Effect of Different Soil and Weeding Management on Early Field Performance and Establishment of *Jatropha curcas* L.

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Abstract: ***An experiment conducted at Research and Development farm, Maheshwer (situated between $22^0 12^{/} 25^{//}$ N latitude, $75^0 35^{/} 26^{//}$ E longitudes, at an elevation of 600 m above the mean sea level) to assess the early field performance and establishment of Jatropha curcas L as influenced by plantation season, soil types and weeding managements. Transplantation done during rainy season can be concluded to be the ideal season for establishing J. curcas plantations compared to summer and winter in agro-ecological conditions like those of Research and development farm of Maheshwer. The study demonstrated J. curcas planting media (red stony, laterite and black soil) treatment to have no effect on the survival and growth of saplings during the first season of establishment. Data collected in future will help determine the most ideal soil condition. As for weed management, the results indicated spot weeding, slashing and both spot weeding and slashing to have the same effect on J. curcas survival and growth in height and basal girth.***

Keywords: Seed germination, Weeding management, Laterite soil and Basal girth

1.Introduction

The crude oil crisis of the 1970s and the subsequent shortages of petro-fuels on the world market have seen the recognition of the limitations of world oil resources (Grimm, 1996; Heller, 1996; Henning, 2008; Pratt *et al*., 2002). Currently, the entire world is faced with critical fuel shortages accompanied with high prices as well as the global warming issue. This has prompted governmental and nongovernmental organizations (NGOs) to search for alternative sources of energy, which are renewable, safe, and non-polluting. In this regard, renewable vegetable fuels have assumed top priority. Special interest has been shown in the cultivation of the tropical physic nut (*Jatropha curcas* L., Euphorbiaceae) for oil extraction (Grimm, 1996; Heller, 1996).

According to Biswas *et al.* (2006), the concept of bio-fuel dates to 1885 when Dr. Rudolf Diesel built the first bio-diesel engine. In 1912, he predicted the potential of biodiesel, "The use of vegetable oils for engine fuels may seem insignificant today. But such oils may in the course of time become as important as petroleum and the coal tar products of present time" (Biswas *et al*., 2006). In the early 1970s, scientists discovered that the viscosity of vegetable oils could reduce by a simple chemical process and that it could perform as petro-diesel in a modern engine (Biswas *et al*., 2006). Since then, technical developments have come a long way and plant oil has highly established as a biofuel, equivalent to diesel. Recent environmental (e.g., Kyoto Protocol) and economic concerns have prompted the resurgence of biodiesel throughout the world. In the present scenario, the appropriate answer to the current oil crisis is to explore the possibility of biodiesel. Biodiesel is an eco-friendly, alternative fuel prepared from vegetable oils (edible or nonedible) and animal fat which are renewable (Singh *et al*., 2007). The non-edible *J. curcas* oil has requisite potential of providing a promising and commercially viable alternative to petro-diesel. *Jatropha curcas* biodiesel has the desired physio-chemical and performance characteristics comparable to petro-diesel (Kureel, 2006). It has a higher cetone value of 51 than other vegetable oils and petro-diesel (46 to 50) (Kureel, 2006). This makes it an ideal alternative fuel and requires no special modification in the engine. The initial flash point of *J. curcas* oil is 100 0C as compared to 50 °C of petro-diesel (Kureel, 2006; Singh *et al*., 2007). This creates initial engine starting problem. Similarly, the higher viscosity of *J. curcas* oil may affect the smooth flow of oil in the engine. However, these problems can be overcome by etherification (Kureel, 2006).

Therefore, the present study was sought to determine region and situation specific propagation method, planting density and weed management method for the cultivation *J. curcas* for seed production to maintain genetic purity, uniformity, and gainful exploitation of useful variation, and to meet the required demand for high-quality planting material at commercial scale.

