49 <sup>c</sup>  |
| T <sub>2</sub> . Cover cropping   | 12               | 15              | 3              | -            | 17.93 <sup>e</sup>  |
| T <sub>3</sub> . Harrowing        | 8                | 18              | 2              | 2            | 39.59 <sup>a</sup>  |
| T <sub>4</sub> . Slashing         | 10               | 16              | 2              | 2            | 21.55 <sup>ed</sup> |
| T <sub>5</sub> . Ploughing        | 10               | 12              | 8              | -            | 31.76 <sup>b</sup>  |
| T <sub>6</sub> . Control          | 8                | 15              | 7              | -            | 22.16 <sup>d</sup>  |
| <b>Total</b>                      | <b>58(32%)</b>   | <b>94 (52%)</b> | <b>24(13%)</b> | <b>4(2%)</b> |                     |
| <b><i>Chromoleana odorata</i></b> |                  |                 |                |              |                     |
| T <sub>1</sub> . Chemical weeding | 28               | 2               | -              | -            | 05.95 <sup>d</sup>  |
| T <sub>2</sub> . Cover cropping   | 18               | 12              | -              | -            | 13.23 <sup>c</sup>  |
| T <sub>3</sub> . Harrowing        | 13               | 17              | -              | -            | 23.13 <sup>a</sup>  |
| T <sub>4</sub> . Slashing         | 25               | 5               | -              | -            | 17.01 <sup>b</sup>  |
| T <sub>5</sub> . Ploughing        | 16               | 14              | -              | -            | 19.26 <sup>b</sup>  |
| T <sub>6</sub> . Control          | 27               | 3               | -              | -            | 03.79 <sup>d</sup>  |
| <b>Total</b>                      | <b>127 (71%)</b> | <b>53 (29%)</b> | -              | -            |                     |
| <b><i>Allmania nodiflora</i></b>  |                  |                 |                |              |                     |
| T <sub>1</sub> . Chemical weeding | 10               | 15              | 4              | 1            | 20.72 <sup>c</sup>  |
| T <sub>2</sub> . Cover cropping   | 12               | 16              | 2              | -            | 30.22 <sup>b</sup>  |
| T <sub>3</sub> . Harrowing        | 8                | 20              | 2              | -            | 36.88 <sup>a</sup>  |
| T <sub>4</sub> . Slashing         | 13               | 14              | 3              | -            | 21.77 <sup>c</sup>  |
| T <sub>5</sub> . Ploughing        | 8                | 18              | 4              | -            | 30.70 <sup>b</sup>  |
| T <sub>6</sub> . Control          | 12               | 10              | 8              | -            | 19.94 <sup>c</sup>  |
| <b>Total</b>                      | <b>63 (35%)</b>  | <b>93(52%)</b>  | <b>23(13%)</b> |              |                     |

- Values followed by the same letters are not different at P<0.05 in each treatment

Table 3: The average number of seedlings of dicotyledonous weeds species which emerged at different soil depths in different ground cover systems

| Species / treatments               | Depths of emergence (cm) |                |                |               | Means emerged depth (mm) |
|------------------------------------|--------------------------|----------------|----------------|---------------|--------------------------|
|                                    | 0-2cm                    | 2- 4cm         | 4- 6cm         | 6-8 cm        |                          |
| <b><i>Mitracarpus villosus</i></b> |                          |                |                |               |                          |
| T <sub>1</sub> . Chemical weeding  | 22                       | 06             | 2              | -             | 13.34 <sup>c</sup>       |
| T <sub>2</sub> . Cover cropping    | 10                       | 15             | 3              | 2             | 21.24 <sup>b</sup>       |
| T <sub>3</sub> . Harrowing         | 05                       | 18             | 3              | 4             | 32.23 <sup>a</sup>       |
| T <sub>4</sub> . Slashing          | 18                       | 05             | 7              | -             | 14.77 <sup>c</sup>       |
| T <sub>5</sub> . Ploughing         | 12                       | 16             | 2              | -             | 30.84 <sup>a</sup>       |
| T <sub>6</sub> . Control           | 15                       | 10             | 3              | 2             | 12.95 <sup>c</sup>       |
| <b>Total</b>                       | <b>82 (46%)</b>          | <b>70(39%)</b> | <b>20(11%)</b> | <b>8 (4%)</b> |                          |
| <b><i>Tephrosia purpuera</i></b>   |                          |                |                |               |                          |
| T <sub>1</sub> . Chemical weeding  | 10                       | 12             | 08             | 8             | 22.32 <sup>b</sup>       |
| T <sub>2</sub> . Cover cropping    | 08                       | 15             | 03             | 4             | 26.90 <sup>b</sup>       |
| T <sub>3</sub> . Harrowing         | 07                       | 10             | 12             | 1             | 37.01 <sup>a</sup>       |
| T <sub>4</sub> . Slashing          | 12                       | 14             | 03             | 1             | 25.89 <sup>b</sup>       |
| T <sub>5</sub> . Ploughing         | 08                       | 09             | 10             | 3             | 39.02 <sup>a</sup>       |
| T <sub>6</sub> . Control           | 12                       | 13             | 05             | -             | 23.94 <sup>b</sup>       |
| <b>Total</b>                       | <b>57(32%)</b>           | <b>73(41%)</b> | <b>41(23%)</b> | <b>11(6%)</b> |                          |
| <b><i>Hyptis suaveolens</i></b>    |                          |                |                |               |                          |
| T <sub>1</sub> . Chemical weeding  | 16                       | 10             | 4              | -             | 19.84 <sup>c</sup>       |
| T <sub>2</sub> . Cover cropping    | 12                       | 15             | 3              | -             | 26.23 <sup>b</sup>       |
| T <sub>3</sub> . Harrowing         | 08                       | 12             | 7              | 3             | 33.63 <sup>a</sup>       |
| T <sub>4</sub> . Slashing          | 15                       | 10             | 5              | -             | 19.26 <sup>c</sup>       |
| T <sub>5</sub> . Ploughing         | 10                       | 18             | 2              | -             | 26.83 <sup>b</sup>       |
| T <sub>6</sub> . Control           | 13                       | 13             | 4              | -             | 19.30 <sup>c</sup>       |
| <b>Total</b>                       | <b>74(41%)</b>           | <b>78(43%)</b> | <b>25(14%)</b> | <b>3 (2%)</b> |                          |

