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Research Paper

Effect of weed management on sisal (*Agave sisalana*) nursery

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ABSTRACT

A field experiment was conducted during June–December of 2009 and 2010 at Bamra, Sambalpur, Odisha, to study the effects of weed-management methods on the weeds of sisal (*Agave sisalana* Perrine ex Engelm.) nursery and their effect on the growth of sisal plants in nursery and also on soil microbes. The dominant grass weeds were *Cynodon dactylon* (L.) Pers., *Eleusine indica* (L.) Gaertn., *Dactyloctenium aegyptium* (L.) P. Beauv., and *Digitaria sangunalis* (L.) Scop. The important broad-leaf weeds were *Solanum nigrum* L., *Amaranthus spinosus* L., *Physalis minima* L. and *Phyllanthus niruri* L. The only sedge weed was *Cyperus rotundus* L. in the experimental plots. At 15 days after planting (DAP), the highest weed-control efficiency (WCE) of 89.2% was recorded with s-metolachlor and at 30 DAP, the highest WCE was obtained from manual weeding (90–93%), followed by s-metolachlor (87.1%). However, at 45 DAP and beyond only 2 manual weeding showed the highest WEC of 92.3 (45 DAP) and 71.8% (60 DAP). Hand-weeding twice produced the most robust type of sisal plantlets (13.9 g/plant), followed by sisal waste (13.3 g/plant). All the tested herbicides reduced the biomass production by sisal bulbils as compared to hand weeding in the order of trifluralin (14.7%) > pretilachlor (22.1%) > s-metolachlor (35.9%) > quizalofop ethyl (39.2%). At the maturity stage of sisal bulbils in the primary nursery, there was little effect of trifluralin and quizalofop ethyl on the total bacteria count. In contrast, the total bacteria population remained depressed in pretilachlor (41.7%) and s-metolachor (42.1%)-treated plots. The total actinomycetes population could not reach to the normal level (57.79×10^4 CFU/g) in case of s-metolachlor (–50.2%), pretilachlor (–46.1%) and quizalofop ethyl (–38.6%). At this stage, the total fungi population was more or less same in all the treatments except in quizalofop ethyl which increased the population by 2.5 folds.

Key words : Crop protection, Chemical and ecological weed management, Nursery, Sisal, Soil microbes

Sisal is an important vegetable fibre obtained from the leaf of *Agave* sp. Among the different species of agave, *Agave sisalana* contributes nearly 85% of the total sisal fibre production of the World (Sarkar *et al.*, 2010). Sisal is propagated by vegetative means known as 'bulbils' and 'suckers'. Bulbils develop from tiny buds present on each flower stalk (pole) emerge after 11–12 years of active growth. A bulbil is a plantlet consisting of a meristem, 4–7 reduced leaves and rudimentary adventitious roots. A pole of a sisal plant produces 400–800 or more bulbils. These bulbils develop and attain a size of 4–5 cm when they are collected during mid-February to mid-April and raised in nurseries. A primary nursery is required to rear fresh bulbils with intensive care and management during 4–6 summer–rainy months. In sisal nursery, planting is done with the onset of monsoon and therefore, the chance of weed infestation is always more. One hectare of sisal nursery requires atleast 150 laboureres in total for manual weeding 2–3 times for which huge wage expenditure is involved. This expenditure adds costs to the establishment of sisal plantation, fibre production and drastically reduces profitability. Weed competition for the first 45 days is very critical for sisal, as heavy competition from weeds during this period reduces emission of new leaves drastically (Alemán Ruiz and Flores López, 2002). Quite some time ago, the weed control with herbicides and its selectivity to sisal were studied on a clay soil by Salgado *et al.* (1980) in Brazil. The grass control was over 90% by trifluralin, bromacil and terbacil, around 80% by simazine and < 75% by other herbicides. The broad-leaves were controlled at a level of 90 to 100% by bromacil and terbacil and 80 to 85% by simazine. Terbacil controlled 75 and 95% of the total quantity of weeds, at the lower and higher doses, respectively, whereas trifluralin controlled 60 to 70% of the weeds in sisal plantation. Herbicides such as fluroxypyr and triclopyr should not be used for weed management in

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sisal, as the herbicides kill agave plant itself (Bickerton, 2006). Meagre information is available on the weed-management aspects in sisal. Results of weed control in India indicate that glyphosate @ 1.5 kg/ha controlled the weeds by 87.2% at 21 days after application (DAA). Although higher rate of weed control was observed with higher rate of application (2.0, 2.5 and 3.0 kg/ha) of glyphosate but showed significant detrimental effect on the growth of sisal bulbils (Sarkar and Abdullah, 2010). No more study on chemical or other method has been tried in managing weeds in primary sisal nursery in India. Therefore, the field experiment was conducted to study the effectiveness of different pre-and post-emergence herbicides, namely trifluralin, pretilachlor, s-metolachlor and quizalofop ethyl, and mulching by sisal waste to find a more effective and economic weed-management method in primary nursery of sisal and on soil microbes.

