Journal of Crop and Weed, 15(2): 148-154 (2019)
ISSN- O : 2349 9400 ; P : 0974 6315
http://cwssbckv.org
www.cropandweed.com

Weed management in arecanut (*Areca catechu* L) plantation during post rainy season through herbicides in Andaman and Nicobar Islands

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Received : 12.03.2019 ; Revised : 27.06.2019 ; Accepted : 30.06.2019

ABSTRACT

A field investigation was made during post rainy season (January-April) of 2017 at Port Blair, to assess the impact of post-emergence herbicides (glyphosate and paraquat),along with weedy check and weed free treatments on management of weeds and thus conserving moisture and nutrients in areca nut plantation.Glyphosate through killing of existing weeds along with their roots and paraquat by desiccating the above ground green portions of weeds reduced the weed count, weed dry weight and thus have weed control efficiency (%) values at par with that of weed free situation (100). Un-controlled weeds of areca nut plantation during rain free period (January-April) have removed 46.4-7.18-52.1 kg ha^{-1} N-P-K from soil and depleted soil moisture quickly to reach permanent wilting point. These colossal loss of water and nutrients from areca nut plantation were reduced with use of herbicides and weed free conditions, however, herbicide use was more economical to weed free treatment. A temporary reduction in dehydrogenase enzyme activity was seen with use of herbicides. Glyphosate and paraquat herbicides were not only highly economical weed management options but also conserve nutrients and moisture in areca nut plantations during post rainy season (January-April) in islands, hence merits adoption.

***Keywords*: Arecanut, glyphosate, moisture, nutrients, paraquat and weeds**

Arecanut (*Areca catechu* L) also known as betel nut or *Supari* is cultivated on 0.956 million (m) ha with a production of 1.34 m tonnes (t) at an average productivity of 1.402 t ha^{-1} during 2017 in the world (FAOSTAT, 2018). In India during 2017-18, it was cultivated on 0.497 m ha with a production and productivity of 0.833 m tand 1.676 t ha^{-1} (NHB, 2018). In Andaman & Nicobar Islands, 4,625 ha were under areca nut plantations producing 10,605 t of areca nut at an average productivity of 2.293 t ha^{-1} (DOES, 2017). Tropical monsoonal humid climate (Am) of islands with copious rainfall (~300 cm), high humidity (66-93%), moderate temperatures (25-33^{0}C) and mild winds (1-5 km hour^{-1}) matching with theareca nut crop requirements results in higher productivity than that ofthe country. Hence, its commercial cultivation under rain fed conditions was taken up by farmers and many of them are small and marginal category right from hill tops to the sea coast. Its cultivation also generates huge employment by way of its processing at farm or house hold level. In Islands, the mean evaporation (PE) far exceeds the precipitation (P) during December-April and thus plantation crops experience moisture stress limiting their productivity substantially. The soil moisture stress sets in quickly in presence of weeds. It was also observed that the weed menace was more in sole stands of areca nut than multi-storey cropping systems due to availability of ample un-utilized space. Nair (1960) observation that on account of high stature, palms do not face any competition for light with the weeds, and competition is only for nutrients and soil moistureis true for islands during post-rainy season. There is dearth of information on weed flora of areca nut plantation in Islands and the only information available pertains to palms in general by Dagar *et al.* (1991) who have enlisted 18 broad leaved weeds excluding grasses. Despite of severe weed stress in plantation crops, due and required emphasis was not given to their management on account of costly manpower, dearth of simple machinery like power tillers for inter culture in tree basins, lack of technical knowledge about use of herbicides and finally inclement weather from May-November with incessant rains that prevents weeding operations and interventions. The utility of weeds in soil conservation on sloppy lands and as grazing resource for livestock also are the reasons behind meagre attention given to the weed management in islands. No information was also available in the country about weed management in areca nut and only information available is for coconut nursery. In the above context, field study was made to assess the diversity of weeds in areca nut plantation, impact of weeds on soil moisture and nutrient depletion and role of herbicides and manual weed management practices in curtailing the moisture and nutrient depletion for successful areca nut cultivation in island ecosystem during post rainy season (January-April).