2.Materials and Methods

Study Site

The present study was conducted at the research and demonstration farm Maheshwar District-Khargone M.P located between $22^0 12^{/} 25^{//}$ N latitude, $75^0 35^{/} 26^{//}$ E longitude with an elevation of 600 meter from sea level. The side formed from annoyed rocks and had a crumb microstructure. Mean annual rain fall ranges from 500 to 650 mm and occurs during a single rainy season extending from June to September. Mean annual temperatures range from 25^{0}C to 45^{0}C. Sometimes the area experiences frost from December to January.

Experimental Design

The research was conducted in a 3^3 factorial randomized complete block design with three replications, involving three propagation methods (transplanting pre-cultivated seedlings), planting density (2500 plant/ha) and three weed management methods (spot weeding, slashing and both slashing and spot weeding). The planting densities chosen after Singh *et al.* (2007) and Heller (1996) recommendations that *J. curcas* planting densities for commercial plantations be 2500 stems/ha. Blocking done perpendicular to the soil (colour) gradient and slope. Soil colour varied from red at the upper part of the experimental site to deep brown at the lower part.

Land Preparation and Planting

The research area was disked to a depth of 0.2 m using a tractor drawn disk plough. Marking and pitting done using a tape measure and manually respectively. Unformed sized seedlings of an average height of 45 cm and a root collar diameter of 11 mm are using for the experiment. 150 seedlings were planted in 5 replications inside 30 cm deep and 15 cm diameter pits by using soil mixture of 1:1:1 of soil, sand and FYM. Transplanting of seedlings done in three soil type (red stony, laterite and black soil) during the season of winter, summer and rainy from the nursery to the research site, for nursery planting of cuttings collected from, one year old branches, were about 5 cm in diameter, 25 cm long, with 4 to 5 buds above the ground level. These specifications were adapted from Singh *et al.* (2007). Thinning to waste done 2 weeks after mergence. Slashing and spot weed management practices done after two months of planting. The total plant density maintained as1000 sapling/acre in entire plantation side.

Field Measurements and Data Collection

Measurements done on all the plants in the plots after one year of plantation. Plant survival was determined by use of Equation 1 and was done after seven months of planting.

$$Total\ Survival\ (\%) = \frac{Plants\ established - Total\ plants\ dead}{Total\ plants\ established}\ X\ 100 \quad \text{………..} (1)$$

Growth in height and root collar diameter (RCD) measured after one and seven months after planting, using a height rod and a verneer caliper, respectively. Plant height measured as the distance in cm, between the RCD and the apical meristem. However, in the few plants, the apical meristem damaged by herbivores, frost, or pathogens. In these cases, branch leader meristems considered for height measurement (Balderrama and Chazdon, 2005). Plant growth evaluated as the mean relative growth rate in height (RGRh) and mean relative growth rate in basal girth (RGR_g) over the total growth period using the formulae for classic plant growth analysis (Balderrama and Chazdon, 2005) as shown in Equations 2 and 3.

$$RGR_h = \frac{\log_e hf - \log_e hi}{t_2 - t_1} \qquad (2)$$

Where RGR_h = Relative growth rate in height,

hi = the initial (a month after establishment, 't_1') growths in height, hf = the final (after 't_2' months) growths in height.

$$RGR_g = \frac{\log_e df - \log_e di}{t_2 - t_1} \qquad (3)$$

Where RGR_g = Relative growth rate in basal girth,

di = the initial (a month after establishment, 't_1') growths in basal girth, df = the final (after 't_2' months) growths in basal girth.

Data Analysis

Data on survival were arcsine transformed before being analysis, to ensure normality. Geometric means calculated for presentation. Plant survival, growth in height and basal girth, RGRh and RGRg evaluated for significance among treatments through a one-way analysis of variance (ANOVA) using SPSS for Window Version 15 2006. Differences between means assessed using LSD post hoc tests at 5% level of significance. Equation 4 shows the model for the experiment.

$$Y_{ijkl} = \mu + S_i + P_j + W_k + SP_{ij} + SW_{ik} + PW_{jk} + SPW_{ijk} + e_{ijkl} \qquad (4)$$

Where: *Yijkl* = Response of trees planted at ith planting density, propagated through the jth method and with weeds managed through the kth method.