| <i>Euphorbia hirta</i>            |                 |                |                |              |                    |
|-----------------------------------|-----------------|----------------|----------------|--------------|--------------------|
| T <sub>1</sub> . Chemical weeding | 12              | 16             | 2              | -            | 20.62 <sup>d</sup> |
| T <sub>2</sub> . Cover cropping   | 15              | 08             | 7              | -            | 17.61 <sup>e</sup> |
| T <sub>3</sub> . Harrowing        | 08              | 16             | 6              | 3            | 34.98 <sup>a</sup> |
| T <sub>4</sub> . Slashing         | 13              | 13             | 4              | -            | 25.76 <sup>c</sup> |
| T <sub>5</sub> . Ploughing        | 09              | 15             | 6              | -            | 32.10 <sup>b</sup> |
| T <sub>6</sub> . Control          | 13              | 11             | 6              | -            | 21.32 <sup>d</sup> |
| <b>Total</b>                      | <b>70 (38%)</b> | <b>79(44%)</b> | <b>31(17%)</b> | <b>3(1%)</b> |                    |

- Values followed by the same letters are not different at P<0.05 in each treatment

Seedlings of the other dicotyledonous weed species in the different weeding treatment plots were derived from seeds in a range of soil depths (Tables 2 and 3). The depth of emergence of dicotyledonous weeds was very high in harrowed and ploughed treatment plots when compared to other methods. Approximately 87% and 67% of the *Urena lobata* seedlings emerged from the surface to 2cm and 2cm - 4cm soil depths respectively.

However, 52% of the *Croton hirtus* seedlings emerged at 2cm - 4cm depth level, 70% of the *Chromoleana odorata* seedlings emerged from the surface to 2cm soil and 39% seedlings emerged at 2-4cm soil level indicating that more small seeds germinate in top soil layers. The highest depth from which *Chromoleana odorata* seedlings emerged was 2.31cm in harrowed plots. Approximately 87% of *Allmania nodiflora*, 73% of *Tephrosia purpurea*, 84% of *Hyptis suaveolens* and 82% of *Euphorbia hirta* populations were derived from seeds in the top 4cm of the soil. In contrast *Mitracarpus villosus* seedling emergence percentage (46%) was high in the top 2cm of the soil. However the depth of emergence of all the weed species was very high in harrowed and ploughed plots when compared to the other weeding methods. This indicated that loosening the soil creates more favorable environment for germinating of weed seeds buried in soil layers. Therefore, it can be argued that the elimination of weed seeds in the top 2cm or 4cm in the soil seed bank by any means is likely to reduce level of weed infestation by 60% and 95% respectively. The results of a similar study conducted [11] showed that 90% of the emerged population of *Alopecurus myosuroides* was derived from seeds in the top 2.5cm of the soil. However the optimum depths for the emergence of seeds vary with different species. By compiling data for 31 species, [7] showed that optimum depth ranged from 0.05cm to 2.5cm and was roughly in proportion to the 1000 seed weight. [13] examined the depth of seed burial in undisturbed and cultivated soil and found seedling emergence was greatest from cultivated soil at shallow depths of burial.

#### IV. CONCLUSION

Application of glyphosate (1.44 kg a.i./ha) and cover cropping (*Pueraria phaseoloides*) are very effective methods to reduce total weed biomass and weed seedling emergence density when compared to other mechanical weeding methods such as harrowing, slashing and ploughing. However, an integrated approach, application of glyphosate followed by establishment of leguminous creeping cover crops is very effective in controlling

monocotyledonous weed biomass such as *Imperata cylindrica*, *Panicum maximum* and *Pennisetum polystachion*. Considering the soil seed bank, the results of this study have provided useful information on timing, emergence density and composition of weed populations that are likely to emerge under different types of weed management systems in relation to the seed bank. However the depths of weed seedling emergence of many species were very high in harrowing and ploughing treatment plots when compared to the other weeding methods. This indicated that loosening the soil creates more favorable environment for germinate weed seeds buried in deep soil layers.

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