MATERIALS AND METHODS

A field investigation was carried out during post rainy season from January–April, 2017 at Garacharma Research Farm of ICAR-Central Island Agricultural Research Institute, Port Blair, Andaman & Nicobar

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Islands, located at 11^0 66′ N latitude and 92^0 75′ E longitudes at an altitude of 6 m above mean sea level. The experimental soil in top 30 cm depth was found to be slightly acidic in reaction (6.5 pH), non-saline (ECe: 0.52 dS m^{-1}) and contained 262, 11.2 and 135 kg ha^{-1} of available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O).The soil with a bulk density of 1.45 g cc^{-1} has a field capacity (FC) and permanent wilting point (PWP) moisture of 20 and 9 per cent. During the study period, 196.8 mm rainfall was received in 15rainy days and temperature ranged from 21.3-32.4^0C. Experimental soil was near FC moisture at the start of study with 444.7 mm rainfall received during December in 11 rainy days. The study was conducted in fully grown up areca nut plantation of 15 years age in sole stands planted at 2.7 × 2.7 m spacing. The experiment was laid out in randomized complete block design (RCBD) with four replications. Nine arecanut trees were taken per treatment (65.61 m^2). Four weed management treatments *viz*. glyphosate (41% SL) 2.0 kg *a.i.* ha^{-1}, paraquat (24% SL)1.20 kg *a.i.* ha^{-1} (both sprayed on 2^{nd} January); weed free manual hoeing with hand hoe at monthly intervals (2^{nd} January, 1^{st}February, $3rd^h$ March and 2^{nd}April) and weedy check (no weeding) were evaluated in the study. Herbicides spray fluid of 750 litres/ha was applied using a manually operated knapsack sprayer fitted with flat fan nozzle in the study. The crop was grown under rain fed conditions with regular organic manure application in rings around tree in April and October every year. Plot wise weed count (grasses and broadleaved weeds i.e., BLW) was recorded from quadrates of 1 m^2 at two spots between the rows. Weeds were removed from the sampling area devoid of their roots and oven dried at 60^0 C for 48 hours so as to attain a constant weight and was expressed as g m^{-2}. Weed Control Efficiency (WCE) in per cent (%) was worked out as per Ahlawat *et al.* (2005); WCE (%) ={Weed dry weight (g) in weedy check plot - weed dry weight in treatment plot/ weed dry weight in weedy check plot} x 100. As weed count and dry weight data have zero values, the data was subjected to square root transformation (" (x + 0.5) prior to statistical analysis. Weed biomass was for nutrient (NPK) concentration as per Singh *et al.* (2005) and nutrient uptake (kg ha^{-1}) of grasses, BLW and their total was estimated as product of nutrient concentration (%) and weed dry matter (kg ha^{-1}). For soil moisture depletion assessment, soil samples were drawn from 0.5 m away from areca nut tree bole at two depths (0-10 and 10-30 cm) and initial weight was recorded. The same samples were oven dried for 48 hours at 60^0C to attain constant weight and was recorded as dry weight. Soil moisture content (%) was arrived at as: {initial soil weight (g) – oven dry weight/ oven dry weight} x 100. Dehydrogenase activity in the soil samples was determined by following the procedure as described by Casida *et al.* (1964). Economics of weed management treatments was worked out by taking prices of herbicides and labour. In herbicide treatments, the market price of herbicides and two labourers cost per spray was used. For manual weeding, 15 man days were used for first weeding and 5 man days for subsequent 3 weddings and in total 30 man days were used. The analysis of variance was done in RCBD. The significance of treatment differences was compared by critical difference at 5% level of significance (p=0.05) and statistical interpretation of treatments was done as per Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Weed flora