MATERIALS AND METHODS

A field experiment was conducted for 2 consecutive years during June–December of 2009 and 2010 at Sisal Research Station (22.0425°N, 84.2958°E, and 292.8 m above mean sea-level), Bamra, Sambalpur, Odisha. The experimental soil was Typic Haplustult, yellowish red to red, sandy loam, slightly hard and very friable having pH (1: 2.5 w/v in water) 5.10, organic carbon 4.50 g/kg, available N 284, P 17.3, K 63 kg/ha.

The weed-management treatments were, T_1, control (no weeding); T_2, manual weeding once at 21 days after planting (DAP); T_3, manual weeding twice at 21 and 35 DAP; T_4, sisal leaf waste @ 2 kg/m^2; T_5, trifluralin 0.75 kg/ha at 3 days before planting (DBP); T_6: s-metolachlor 0.50 kg/ha at 1 DBP; T_7, pretilachlor 0.50 kg/ha at 1 DBP; and T_8, quizalofop ethyl 0.075 kg/ha at 14 and 28 DAP. After extraction of fibre, dried waste of leaf was used as mulch, spread over the soil uniformly after final land preparation. Pre-emergence herbicide, trifluralin was applied in the soil as pre-plant soil incorporation 3 DBP of sisal bulbils; whereas other pre-emergence herbicides, namely s-metolachlor and pretilachlor were applied 1 DBP on the soil surface. Quizalofop ethyl was applied as post-emergence spray 2 times at 14 and 28 DAP. The 8 treatments were replicated thrice in randomized block design (RBD) with individual plot size of 6 m × 1.5 m, which is the standard plot size for sisal nursery (Sarkar *et al.*, 2010). A spacing of 10 cm × 7 cm was followed in flat raised beds of 1.5 m width. Sisal bulbils were planted in line on 13 June in 2009 and on 9 June in 2010 by following standard agronomic practices recommended for primary sisal nursery. Biometrical observations regarding weeds and sisal plantlets were recorded at regular interval.

Soil samples collected before applying treatments (initial), at 4 weed after application (WAA) and at maturity of bulbil were analysed for changes in soil microbial populations over time. The enumeration of soil microbial population was done on agar plate containing appropriate media following serial dilution technique and pour plate method (Pramer and Schmidt, 1966). Thornton's agar media for total bacterial count (Thornton, 1922), Martin's rose Bengal streptomycin agar media for total fungi count (Martin, 1950), and Kenknight and Munaier's media for total actinomycetes counts were used. The statistical analysis of the experimental data was carried out by using SPSS package (version 10.0).

RESULTS AND DISCUSSION

Weed flora

The experimental plots were infested by all 3 categories of weeds, namely grass, sedge and broad-leaf weeds. The dominant grass weeds were: *Cynodon dactylon* (L.) Pers., *Eleusine indica* (L.) Gaertn., *Dactyloctenium aegyptium* (L.) P. Beauv. and *Digitaria sangunalis* (L.) Scop. The important broad-leaf weeds were: *Solanum nigrum* L., *Amaranthus spinosus* L., *Physalis minima* L. and *Phyllanthus niruri* L. The only sedge weed was *Cyperus rotundus* L. in the experimental plots.

Effect on weed

Total weed biomass: At 15 days after planting (DAP), the lowest weed biomass was recorded in s-metolachlor-treated plots, which was followed by the weed biomass in pretilachlor treatment. The first manual weeding was given at 21 DAP, so the weed biomass was the lowest in manually weeded plots at 30 DAP. Among the herbicides used, at 30 DAP s-metolachlor controlled the weeds better as observed from the lowest weed biomass, followed by quizalofop ethyl, pretilachlor and trifluralin (Table 1). At 45 DAP, twice manual weeded plots had the lowest weed biomass (7.4 g/m^2), followed by 1 manual weeding, s-metolachlor and quizalofop ethyl. At 60 DAP, except 2 manual weedings, no other herbicide was very effective in controlling weeds in primary nursery of sisal. However, among the herbicide treatments, quizalofop ethyl and trifluralin produced comparatively lower weed biomass.

