Indian Journal of Ecology (2024) 51(3): 559-563
DOI: https://doi.org/10.55362/IJE/2024/4273

Manuscript Number: 4273
NAAS Rating: 5.38

Standardization of Land Preparation Method to Exhaust Tuber Reserve and Regeneration of Purple Nut Sedge (*Cyperus rotundus* L.)

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Abstract: The unmanageable proliferation of purple nutsedge (*Cyperus rotundus* L.), coupled with the persistent nature of its tubers hinders effective control through cultural and mechanical methods. Experiment was conducted during the *kharif* and summer season at College of Agriculture, Vellayani to assess the effectiveness of land preparation methods to exhaust the tuber reserve and extent of regeneration of the weed. The treatments included stale seedbed (SSB) preparation followed by chemical and mechanical methods. SSB with halosulfuron methyl (HSM) 67.5 g ha^{-1} applied at 3-4 leaf stage of the weed resulted in a higher percentage reduction in population (66.10 and 60.80%), shoot dry weight (89.66 and 81.29%), tuber dry weight (75.18 and 69.76%) during summer and *kharif*, respectively. It was comparable with glyphosate 1.5 kg ha^{-1}. During both seasons, higher weed control efficiency, lower regeneration count, and tuber viability were noted with SSB + HSM at 67.5 g ha^{-1} which was on par with SSB + glyphosate 1.5 kg ha^{-1} making it a promising alternative for depleting nutsedge tuber reserves in sandy loam with lower regeneration, especially in light of the restricted use of glyphosate.

Keywords: Halosulfuron methyl, Nutsedge tuber dry weight, Regeneration count, Stale seedbed, Tuber viability, Weed control efficiency

Purple nutsedge (*Cyperus rotundus* L.), native of India, is a persistent agricultural weed that troubles over 90 tropical and subtropical countries, infesting 52 crop varieties and causing significant yield losses in different crops such as cotton (70-85%), soybean (23-89%), direct seeded rice (42-50%), sugarcane (20-30%) and maize (10-30%), if they are not managed timely (Peerzada 2017). Its rapid propagation, with a single tuber generating 1900 plants and 8900 tubers within 31.6 square meters in a year, leads to cultivation abandonment, particularly in uplands. Thus, it was considered as one of the most troublesome invasive weeds (Chaudhary et al 2022). The resilience of the weed under various stresses is due to its vigorous subterranean tuber network, where each tuber produces multiple active buds, resulting in persistent growth along with its allelopathic effect (Webster et al 2008; Ameena et al 2015). Controlling it through cultural or mechanical means proves challenging due to the tuber viability and their ability to sprout repeatedly (Nelson and Renner 2002; Ameena et al 2014). Even herbicides have not proven entirely successful in curbing its growth due to poor translocation and the dormant nature of tuber, necessitating the use of effective chemicals like glyphosate and 2,4-D. Consequently, the use of suitable herbicides has become imperative in the battle against this persistent weed.

Glyphosate, alone or combined with 2,4-D, has shown promise in controlling purple nutsedge growth since it translocated rapidly to the tubers (Das and Yaduraju 2002, Ameena and George 2004). However, the restricted use of these herbicides in many regions requires evaluating new and effective molecules. Chlorimuron-ethyl (CUE) and halosulfuron methyl (HSM) have displayed efficacy in reducing *Cyperus rotundus* populations and tuber viability, making them potential alternatives for control (Kaur et al 2009, Webster and Grey 2014). Reduced tuber viability (20-23.3%) and regeneration (6-8 sprouts per m^2) were documented when employing a stale seedbed along with pre-plant application, followed by directed post-emergence glyphosate application (Ameena et al 2006). However, the efficacy of the molecule in containing tuber regeneration and viability need to be checked under field condition. In this backdrop, an experiment was conducted to standardize the land preparation methods using different herbicides to exhaust tuber reserve and regeneration of purple nut sedge.

MATERIAL AND METHODS

The experiment was conducted during the summer and *kharif* season of 2022 at College of Agriculture, Vellayani in two different locations having severe nutsedge infestation with a density of more than 10 plants per sq. m. The experiment was laid out in randomized complete block design with eight treatments replicated thrice (Table 1). The stale seedbed plots were prepared by digging the field to a depth of 15 cm to break and expose the tuber chains of the weed followed by irrigation to facilitate the germination of dormant tubers. Later, the sprouted plants were sprayed with herbicides as per treatments at one week after SSB with weed at its 3-4 leaf stage. The initial (one week after SSB) and final (six weeks after spraying) count, shoot and tuber dry weight (g/m^2) of *Cyperus rotundus* were taken using a 25 cm x 25 cm quadrant and their respective percentage reductions were worked out. Weed control efficiency (WCE) was worked out by taking the difference in weed dry weight of weedy check and corresponding treatment plot and divided by weed dry weight in weedy check plot (Mani et al 1973). Ten tubers from each treatment were collected at 6 weeks after spraying (WASP) and sown in different containers having sand to observe the tuber viability. Number of tubers sprouted were recorded after 2 weeks and tuber viability was worked out and expressed as percentage. The area of 15cm x 15cm was marked in each plot just before imposing herbicide applications. The number of nutsedge sprouts regenerated were counted at 2, 4 and 6 WASP.