Weed flora was recorded from the whole experimental plot and also treatment wise at the start of the experiment. The weed flora was dominated by grasses followed by broad leaved weeds (BLW) and includes 3 epiphytes (trailing on tree). The grassy weeds as a thick mat on ground, epiphytes on tree trunks were uniformly distributed; however, the BLW distribution was irregular in the experimental area and varied among treatments. Seven grassy weeds *i.e*. *Ischaemum rugosum* Salisb.; *Eleusine indica* (L.) Gaertner; *Oplismenus compositus* (L.) Beauv.; *Cynodon dactylon* (L.) Pers.; *Digitaria sanguinalis* L.(Scop.); *Themeda traindra* Forssk; *Setaria viridis* (L.) P. Beauv. were recorded in the experiment. There were 14 genera of BLW in the whole experimental area that include: *Mucuna gigantea* (Willd.) DC.; *Ipomoea pes-caprae* (L.) R.Br.: *Mikania micrantha* H.B.K.; *Phyllanthus niruri* L.; *Tridax procumbense* L.; *Mimosa pudica* L.*; Ageratum conyzoides* L.; *A. houstonianum* Mill.; *Alysicarpus ovalifolius* (Schumach.) J. Leonard.; *Chromolaena odorata* (L.) King & Robins.; *Convolvulus arvensis* L.; *Euphorbia geniculata* Orteg.; *Achyranthes aspera* L.; *Euphorbia hirta* L.; *Melastoma malabaricum* L. Epiphytes recorded were *Dischidia nummularia* R.Br. (String of nickels or button orchid)*; Dischidia major* (Vahl) Merr (the Malayan urn vine) and *Drynaria quercifolia* (L.) J. Sm. (oak leaf fern).The weed flora reported in the current study from well managed plantation (animal grazed regularly prior to the current experiment) wasless diverse than thereported weed flora of plantations in the islands. This was evident from the fact that there were 18 non-grassy weeds reported from plantation crops (Dagar *et al.,* 1991), however, in the current study, only 5 weeds form part of the species documented earlier. Further, in this experiment nine new genera of weeds were added to the BLW flora of plantation crops.

Table 1: Weed count, weed dry weight and nutrient content of weeds at imposition of treatments

Treatment	Weed population (at the time of treatment)			Weed dry weight (g m^{-2}; in first weeding)			Nutrients in weeds (kg ha^{-1})		
	Grasses	BLW	Total	Grasses	BLW	Total	N	P	K
Glyphosate	31.7	7.2	38.9	-	-	-	-	-	-
Paraquat	33.2	6.7	39.9	-	-	-	-	-	-
Weed free	32.5	7.6	40.1	100.2	48.6	148.8	26.4	5.54	32.1
Weedy control	30.8	6.4	37.2	-	-	-	-	-	-
Mean	32.0	7.0	39.0						

Table 2: Weed count at different periods after imposition of treatments

Treatment	Weed count (7thday of treatment)			Weed counton(30April, 2017)		
	Grasses	BLW	Total	Grasses	BLW	Total
Glyphosate	0.707	0.707	0.707	2.345	1.581	2.739
	(0.0)	(0.0)	(0.0)	(5.0)	(2.0)	(7.0)
Paraquat	0.707	0.707	0.707	3.937	1.871	4.301
	(0.0)	(0.0)	(0.0)	(15.0)	(3.0)	(18.0)
Weed free	0.707	0.707	0.707	2.739	1.581	3.082
	(0.0)	(0.0)	(0.0)	(7.0)	(2.0)	(9.0)
Weedy check	5.595	2.627	6.140	5.657	2.646	6.205
	(30.8)	(6.4)	(37.2)	(31.5)	(6.5)	(38.0)
LSD (0.05)	**0.43**	**0.27**	**0.58**	**0.75**	**0.36**	**0.89**