Weed control efficiency: At 15 DAP, the highest weed-control efficiency (WCE) was recorded with s-metolachlor and at 30 DAP the highest WCE was obtained from manual weeding, followed by s-metolachlor (87.1%). However at 45 DAP and beyond, only 2 manual weeding resulted in the highest WEC at 45 DAP (92.3%) and60 DAP (71.8%).

Relative dominance of different categories of weeds

Natural condition of growth of weeds without any interruption in sisal nursery dominated by grass (50.7%), followed by sedges (44.2%) and remaining few were broad-leaf weeds (5.1%). Whereas, trifluralin, a grass and broad-leaf controlling pre-emergence herbicide favoured growth of sedges (89.2%) by controlling and reducing natural competition from grass (8.5%) and broad-leaf weeds (2.2%). Therefore, shifting of weed flora from grass to sedge was observed where trifluralin was used for controlling grass/broad-leaf weeds in sisal nursery. Similar, observation was reported in jute weed management by Sarkar *et al.* (2005) where it was said that application of trifluralin favoured growth of sedge weeds due to absolute control of predominant grass leaving little interspecific competition for sedge. At 30 DAP also, in the control plots the grass weeds dominated (79.0%) to sedge (16.7%) and broad-leaf weeds (4.3%) (Fig 1). As observed at 15 DAP, at 30 DAP also trifluralin encouraged growth of sedges (87.7% dominance) by controlling grass (relative dominance 9.9%) and broad-leaf weeds (2.3%). The post-emergence grass-controlling herbicide, i.e. quizalofop ethyl controlled the grass well (3.1% relative dominance) but at the same time encouraged sedge (77.9% relative dominance) and broad-leaf weeds (19.0%). It was observed that the relative dominance of sedge was low (12.9%) in s-metolachlor treatment; whereas the same encouraged more dominance of grass (57.7%) and broad-leaf weeds (29.4%). In contrast, the dominance of sedge (50.0%) and broad-leaf weeds (46.2%) was more in quizalofop ethyl treatment, which controlled the grass well. After 2 months of sisal nursery planting, the weed flora in unweeded condition remained dominated by the grass (90.2%) and the dominance of sedge (3.7%) and broadleaf weeds (6.1%) were meagre (Fig. 2). At 60 DAP, increase of more dominance of grass (77.6%) was noted in s-metolachlor treatment which reduced the relative dominance of sedge by 3.2%. Like the observation at 45 DAP, the relative dominance of sedge was remained higher (26.0%) with quizalofop ethyl, but the relative dominance of broad-leaf weeds increased

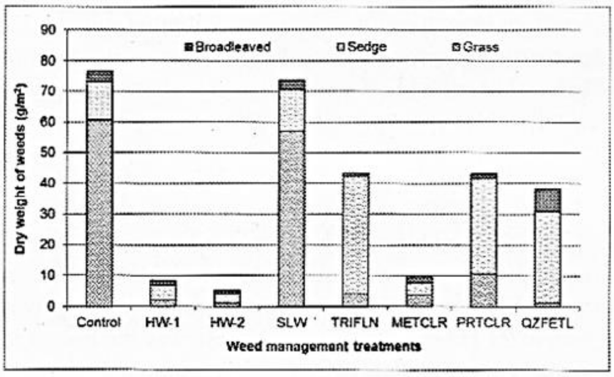

Fig. 1. Effect of weed-management treatments on relative dominance of different categories of weeds in sisal nursery at 30 days after planting

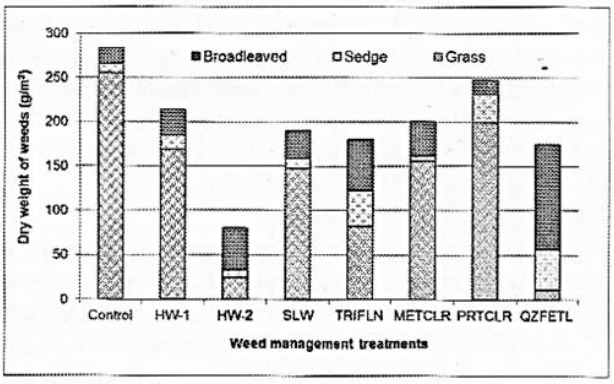

Fig. 2. Effect of weed-management treatments on relative dominance of different categories of weeds in sisal nursery at 60 days after planting