RESULTS AND DISCUSSION

Influence of Land Preparation Methods on *Cyperus rotundus* L

Population: The different land preparation methods exerted significant variation in the population of nutsedge (Table 1). The initial population of *Cyperus rotundus* L. sprouted after SSB ranged between 83.11 to 135.56 per m^2 during summer, while it was between 60.44 to 78.67 per m^2 during *kharif*. Among all the treatments, SSB with glyphosate application (T_6) recorded lower final *Cyperus rotundus* L. population during both seasons (25.78 and 17.77 per m^2, respectively). Further, SSB with HSM at 75 g ha^{-1} (T_3) and at 67.5 g ha^{-1} (T_2) were comparable with T_6. The percentage reduction in *C. rotundus* L. population was higher in T_6 and was on par with T_3 and T_2 in summer and *kharif*, respectively. The plots where the stimulation alone was given by way of seedbeds (T_8) there was a 14.74 and 38.18% increase in purple nutsedge population during both summer and *kharif*, respectively. Stale seedbed preparation had promoted the germination of dormant tubers and subsequent application of glyphosate or HSM at 3-4 leaf stage of weed had effectively controlled nutsedge population. The highest percentage reduction of nutsedge population with glyphosate in SSB was earlier reported by Ameena et al (2006). The effectiveness of SSB in combination with HSM, in managing *C. rotundus* similar to glyphosate, is supported by the findings of Manisankar et al (2022).

Shoot dry weight: The land preparation methods caused significant variation in nutsedge shoot dry weight (Table 2). The initial shoot dry weight of *C. rotundus* L. ranged from 38.85 to 129.79 g/m^2 during summer and 43.01 to 52.84 g/m^2 during *kharif*. The final shoot dry weight of *C. rotundus* L. was recorded lower in SSB with glyphosate at 1.5 kg ha^{-1} (T_6) (5.73 and 3.99 g/m^2) during both summer and *kharif,* respectively at 6 WASP which was comparable with SSB + HSM at 75 g ha^{-1} (T_3) and at 67.5 g ha^{-1} (T_2). On the whole, T_6, T_3 and T_2 recorded significantly higher percentage reduction in shoot dry weight of *C. rotundus* L. during summer as well as *kharif*. The dry weight of shoots showed an increase of 18.16% in the *kharif* season, compared to a modest increase of 2.57% during the summer, specifically when sole SSB practices were employed. This might be ample rainfall in *kharif* has allowed the weed to efficiently utilize moisture attributed to its C_4 pathway resulting in superior growth (Mandal et al 2022).

Table 1. Effect of different land preparation methods on population of purple nutsedge (*Cyperus rotundus* L.) per 1.0 m^2

Treatments		Summer, 2022			*Kharif*, 2022			Pooled data (6 WASP)
		Initial population	Final population	Percent reduction in population	Initial population	Final population	Percent reduction in population	
T_1	SSB with HSM at 60g ha^{-1} at 3-4 leaf stage of weed	130.67^{a}	58.67^{b}	54.60^{bc}	61.78	30.22^{d}	50.56^{bc}	6.29^{bcd}
T_2	SSB with HSM at 67.5g ha^{-1} at 3-4 leaf stage of weed	99.11^{b}	33.33^{cd}	66.10^{ab}	60.44	23.56^{de}	60.80^{ab}	4.24^{cd}
T_3	SSB with HSM at 75g ha^{-1} at 3-4 leaf stage of weed	98.67^{b}	32.00^{d}	67.97^{ab}	74.22	22.67^{de}	69.48^{a}	4.07^{d}
T_4	SSB with CUE at 9g ha^{-1} at 3-4 leaf stage of weed	88.00^{bc}	62.22^{b}	29.16^{d}	70.22	54.22^{b}	22.38^{e}	8.98^{bc}
T_5	SSB with CUE at 12g ha^{-1} at 3-4 leaf stage of weed	83.11^{c}	48.89^{bc}	41.34^{cd}	69.33	40.00^{c}	40.83^{cd}	6.78^{bcd}
T_6	SSB with glyphosate at 1.5 kg ha^{-1}	92.00^{bc}	25.78^{d}	71.47^{a}	66.67	17.77^{e}	72.97^{a}	3.23^{d}
T_7	SSB with mechanical destruction	135.56^{a}	61.78^{b}	52.95^{bc}	78.67	56.44^{b}	28.25^{de}	9.18^{b}
T_8	SSB alone	99.56^{b}	114.22^{a}	-15.87^{e}	73.33	101.33^{a}	-39.45^{f}	16.66^{a}