μ = Grand mean,

Si = Response to the ith planting density (i=2500 seedlings/ha),

Pj = Response to the jth propagation method (j=pre-cultivated seedlings).

Wk = Response to the kth weed management method (k=spot weeding; slashing and the two weed management methods combined),

SPij = Response to the effect of the interaction between planting density and propagation method,

PWjk = Response to the effect of the interaction between propagation method and weed management technique,

SPWijk = Response to the effect of the interaction among planting densities, propagation methods and weed management techniques,

ijkl e = The error term.

3. Results

Survival Variation by Propagation Season

Arcsine transformed survival data showed that saplings established by means of pre-cultivated seedlings during rainy season (81.42 %) outperformed (P<0.05) and those planted during winter and summer season exhibited 38.07, and 19.41 %, respectively, when the three planting soil types and weed management techniques evaluated. In turn, *J. curcas* planted during winter season outperformed (P<0.05) the ones propagated in summer season in terms of survival (Table.1).

Survival Variation by Soil type

Soil type did not differ significantly (P>0.05) among themselves in terms of *J. curcas* survival. The overall survival of saplings established in red stony, laterite and black soil with the density of 2500 seedlings/ha found 45.60 %, 46.28 % and 45.36 % respectively. Soil types also showed no significant differences (P>0.05) among themselves in terms of the survival of saplings propagated in rainy, with red stony soil recording 79.17 %; laterite soil, 83.50 % and in black soil exhibited 81.61 %. Similarly, soil levels did not differ significantly (P>0.05) on the survival of saplings propagated in winter (40.14 %) for those planted at red stony soil 36.58 % recorded height among other two season and soil types. As for saplings propagated in summer season shown non-significant differences in percentage survival (P>0.05) among cuttings established in red stony (18.67 %), laterite (19.44 %) and black soil (20.11 %) (Table.1).

Survival Variation by Weed Management Method

Weed management techniques did not differ significantly (P>0.05) among themselves in terms of survival. The overall survival of saplings subjected to slashing, spot weeding and both slashing and spot weeding were 43.44 %, 50.79 % and 42.74 % respectively. Slashing (81.61 %), spot weeding (79.86 %) and both slashing and spot weeding (82.81 %) did not result in significant differences (P>0.05) on survival of saplings propagated in rainy season. Saplings propagated during winter with subjected to spot weeding (50.19 %) recorded a higher (P<0.05) survival percentage when compared to those subjected to slashing (35.19 %) and both slashing and spot weeding (28.13 %). As for saplings propagated in summer, weed management practices exhibited no significant differences (P>0.05) among themselves in terms of survival, with those subjected to slashing scoring 15.97 %, spot weeding, 20.78 % and both slashing and spot weeding (21.47 %) (Table.1).

Growth performance

In terms height, saplings propagated in rainy season seedlings indicated no significant differences (P>0.05) among those subjected to slashing (Mean; 107.94 cm), spot weeding (85.03 cm) and both slashing and spot weeding (117.67 cm). The same scenario observed with mean basal girth, recording no significant differences (P>0.05) among saplings which subjected to slashing (26.93 cm), spot weeding (19.14 cm) and both slashing and spot weeding (25.34 cm). Various soil types had no effect (P>0.05) on growth in height as well as with basal girth. The mean heights and basal girth achieved in black soil, followed by laterite and red stony soil (Table.1).

Relative Growth Rates in Height and RCD

Relative growth rates of saplings in height (RGRh) and basal girth (RGRg) over a one-year period propagated in different season of rainy, winter and summer and various soil types as red stony, laterite and black soil, planted at densities of 2500 stems/ha and subjected to slashing, spot weeding and both slashing and spot weeding shown in Table 2.