Figures in parenthesis are original values. "(x + 0.5) transformed values

Table 3: Weed dry weight at different periods after imposition of treatments

Treatment	Weed biomass (g m^{-2}) 7 days after treatment			Weed biomass (g m^{-2}) 30th April, 2017		
	Grasses	BLW	Total	Grasses	BLW	Total
Glyphosate	0.707	0.707	0.707	5.339	3.536	6.364
	(0.0)	(0.0)	(0.0)	(28.0)	(12.0)	(40.0)
Paraquat	0.707	0.707	0.707	7.616	4.000	8.573
	(0.0)	(0.0)	(0.0)	(57.5)	(15.5)	(73.0)
Weed free	0.707	0.707	0.707	6.124	3.674	7.106
	(0.0)	(0.0)	(0.0)	(37.0)	(13.0)	(50.0)
Weedy check	10.035	6.935	12.219	13.557	9.083	16.303
	(100.2)	(48.6)	(148.8)	(183.3)	(82.0)	(265.3)
LSD (0.05)	**0.55**	**0.32**	**0.64**	**0.86**	**0.41**	**1.05**

Green weed biomass was only accounted

Table 4: Weed control efficiency (%) after 7th day of imposition and end of study period in different weed management treatments

Treatment	WCE (%) 7 January			WCE (%) 30th April		
	Grasses	BLW	Total	Grasses	BLW	Total
Glyphosate	100.0	100.0	100.0	84.7	85.4	84.9
Paraquat	100.0	100.0	100.0	68.6	81.1	72.5
Weed free	100.0	100.0	100.0	79.8	84.1	81.2
Weedy check	0.0	0.0	0.0	0.0	0.0	0.0

Table 5: Soil moisture status during rain free period under different weed management treatments

Treatment	Soil moisture content (%) in rain free period							
	10th February		20th February		10th March		30th March	
	0-10 cm	10-30 cm	0-10 cm	10-30 cm	0-10 cm	10-30 cm	0-10 cm	10-30 cm
Glyphosate	17.0	18.5	14.3	17.5	11.9	14.2	10.4	10.9
Paraquat	16.8	18.2	13.6	17.4	11.3	13.8	10.0	10.5
Manual weeding	16.5	18.0	12.3	17.8	9.8	13.2	9.5	11.0
Weedy check	14.5	16.9	10.9	14.9	9.3	11.9	9.2	10.4
LSD (0.05)	**1.45**	**1.92**	**0.76**	**1.15**	**0.48**	**0.70**	**0.38**	**NS**

Table 6: Soil dehydogenase activity in areca nut as influenced by different weed management treatments

Treatment	Soil dehydrogenase activity (µg TPF formed/g soil/day) days after treatment	
	10 days	25 days
Glyphosate	2.87	5.63
Paraquat	3.02	6.06
Weed free	3.93	6.97
Weedy check	6.00	7.63
LSD (0.05)	**0.83**	**1.08**

Table 7: Economics of different weed management treatments in arecanut

Treatment	Cost of treatment (Rs. ha^{-1})		
	Chemical	Labour	Total
Glyphosate 41% SL (Rs. 375/litre)	1829	920	2749
Paraquat 20% SL (Rs. 400/litre)	2500	920	3420
Manual weeding (30 man days @Rs. 400/labour)	-	12000	12000
Weedy control (no weeding)	-	-	-