Note: (SSB- Stale Seedbed); (WASP-Weeks after spraying)
Figures with same letter in column do not differ significantly (CD p=0.05)

Further, the effect of HSM on nutsedge shoot dry weight was similar to glyphosate under SSB due to its rapid absorption by the foliage, facilitating its translocation throughout the entire plant causing substantial decrease in plant biomass. Maurya et al (2021) also reported that the application of HSM at 67.5, 75.0, and 150.0 g ha^{-1} resulted in significantly lower weed dry biomass for *C. rotundus*, ranging from 0.45-0.49 g m^{-2}.

Tuber dry weight: The nutsedge tuber dry weight varied significantly with respect to the land preparation methods tested (Table 2). The initial tuber dry weight of *C. rotundus* L. ranged from 157.52 to 252.96 g/m^2 during summer to 53.15 to 61.64 g/m^2 during *kharif*. However, final *C. rotundus* L. tuber dry weight was recorded lower in SSB with glyphosate at 1.5 kg ha^{-1} (T_6) and SSB with HSM at 75 g ha^{-1} (T_3) at 6 WASP (46.64 and 47.49 g/m^2, respectively) which was on par with SSB with HSM at 67.5 g ha^{-1} (T_2) in summer. In *kharif*, T_6 recorded lower final *C. rotundus* L. tuber dry weight (11.04 g/m^2) which was on par with T_3 and T_2. In general, T_2, T_3 and T_6 recorded significantly higher percentage reduction in tuber dry weight (75.18, 74.99 and 73.90%, respectively) followed by T_5 in summer. However, during *kharif*, T_6 and T_3 recorded significantly higher percentage reduction in tuber dry weight (80.78 and 76.05%, respectively) and were on par with T_2. An elevated tuber dry weight, with an increase of 18.97% was noticed in the summer compared to 13.04% during the *kharif* season in SSB alone control plots. The SSB treatments using HSM at 67.5 and 75 g ha^{-1} have significantly decreased tuber dry weight, showing comparable effectiveness to glyphosate. This could be achieved due to effective herbicidal translocation to tubers thereby killing the underground propagules. Webster et al (2008) observed reduced total tuber biomass with halosulfuron similar to glyphosate in purple nutsedge.

Weed control efficiency and tuber viability of *C. rotundus:* The weed control efficiency (WCE) as influenced by land preparation methods showed significant variation (Figure 1 and 2) during both summer and rainy season. Significantly higher WCE was recorded by SSB with glyphosate at 1.5 kg ha^{-1} (T_6), SSB with HSM at 75 g ha^{-1} (T_3) and SSB with HSM at 67.5 g ha^{-1} (T_2) in summer and *kharif* respectively. Ghosh et al (2017) observed post-emergence application of HSM 75% WG as exceptional with WCE of 86.6 to 90% at 45 days after application. Similarly, Maurya et al (2021) reported that the application of halosulfuron at rates of 67.5, 75.0, and 150.0 g ha^{-1} resulted in higher weed control efficiency.

Tuber viability was significantly affected by different land preparation methods. In both seasons, SSB with glyphosate at 1.5 kg ha^{-1} (T_6) and SSB with HSM at 75 g ha^{-1} (T_3) recorded significantly lower tuber viability (13.33 and 26.67%) and (6.67 and 13.33%), respectively. They were on par with SSB with HSM at 67.5 g ha^{-1} (T_2). The treatment T_2 recorded about 66.67 and 80 percent reduction in tuber viability over plots where SSB alone was employed (T_8) respectively in both seasons. This implied that the herbicidal effect might have made the tubers incapable of growth after new shoots had emerged. Giraldeli et al (2020) also found that halosulfuron, applied @ 105 g ha^{-1}, significantly decreased the number of viable tubers by 62% (4-5 leaves), 54% (5-7 leaves) and 46% (7-8 leaves) at 90 days after application.