Table 1. Effect of weed-management treatments on periodical weed growth and weed control efficiency in sisal nursery (pooled data of 2 years)

Treatment	Weed biomass (g/m²)		Weed-control efficiency (%)	
	30 DAP	60 DAP	30 DAP	60 DAP
Control (no weeding)	8.7 (76.6)	16.8 (283.3)	-	-
Hand-weeding (once) at 21 DAP	2.9 (8.4)	14.6 (213.2)	90.0	24.7
Hand-weeding (twice) at 21 and 35 DAP	2.3 (5.3)	8.9 (79.9)	93.0	71.8
Sisal leaf-waste @ 2 kg/m²	8.6 (73.6)	13.7 (189.4)	4.0	33.1
Trifluralin 0.75kg/ha at 3 DBP[2]	6.6 (43.2)	13.4 (179.5)	43.5	36.6
S-Metolachlor 0.50 kg/ha at 1 DBP	3.1 (9.9)	14.1 (199.7)	87.1	29.5
Pretilachlor 0.50 kg/ha at 1 DBP	6.6 (43.2)	15.7 (247.2)	43.6	12.7
Quizalofop ethyl 0.075 kg/ha at 14 and 28 DAP	6.2 (38.3)	13.2 (174.5)	50.0	38.4
SEm±	0.219	0.535		
CD (P=0.05)	0.671	1.613	-	-

Figures in parentheses indicate original values; weed data were subjected to square-root transformation; [1]DAP, Days after planting; [2]DBP, days before planting to a great extent (68.0%) by use of quizalofop ethyl as post-emergence herbicide in sisal nursery.

Effect of weed-management on weeds

Grass weeds: Grass weeds were better controlled by manual weeding twice at 21 and 35 DAP. Sisal leaf waste (2 kg/m^2) could not control the grass weeds, whereas it encouraged grass weed growth, might be acting as physical mulch over the soil surface in hot summer of the second fortnight of June (having mean maximum temperature 38.6°C, RH ± 40%, with no rainfall) resulting comparative lowering of soil temperature and conservation of soil moisture. Among the herbicides, the grass weeds were controlled by trifluralin, s-metolachlor and pretilachlor (Fig 3). Application of quizalofop ethyl controlled the grass weeds better than other pre-emergence herbicides even up to 60 DAP, whereas pre-emergence herbicides controlled the grass weeds up to 30 DAP.

Sedge weeds: Over the period of observation from 15 to 60 DAP, the sedge weeds were stable in the control condition and the sisal leaf waste did not affect the sedge weeds. However, it was partially controlled by uprooting of the emerged sedges by manual weeding twice. Among the herbicide tested, sedge weeds were much affected by s-metolachlor throughout the observation period (up to 60 DAP). Sedge weeds were not affected by trifluralin and quizalofop ethyl (Fig. 4).

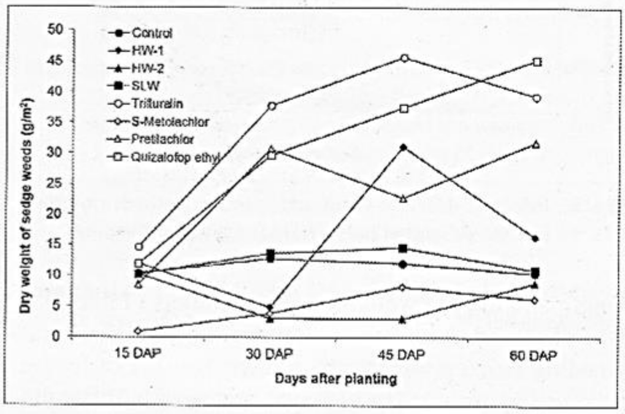

Fig. 4. Effect of different weed-management methods on sedge weeds in sisal nursery(DAP, days after planting)

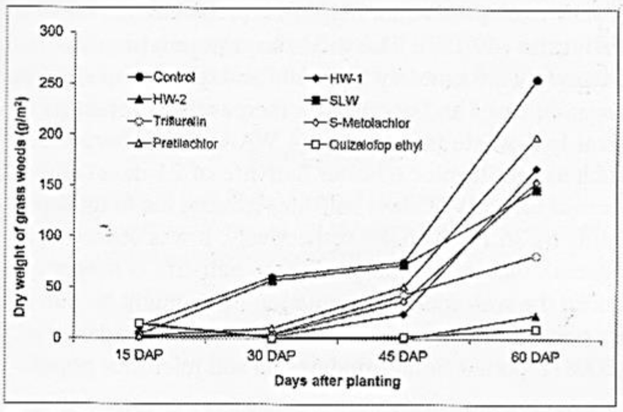

Fig. 3. Effect of different weed-management methods on grass weeds in sisal nursery (DAP, days after planting)