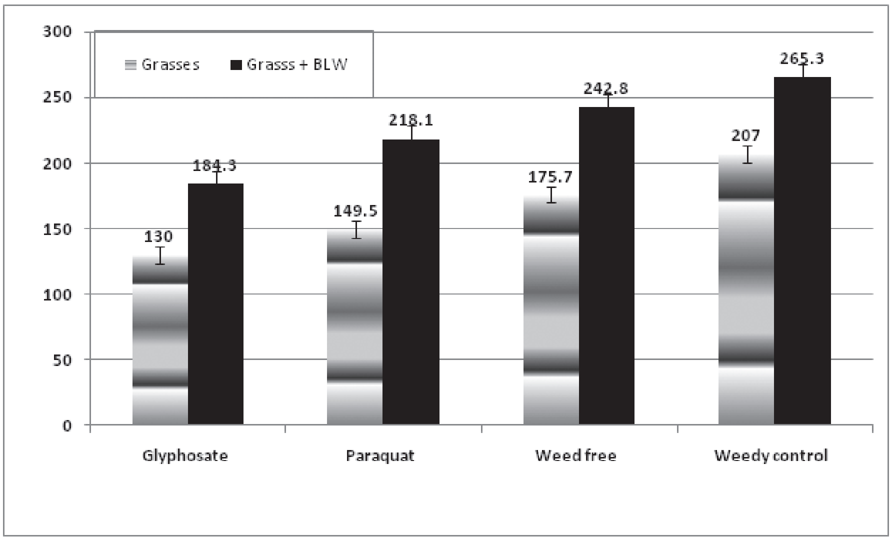

Fig. 1: Weed biomass (g m^{-2}) under different weed management treatments in areca nutfor January-April period of study (Error bars are CD values: for grasses: 6.0 and grasses + BLW: 9.2)

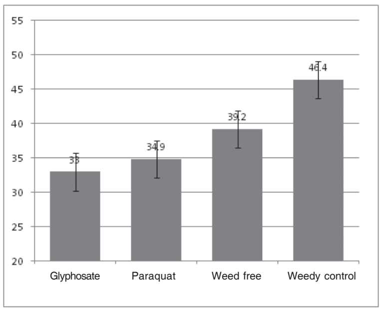

Fig. 2a. N uptake (kg ha^{-1}) by weeds during January-December (CD: 2.3)

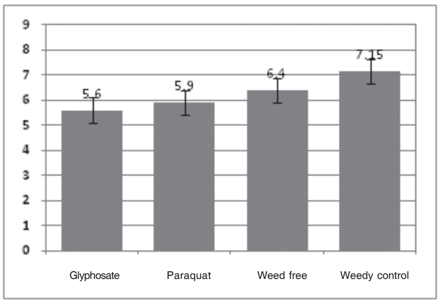

Fig. 2b. P uptake (kg ha^{-1}) by weeds during January- December (CD:0.4)

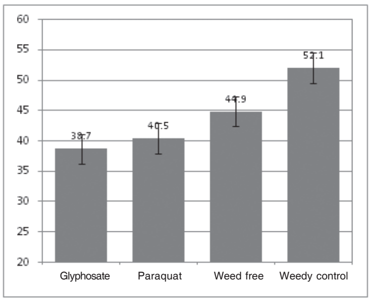

Fig. 2c. K uptake (kg ha^{-1}) by weeds during January-December (CD: 2.5)

Weed count, weed dry weight and weed control efficiency

Weed count recorded at the time of imposition of treatments (Table 1) indicate that on an average 39 weeds (32 grasses and 7 BLW) were present in m^2 area.In weed free treatment, the above ground dry weight of these weeds was recorded as148.8 g m^{-2} and of the total weed dry weight, 69.8per cent was ofthe grasses and the rest 30.2per cent comprised of BLW. Weeds in their above ground biomass contained 26.4- 5.54-32.1 kg ha^{-1} of N-P-K.