Regeneration count of *Cyperus rotundus* L.: No signs of regeneration were observed at 2 weeks after spraying, but the reappearance of purple nutsedge became apparent at 4 and 6 weeks after herbicide application. The lower regeneration count per 0.15 sq. m was recorded in SSB with

Table 2. Effect of different land preparation methods on shoot and tuber dry weight (g/m^2) of purple nutsedge (*Cyperus rotundus* L.)

Treatments	Shoot dry weight							Tuber dry weight						
	Summer, 2022			*Kharif*, 2022			Pooled data (6 WASP)	Summer, 2022			*Kharif*, 2022			Pooled data (6 WASP)
	Initial	Final	% reduction	Initial	Final	% reduction		Initial	Final	% reduction	Initial	Final	% reduction	
T_1	100.13^{b}	22.80^{b}	77.52^{a}	43.65	19.51^{d}	54.80^{b}	5.28^{bc}	234.93^{ab}	80.32^{b}	65.48^{ab}	53.15	22.93^{c}	56.35^{b}	4.28^{bc}
T_2	75.87^{bcd}	7.13^{d}	89.66^{a}	43.01	7.93^{e}	81.29^{a}	1.88^{cd}	195.56^{bc}	49.01^{cd}	75.18^{a}	49.92	15.00^{cd}	69.76^{ab}	2.70^{c}
T_3	70.07^{cd}	6.23^{d}	90.67^{a}	48.27	6.81^{e}	85.53^{a}	1.63^{cd}	188.11^{bc}	47.49^{d}	74.99^{a}	57.40	13.75^{cd}	76.05^{a}	2.55^{c}
T_4	54.56^{de}	30.37^{b}	41.86^{c}	49.45	29.76^{bc}	40.45^{bc}	7.52^{b}	176.60^{c}	78.29^{bc}	55.20^{b}	59.39	43.52^{b}	26.66^{c}	6.00^{b}
T_5	38.85^{e}	15.00^{c}	61.07^{b}	46.05	22.63^{cd}	48.38^{bc}	4.70^{bcd}	157.52^{c}	67.57^{bcd}	57.44^{b}	53.75	35.42$_{b}$	32.44^{c}	4.99^{bc}
T_6	61.64^{cde}	5.73^{d}	90.81^{a}	48.27	3.99$_{e}$	91.62^{a}	1.22^{d}	180.60^{c}	46.64^{d}	73.90^{a}	56.88	11.04^{d}	80.78^{a}	2.29^{c}
T_7	129.79^{a}	26.64^{b}	79.10^{a}	46.99	35.07^{b}	25.39^{c}	7.71^{b}	252.96^{a}	88.45^{b}	64.24^{ab}	55.65	39.85^{b}	28.19^{c}	5.97^{b}
T_8	82.45^{bc}	84.57^{a}	-4.26^{d}	52.84	62.43^{a}	-23.13^{d}	18.38^{a}	201.12^{bc}	239.29^{a}	-20.05^{c}	61.64	69.70^{a}	-15.32^{d}	12.86^{a}

WASP- Weeks after spraying. See Table 1 for treatment details
Figures with same letter in column do not differ significantly (CD-p 0.05)

glyphosate at 1.5 kg ha^{-1} (T_6), SSB with HSM at 75 g ha^{-1} (T_3) and SSB with HSM at 67.5 g ha^{-1} (T_2) at 4 and 6 WASP in summer (Fig. 1). However, in *kharif*, T_6 lower regeneration count (1.00) and was on par with T_3 at 4 WASP. In the same season, T_6, T_3 and T_2 recorded lower regeneration count at 6 WASP (Fig. 2). In the control plot there was a rise in the regeneration of purple nutsedge, amounting to 7.14% during the summer and 12.14% during the *kharif* season. Ameena et al (2013) demonstrated the highest percentages of regrowth and viability in the weedy check plots without herbicide application which indicated that the newly formed tubers of purple nutsedge readily sprouted, displaying no seasonal dormancy. The reduced regeneration observed in HSM treatments, similar to glyphosate under SSB, may be attributed to their mechanism of action in disrupting the ALS enzyme. This disruption results in a swift cessation of cell division and plant growth which might ultimately result in reduction in the regrowth of purple nutsedge (Rathika et al