Broadleaf weeds: In general, broad-leaf weeds did not pose serious problem in sisal nursery. In the manually weeded plots, the broad-leaf weeds boosted beyond 45-60 DAP. Broad-leaf weeds were controlled to some extent up to 45 DAP by the pre-emergence application of trifluralin (Fig. 5). This category of weed was not affected by quizalofop ethyl and s-metolachlor; however, the performance of pretilachlor was better in controlling broad-leaf weeds over the period of observation, i.e. up to 60 DAP.

Effect of weed management on sisal bulbils in primary nursery

Effects of different weed management methods on sisal bulbils were compared based on the number of leaves, leaf

Table 2. Growth of sisal bulbils as affected by different weed management methods (pooled data of 2 years)

Treatment	No. of leaves	Leaf length (cm)	Weight of bulbil (g)	% reduction of weight
Control (no weeding)	5.3	11.8	11.7	15.6
Hand-weeding (once) at 21 DAP	7.0	13.3	12.2	12.4
Hand-weeding (twice) at 21 and 35 DAP	7.6	15.8	13.9	-
Sisal leaf-waste @ 2 kg/m^2	6.7	14.0	13.3	4.5
Trifluralin 0.75 kg/ha at 3 DBP	7.4	15.7	11.9	14.7
S-Metolachlor 0.50 kg/ha at 1 DBP	6.8	15.2	8.9	35.9
Pretilachlor 0.50 kg/ha at 1 DBP	7.2	14.9	10.8	22.1
Quizalofop ethyl 0.075 kg/ha at 14 and 28 DAP	6.2	15.2	8.5	39.2
SEm±	0.41	0.52	0.71	-
CD (P=0.05)	1.26	1.59	2.15	-

DAP, Days after planting; DBP, days before planting

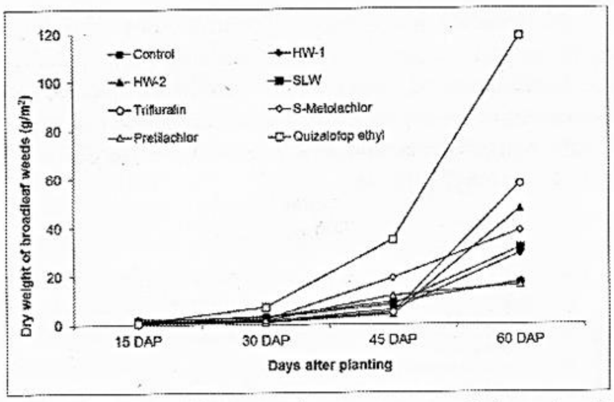

Fig. 5. Effect of different weed-management methods on broad-leaf weeds in sisal nursery(DAP, days after planting)

length and the dry weight of sisal plantlets (Table 2). It was observed that after 6 months after planting, hand-weeding twice produced the highest number of leaves, followed by the number of leaves produced in trifluralin- and pretilachlor-treated plots; whereas no-weeding (control) resulted in lowest number of leaves. Manual weeding twice produced the sisal bulbils having the highest leaf length, closely followed by the leaf length obtained in trifluralin and s-metolachlor. The biomass productions by sisal bulbils under different weed-management methods were also differed significantly. Hand-weeding twice resulted in the most robust type of sisal plants, followed by the plant dry weight obtained with sisal waste. No weeding in sisal nursery reduced the bulbil weight by 15.6% (Table 2). All the tested herbicides also reduced the biomass production by sisal bulbils as compared to hand-weeding in the order of trifluralin (14.7%) > pretilachlor (22.1%) > s-metolachlor (35.9%) > quizalofop ethyl (39.2%).

Effect of weed-management on soil microbial population in sisal nursery

Total soil bacteria, actinomycetes and fungi population were recorded initially, at 4 weeks after application (WAA) of the weed management treatments and at maturity of sisal bulbils (6 months after planting).

Initial population: At the start of the experiment (initial), the total microbial population in respect to bacteria was 3.27×10^5, actinomycetes was 20.63×10^4 and fungi was 17.58×10^3 CFU/g soil.