Plants established during the rainy season did not significantly differ (P>0.05) from those established by winter season in terms of RGRh. As for saplings planting in various soil types, RGRh did not vary (P>0.05) among plants established in red stony, laterite and black soil. Similarly, RGRg did not significantly differ (P>0.05) among plants where slashing, spot weeding and both slashing and spot weeding practiced after one month of plantation. The interaction between propagation season and planting media (soil type) as well as the one between soil type and weed management techniques did not result in significant differences (P>0.05) on *Jatropha* RGRh after one year of transplanting. Similarly, the interaction between propagation season, planting media and weed management techniques did not result in significant differences (P>0.05) on plants' RGRh within a year of plantation. There was no significant difference (P>0.05) between seedlings planted in rainy and winter season in terms of RGRg after one year of transplantation. Plants response to weed management indicated no significant differences (P>0.05) in RGRg within a year, among those subjected to slashing, spot weeding and both slashing and spot weeding. Plants' response to the interaction between propagation season, planting media and weed management techniques indicated no significant differences (P>0.05) in RGRg after one year of transplanting.

4. Discussion

Propagation Methods

Despite the high expenses involved, results on survival percentages achieved by *J. curcas* in this research indicated the necessity of pre-cultivating seedlings in a nursery, prior to transplanting them during the month of June. The high survival percentages observed on plants established by planting pre-cultivated seedlings also reported by Kobilke (1989) and Heller (1992). This observation is scientifically sensible because the pre-cultivation of seedlings planted in rainy season under closely monitored nursery conditions gives them a physiological advantage over plants established by direct planting of either seed or cuttings during the season of winter. In rainy season the well-developed root system and stem increase the potential to survive water and other stresses. Although the pre-cultivated seedlings observed to initially lose leaves due to transplantation shock, the roots and stem organs enabled them to quickly develop new leaves thereby increasing chances of survival. Thus, pre-cultivated seedlings easily adapted to the harsh, less controlled field environment than non-rooted cuttings and seed during rainy season as compared to summer and winter season. However, during winter, plants established by planting pre-cultivated seedlings were the most affected, losing their apical meristems to frost, forcing the plants to develop some shoots in response to the loss of apical dominance. This is consistent with observations by Wini *et al*. (2006) and Singh *et al*. (2007) that *J. curcas* cannot withstand frost. Although the survival of *J. curcas* propagated through pre-cultivated seedlings surpassed those by non-rooted cuttings and direct seeding, the mortality was high considering the maximum allowed during the first year of plantation establishment. The minimum percentage survival required to avoid blanking costs is 85% compared to 81.42% recorded in this study. The mortality was attributed to frost which attacked the saplings' shoots during winter (Wini *et al*., 2006; Singh *et al*., 2007) and defoliation by mammals, rodents and locusts (Heller, 1992). Unlike pre-cultivated seedlings, directly planted seed need to germinate and survive the critical, initial stages of growth and development which occurs in an unpredictable natural environment characterized by harsh weather conditions, pests, and diseases. Comparable results observed elsewhere (Kobilke, 1989; Heller, 1992; Kureel, 2006; Feike *et al*., 2007). Salisbury and Ross (1992) explained that the period from germination to the time the seedling becomes established as an independent organism constitute the most critical phase in the life history of the plant. During this period, the plant is most susceptible to injury by a wide range of insect pests and parasitic fungi and water stress can prove to be fatal. Direct field observations from this study attributed the high mortality to pests and diseases chief of which were damping off (Heller, 1992; Singh, 1983), defoliation by millipedes (Heller, 1992), locusts (Heller, 1996), termites and rodents (Kar and Das, 1988; Meshram and Joshi, 1994; Biswas *et al*., 2006; Rao, 2006). The high incidence of pests and diseases explains the high vulnerability of the tender, post germinated juvenile plants.