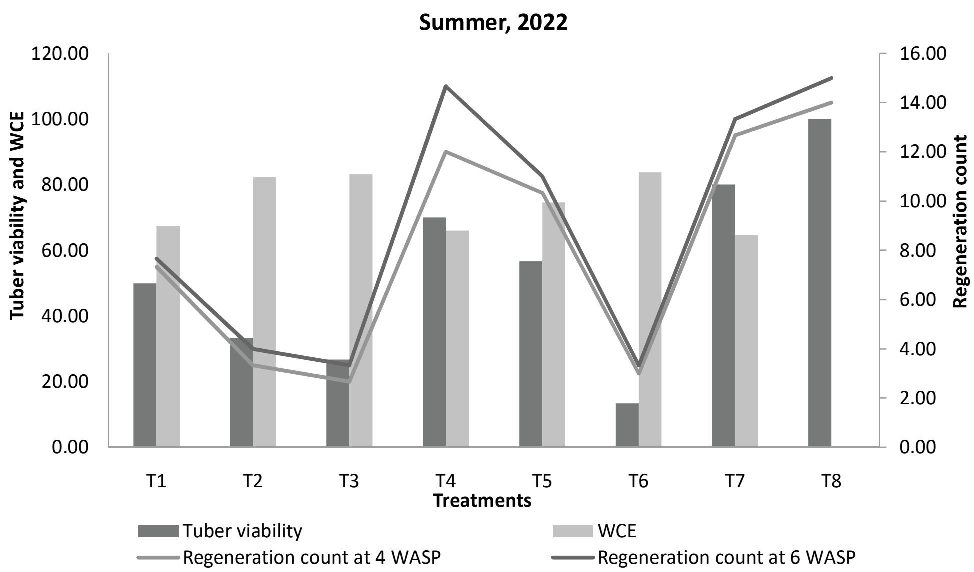

Fig. 1. Effect of different land preparation methods on tuber viability (%), WCE (%) and regeneration count of *Cyperus rotundus* L. during summer, 2022

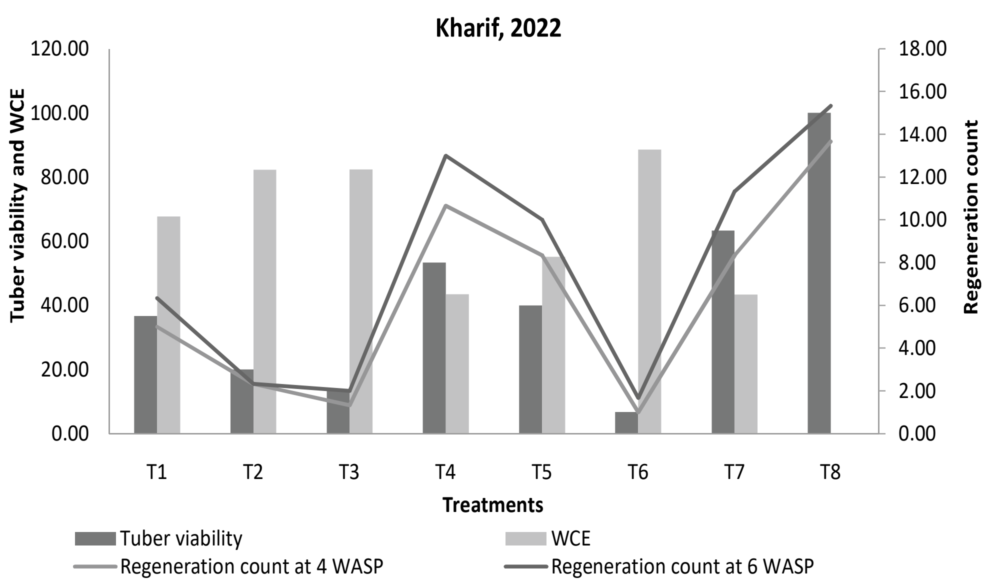

Fig. 2. Effect of different land preparation methods on tuber viability (%), WCE (%) and regeneration count of *Cyperus rotundus* L. during *kharif*, 2022

2013 and Desai et al 2017). Mathukia et al (2018) reported the most notable reduction in regrowth (5.76%) at 60 days after spraying through a tank-mix spray of glyphosate at 1230 g ha^{-1} combined with HSM at 33.75 g ha^{-1}, applied at 30 days after emergence (DAE). This outcome remained statistically comparable to the regrowth rates observed with HSM at 80 g ha^{-1} at 30 DAE (7.76%) and HSM at 67.5 g ha^{-1} at 30 DAE (8.48%).

CONCLUSION

The application of HSM at 67.5 g ha^{-1} applied at 3-4 leaf stage of purple nutsedge under stale seedbed method is equally effective as glyphosate at 1.5 kg ha^{-1} and could be effectively employed for exhausting tuber reserve of nutsedge with reduced tuber dry weight, tuber viability and regeneration. As glyphosate is under restricted use, HSM could be suggested as its substitute for nutsedge management in uplands.

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Received 25 January, 2024; Accepted 21 May, 2024

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