Population one month after application: It was observed that at 4 WAA the total bacterial population was increased by 2.7 folds with trifluralin (half-life 45 days) and 36.1% increase was recorded in sisal leaf-waste treatment (Table 3). However, the total bacterial population was reduced considerably by quizalofop ethyl (31.1%) whose half-life is more (60 days) and by s-metolachlor (28.0%), whose half-life is 30–50 days. In case of total soil actinomycetes at 4 WAA, sisal leaf waste had slight positive impact, as it increased the population by 12.2%. However, all the tested herbicides reduced the actinomycetes population in the ascending order of quizalofop ethyl (11.3%) > s-metolachlor (21.4%) > pretilachlor (44.5%) > trifluralin (49.1%). The total fungi population was increased by 2.6 times by trifluralin and quizalofop ethyl in separate cases and about 70% increase was recorded in sisal leaf-waste treatment at 4 WAA. Other herbicides such as pretilachlor (shorter half-life of 21 days) and s-metolachlor (30–50 days half-life) reduced the fungi population by 36.1 and 56.4% respectively. It was observed, in general, that the herbicides whose half-life is longer reduced the soil-microbe population more might be due to its persistence in soil for longer time. Majumdar *et al.* (2008) reported similar findings on soil microbial popula-

Table 3. Effect of different weed-management treatments on soil microbial population in primary nursery of sisal (pooled data of 2 years)

Treatment	CFU per g of soil					
	4 weeks after application			At maturity of sisal bulbil		
	Bacteria ($\times 10^5$)	Actinomycetes ($\times 10^4$)	Fungi ($\times 10^3$)	Bacteria ($\times 10^5$)	Actinomycetes ($\times 10^4$)	Fungi ($\times 10^3$)
Control (no weeding)	3.22	20.04	17.71	7.78	57.79	26.65
Hand-weeding (once) at 21 DAP	3.20	19.98	17.53	7.68	56.94	26.58
Hand-weeding (twice) at 21 and 35 DAP	3.31	20.06	17.70	7.83	57.86	27.34
Sisal leaf-waste @ 2 kg/m²	4.38	22.48	30.11	8.84	48.78	21.31
Trifluralin 0.75 kg/ha at 3 DBP	8.75	10.19	46.62	7.39	45.49	22.20
S-Metolachlor 0.50 kg/ha at 1 DBP	2.32	15.75	7.72	4.50	28.79	32.19
Pretilachlor 0.50 kg/ha at 1 DBP	3.31	11.12	11.31	4.53	31.18	26.65
Quizalofop ethyl 0.075 kg/ha at 14 and 28 DAP	2.22	17.78	45.46	7.82	35.46	67.70
SEm±	0.115	0.489	0.915	0.471	1.765	1.109
CD (P=0.05)	0.355	1.489	2.771	1.432	5.359	3.363

Initial values: Bacteria 3.27×10^5, Actinomycetes 20.63×10^4, and Fungi 17.58×10^3; DAP, Days after planting; DBP, days before planting tion dynamics after application of pre-and post-emergence herbicides in jute soil.

Population at maturity of sisal bulbils: At the maturity stage of sisal bulbils in the primary nursery, there was little effect of trifluralin and quizalofop ethyl on the total bacteria count (Table 3). In contrast, the total bacteria population remained depressed in pretilachlor (41.7%)-and s-metolachlor (42.1%)-treated plots as compared to no-weeding. The total actinomycetes population could not reach to the normal level (57.8×10^4 CFU/g) in case of s-metolachlor (–50.2%), pretilachlor (–46.0%) and quizalofop ethyl (–38.6%). At this stage, the total fungi population was more or less same in all the treatments except in quizalofop ethyl which increased the population by 2.5 folds.

It may be concluded that in sisal nursery, s-metolachlor @ 0.5 kg/ha at 1 DBP can control the weeds (89.2%) up to 45 days; and beyond that point only 2 manual weeding gave the highest WCE of 92.3 (45 DAP) and 71.8% (60 DAP) respectively. Hand-weeding twice produced the most robust type of sisal plantlets (13.9 g/plant), followed by sisal waste (13.3 g/plant). All the tested herbicides reduced the biomass of sisal bulbils as compared to hand-weeding in the order of trifluralin (14.7%) > pretilachlor (22.1%) > s-metolachlor (35.9%) > quizalofop ethyl (39.2%).

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