Perry (1980) reported plants established by direct planting of seed to give mixed results on survival those planted in various season. Besides, success in terms of survival percentage in different month of transplantation has reported with plants established by direct seeding in Thailand (Sukarin *et al*., 1987). This inconsistence with the findings of this research is reasonable because the method, as explained above, is heavily influenced by critical factors (moisture availability, pests, and diseases etc) which if favourable, give high survival percentages and vice-versa.

Additionally, Kureel (2006) reported large scale *J. curcas* mortality in non-rooted cuttings planted during the rainy season. This attributed to the high moisture levels which promoted fungal infection. Kobilke (1989) and Heller (1992) reported non-rooted *J. curcas* cuttings to give more than 80 % survival. The inconsistence with the findings of this research could be a result of a complex interaction of factors among them agro-ecological differences, different cutting morphologies. Unlike the cuttings used in this research which despite being 5 cm thick and 25 cm long recorded low percentage survival; Thitithanavanich (1985) reported cuttings of 3 cm diameter and 30 cm length to form more roots than those of 1 and 2 cm diameter and 15 cm length. Heller (1996) reported the rooting potential of cuttings to be influenced by the nature of the rooting media, aeration and drainage. Thus, the medium to poor aeration and drainage associated with the soils on the trial site caused water logging, conducive for *Phytophthora spp*, *Pythium spp* and *Fusarium spp* which caused stem and root rot (Heller, 1992) and contributed to the low survival recorded for non-rooted cuttings. Further, the anaerobic conditions could have limited aerobic respiration (Salisbury and Ross, 1992) since the cuttings had less or no leaves for oxygen absorption, thus retarding the growth process, culminating in the death of the cuttings. The lack of significant differences in RGRh and RGRg after one year of plantation responses of pre-cultivated seedlings and direct seeding could be explained by environmental and physiological factors when those are planted in various season. The loss of the physiological advantage associated with saplings established through pre-cultivated seedlings could explained by transplanting shock as well as the harsh climatic and edaphic conditions on the field. Transplanting seedlings from the closely monitored nursery to the field, characterized mainly by episodes of moisture deficiency could have significantly lowered the plants' external water potential in summer season which could have caused a decrease in cellular growths (Sakurai and Kuraishi, 1988) and thus negatively impacted on height and basal girth resulting in the lack of significant difference between *J. curcas* established by pre-cultivated seedlings and seedlings in various month. It may be possible that the effect of the transplanting time prolonged enough to overshadow the established root system and shoot advantage characteristic of pre-cultivated seedlings.

Planting media and density

Premature to the widely publicized inverse relationship between planting media (soil types) density and tree survival (Lohani, 1980) as well as the one between planting density and growth in height and RCD (Bhatia, 1980; Lohani, 1980; Jamroenprucsksa, 1989; Effendi and Bachtiar, 1994; Nilsson, 1994; Taurins, 1997; Jaeghagen, 1997; Loutfy *et al*., 1998), findings from this research indicated planting density to have no effect on *J. curcas* survival and growth in height and RCD in the first season of establishment mainly because of the lack of intra-specific competition. This is reasonable considering the growth rate of *J. curcas* which in the favourable conditions for instance those of Thailand, is averaged at 1 m in height and 0.75 m crown diameter after 5 months of establishment (Heller, 1996) as well as the planting density treatments which were low enough to avoid canopy closure during the first season of establishment. However, depending on climatic and edaphic conditions and management prescriptions later in the life cycle of *J. curcas*, canopy closure would suppress and eliminate weaker trees. Until then, none of the three-planting media can be considered ideal for the establishment of a *J. curcas* plantation for seed production in conditions similar to those at Maheshwar conditions.