Weed count (living weeds as evident from green leaves) recorded on 7th day after imposition of treatment (Table 2) show 0 (zero) values in both herbicide (glyphosate and paraquat) treated plots and weed free treatment. Weed dry weight followed the weed count (Table 3). Complete kill of weeds by herbicides and their physical removal by hoeing in weed free treatment are the reasons behind the zero weed counts. Because of rains (94.7 mm in January in 6 rainy days), few new weeds germinated in the experiment after herbicide application however, their growth was retarded by the moisture stress in subsequent months of February and March (0.6 and 6.8 mm rain) and the high temperature and humidity also contributed to their poor growth. However, more weeds germinated with April rains (94.7 mm in 8 rainy days) in all treatments to exert pressure in succeeding rainy season (May-December). More weeds started regrowth in paraquat treatment from their roots; however, no such regrowth was seen in glyphosate applied treatment. New weeds also germinated on account of both herbicides killing the existing weeds, thus paraquat has gained nearly 50% weed count back at end of study in April. The corresponding weed count increase was only 20-25per cent in glyphosate and weed free treatments as compared to weedy check. In weed free treatment, 34, 6.5, 3.5 and 50 g m^{-2} of weed biomass was produced by the weed regrowth or new weed seed germination in 1stFebruary, 3rdMarch, 2ndApril and 30th April observations, respectively. Thus, 242.8 g m^2 weed biomass was produced in weed free treatment during 2ndJanuary-30th April, 2017 (Fig.1). In glyphosate and paraquat treatments, 40 and 73 g m^{-2}weed biomass was recorded on 30th April, 2017. In weedy treatment on 30thApril 2017, there was 265.3 g m^{-2}of above ground weed biomass that was highest among all the treatments. The weed count remained unchanged in weedy check throughout the study and only their biomass increased with time due to increases in height and branching of weeds (Table 3). A significant reduction in weed biomass with use of glyphosate reported by Samarajeewa *et al.* (2004) in coconut crop supports the current study findings. Total weed biomass from the study period was given in fig.1.

The weed control efficiency (WCE) values of 0 (zero) and 100 were recorded in weedy check and weed-free and herbicide treatments at 7 days after treatment imposition on account complete removal of weeds and their kill by herbicides (Table 4). Last manual weeding was done on 1stApril, 2017 and on account of 94.7 mm rainfall in April, weeds started their regrowth or new weed seeds germinated in all treatments. Thus by end of April, the WCE started declining on account of higher biomass production. At this stage, paraquat has least WCE followed by weed free and glyphosate treatment.

Nutrient removal by weeds

Nutrient (NPK) removal by weeds (uptake of killed/ removed weeds + regrowth till 30th April, 2017) was significantly influenced by weed management treatments (Fig. 2a-c). Nutrient uptake was significantly lower in herbicide treatments and both the herbicides have statistically similar uptake values. Weed free and weedy check treatments differed significantly with herbicides and also among themselves for weed nutrient uptake. On an average, herbicide controlled weeds have 26.1-5.5-31.7 kg ha^{-1} N-P-K in their biomass on 7th January. New weeds germinating (both herbicides) and regrowth of weeds (paraquat) subsequently in herbicide treatments have accounted for a mean nutrient uptake of 7.9-0.3-8.0 kg ha^{-1} N-P-K. Weedy check has recorded the highest nutrient uptake (46.4-7.15-52.1 kg ha^{-1} N-P-K) than weed free treatment (39.2-6.4-44.9 kg ha^{-1} N-P-K). In herbicide treatments, all the weeds got killed and retained on the soil as mulch that over time might add to soil nutrient reserves through their decomposition. However, the later weed growth put-up post herbicide application and their nutrient uptake accounted for the loss of nutrients from the system. In weed free treatment, removal of weeds every month promoted germination of new weeds and also the regrowth of weeds from their partially removed roots and thus produced 242.8 g m^2 weed biomass during rain free period of January-April. In weedy check, weed biomass increased continuously with time to reach 265.3 g m^{-2}. Many grasses have completed their life cycle adding huge seed stocks to the soil to serve as seed reserves for the coming season (s) in weedy check treatment. Taking the nutrients removed in weed free treatment in areca nut plantation as benchmark, 105.7 kg ha^{-1} of nutrients (N+P+K) was siphoned off by weeds that otherwise were meant for crop uptake or to remain as soil reserve. The weed biomass of the current study in islands were under estimated as animal grazing was done in the experiment to reduce the thick and tall canopy of weeds for ease of herbicide application and manual hoeing. Thus actual nutrient uptake estimated from representative sample area prior to animal grazing has 1.7 times more nutrients in their above ground biomass than the reported in this study in all weed management treatments. However, in weedy check, no such differences would be there as weeds regrew to original situation in 4 months study period.