Weed Management Techniques

Vegetation management is a routine practice in plantation forests and is essential for achieving high rates of productivity (Richardson, 1993). It has shown to be critical immediately after plantation establishment, with researchers reporting substantial growth benefits from weed control (Morris, 1994; Little and Rolando, 2001; South *et al*., 2001; Little and Staden, 2003). In most resource poor developing countries, spot weeding and slashing provide the foundation of weed management wherever intensive plantation management has developed. In this study, weed management treatments caused the same survival and growth responses although spot weeding and both spot weeding and slashing expected to give outstanding outcomes compared to slashing (Richardson, 1993; Kyato and Okamoto 2002; Coll *et al*., 2005; Kagombe and Gitanga, 2005, Sarraf *et al*., 2011). Since spot weeding and slashing liberated *J. curcas* saplings by removing the aboveground weed biomass with slashing leaving 5 cm high stumps, it may argue that the effect was the same, resulting in the lack of significant differences among the weed management treatments in terms of survival and growth in height and RCD. Thus, the ability of spot weeding to damage the weed's root system overshadowed by the removal of aboveground biomass and hence had no visible effect on *J. curcas* survival and growth. In support, Schwinning and Weiner (1998) reported aboveground weed competition to strongly affect seedlings than belowground competition hence the lack of significant difference between spot weeding and slashing. Additionally, the fact that the weed management treatments prescribed once, basing on financial constraints than weed re-growth and re-infestation potential could have contributed to the lack of differences among *J. curcas* saplings subjected to spot weeding, slashing and both spot weeding and slashing. This is reasonable considering the fast re-growth vigour associated with *Rottboellia exaltata* which dominated the study site. *Rottboellia exaltata* characterized by long and horizontally oriented leaf blades which together with the observed high density of the weed shaded the *J. curcas* saplings from sunlight thus negatively impacting on the process of photosynthesis. Thus, the initial effects of the weed management treatments on *J. curcas* survival and growth in height and basal girth could have overshadowed by weed re-growths as the season progressed.

The survival and growth responses of *J. curcas* saplings was not a function of weed management alone but factors a combination of which could have led to the observed results. Thus, the lack of significant differences among the weed management treatments could explain by the ability of *J. curcas* to tolerate weed competition as well. In support, Jongschaap *et al*. (2007) reported *J. curcas* to weed tolerant and to have low nutrient requirements. Basing on the later, it may argue that the degree of competition after either spot weeding or slashing was low to cause water, nutrient, and light deficiencies to affect the *J. curcas* saplings survival and growths in height and RCD. However, unlike the findings of this research, Kyato and Okamoto (2002) and Coll *et al.* (2005), reported trees subjected to spot weeding to achieve better heights and RCDs than those subjected to slashing. This is sound since spot weeding entirely removes the weeds' aerial biomasses unlike slashing which leaves stumps and juvenile weeds below the 5 cm slashing height thus leaving a certain degree of competition for light, water, nutrients, and space. Further, spot weeding damages the weeds' root systems thus reducing root competition compared to slashing. Wilson (1988), Parker *et al*. (1993), Gerry and Wilson (1995), Weiner *et al*. (1997), Davis *et al*. (1999), and Rikala and Sajala (2002) reported root competition to have a greater impact than shoot competition on the survival and growth of saplings since the roots of both the tree crop and weeds particularly grass and shrubs use water and nutrients from the same layers. Casper and Jackson (1997) reported belowground competition to cause water and mineral nutrient deficiencies to saplings.

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Table 1: Survival, and growth performance of *Jatropha curcas* after one year of plantation

Propagation Season	Soil type	Weed Management Method	Survival (%)	Mean Height (cm) ±SD	Mean Basal Girth (cm) ±SD
Winter	Red stony soil	Slashing	51.39	83.21	20.52
		Spot & slashing	25.00	102.66	21.98
		Spot	49.67	86.76	17.63
	Laterite soil	Slashing	25.00	90.90	20.90
		Spot & slashing	31.25	123.26	24.18
		Spot	53.50	75.40	17.31
	Black Soil	Slashing	29.17	127.87	28.45
		Spot & slashing	31.25	116.92	23.57
		Spot	47.92	94.96	16.72
Summer	Red stony soil	Slashing	10.42	85.88	19.88
		Spot & slashing	20.67	110.38	20.02
		Spot	24.92	84.15	13.98
	Laterite soil	Slashing	22.92	95.24	21.45
		Spot & slashing	16.67	109.86	21.34
		Spot	18.75	75.83	17.06
	Black Soil	Slashing	14.58	121.00	26.30
		Spot & slashing	27.08	111.07	22.77
		Spot	18.67	99.54	18.45
Rainy	Red stony soil	Slashing	83.33	91.41	23.58
		Spot & slashing	83.33	118.12	22.51
		Spot	78.17	91.06	19.39
	Laterite soil	Slashing	77.08	102.33	24.69
		Spot & slashing	83.33	117.62	25.05
		Spot	87.50	77.37	17.45
	Black Soil	Slashing	77.08	130.07	32.53
		Spot & slashing	83.33	117.28	28.45
		Spot	78.17	86.65	20.57
Significance	Propagation season		**	**	**
	Weed management (Weed Mgt)		NS	NS	NS
	Soil type		NS	NS	NS
	Propagation season*Soil type		NS	NS	NS
	Propagation season *Weed Mgt		NS	NS	NS
	Soil type*Weed Mgt		NS	NS	NS
	Propagation season *Weed Mgt*soil type		NS	NS	NS

**Significant difference at P= 0.05; NS= not significant.

Table 2: Relative growth rate in height and collar diameter of *Jatropha curcas* after one year of plantation

Propagation Season	Soil type	Weed Management Method	RGRh 12months ±SD	RGRg 12months±SD
Winter	Red stony soil	Slashing	0.084±0.021	0.181±0.017
		Spot & slashing	0.122±0.043	0.160±0.039
		Spot	0.081±0.012	0.121±0.027
	Laterite soil	Slashing	0.104±0.010	0.120±0.076
		Spot & slashing	0.179±0.023	0.150±0.068
		Spot	0.124±0.030	0.072±0.016
	Black Soil	Slashing	0.072±0.019	0.085±0.025
		Spot & slashing	0.192±0.017	0.138±0.065
		Spot	0.095±0.010	0.085±0.020
Summer	Red stony soil	Slashing	0.093±0.013	0.183±0.032
		Spot & slashing	0.192±0.019	0.242±0.027
		Spot	0.108±0.008	0.156±0.089
	Laterite soil	Slashing	0.169±0.015	0.168±0.013
		Spot & slashing	0.215±0.011	0.197±0.067
		Spot	0.122±0.029	0.091±0.045
	Black Soil	Slashing	0.101±0.077	0.131±0.031
		Spot & slashing	0.212±0.081	0.204±0.016
		Spot	0.089±0.025	0.062±0.033
Rainy	Red stony soil	Slashing	0.103±0.035	0.145±0.059
		Spot & slashing	0.202±0.079	0.199±0.054
		Spot	0.107±0.034	0.101±0.045
	Laterite soil	Slashing	0.137±0.023	0.140±0.076
		Spot & slashing	0.195±0.051	0.175±0.037
		Spot	0.122±0.015	0.114±0.071
	Black Soil	Slashing	0.074±0.095	0.102±0.027
		Spot & slashing	0.195±0.044	0.149±0.031
		Spot	0.107±0.019	0.094±0.015
Significance	Propagation season		NS	NS
	Weed management (Weed Mgt)		NS	NS
	Soil type		NS	NS
	Propagation season*Soil type		NS	NS
	Propagation season *Weed Mgt		NS	NS
	Soil type*Weed Mgt		NS	NS
	Propagation season *Weed Mgt*soil type		NS	NS

NS= not significant different

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