Weed management and moisture conservation

Soil moisture measurements (in 0-10 and 10-30 cm depths) during rain free period (February and March, 2017) reveal significant differences in soil moisture content due to weed management treatments (Table 5) at all the observations with the exception during 30th March observation in which at 10-30 cm depth, all the treatments have at par moisture values. Herbicide treatments recorded higher soil moisture content in 0-10 cm layer than weed free treatment and this effect was not visible in sub soil (10-30 cm).The differences between herbicide and weed free treatments were significant in 20th February-30th March observations.

Lower moisture content of weed free treatment in top soil layer was ascribed to the enhanced evaporation losses from weed free, bare and a little loose soil created by manual hoeing. Higher soil moisture of herbicide treatments was ascribed to undisturbed soil with mulch like cover formed by the killed weeds. Thus herbicide and weed free treatments have favourable soil moisture during rain free period, while weedy check has reached PWP moisture levels by end of February and by end of March in 0-10 cm and 10-30 cm layer, respectively. Both the layers have soil moisture nearing PWP in 30th March observation, however, the moisture was used by palms in weed free and herbicide treatments and by palms and weeds in weedy check. On combined use of soil moisture by weeds and palms, weedy check treatment has quickly attained PWP status and faced severe moisture stress. As per Nair (1960), every tonne of weeds remove 3 inches (7.5 cm) of rainfall from soil in coconut orchard, based on similar assumption; the weeds present in areca nut in herbicide or hoeing treatment in their 1.48 ha^{-1} biomass were removing 10.73 cm of water, which was saved for extraction by areca nut crop. Similarly, the 2.65 t ha^{-1} of weedy biomass in weedy check accounted for 17.89 cm water removal.

Soil dehydrogenase activity

Soil dehydrogenase activity was significantly reduced by herbicide use, and also in weed free conditions created through hoeing at 10 day after treatment and gradually improved by 25 days after treatment (Table 6). Dehydrogenase activity of glyphosate used plots being at par with paraquat plots was significantly lower (2.87 TPF /g soil/day) than weed free and weedy treatments. Dehydrogenase activity was highest in weedy checktreatment and varied from 6.00-7.93 TPF/g soil/ day during two observations. The decrease in dehydrogenase activity was in herbicide and manual hoeing treatments was ascribed to loss of biomass supporting microbial activity through killing and physical removal respectively. The rapid degradation of herbicides in the soil by certain natural soil microorganisms has enhanced the dehydrogenase enzyme activity with time. A similar reduction in dehydrogenase activity with herbicide applications in groundnut were observed by Singh and Singh (2009) corroborates the current investigation findings.

Use of glyphosate was 1.24 and 4.37 times cheaper than paraquat and weed free treatments (Table 7). The current investigation indicates 77.1 and 72.5per cent cheaper weed management in areca nut through use of glyphosate and paraquat as compared to weed free treatment. Studies of Joseph and Jessy (2013) in rubber plantations reporting a 65per cent reduction in weeding costs with herbicides as compared to manual weeding corroborates the findings of the current investigation.

Thus, it can be summarized that application of post-emergence herbicides of glyphosate and paraquat provided economical weed management solution to areca nut plantation of Andaman and Nicobar Islands during post rainy season (January-April) and thus is recommended for wider adoption. As it is a perennial crop, only two early formed bunches were harvested during the study period that have not shown any yield differences. For yield differences to quantify, year round weeding trails are required that are not possible in ANI with continuous rains (May-November) that prevent herbicide use.

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