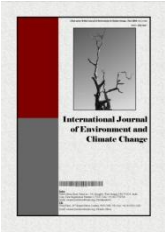

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"Agricultural Weeder with Nail Assembly" for Weed Control, Soil Moisture Conservation, Soil Aeration and Increasing Crop Productivity

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

"Agricultural weeder with nail assembly" (Design registration no. 289754 in class 15-03, dt. 13-09-2019, Patent Office Kolkata, GOI) has been developed to mechanically weed out young composite weed flora including germinating ones, since 5-7 days of crop sowing at field capacity (FC), from line sown and broadcast field (cereals, pulses, oilseeds, jute, mesta, flax, sunnhemp,) and horticultural crops (vegetables and flowers etc.). This tool contains i) a nail assembly with 5-6 nos. of nails (6-8 mm dia.) fixed with nuts at 3 cm apart in series ii) scrapper (of different types) and iii) tine, to suit different types of operations. Addition of a boat replacing its front wheels and two conical rotors in the main frame, make it suitable to control weeds in transplanted rice field also. With the help of this tool, 85 to 90 per cent of composite weeds can be controlled. In two successive operations, at 5 days intervals since 5 days after crop emergence, it requires only 12-18 man days/ha and saves Rs.15000 to Rs.20000/ha. It produced 33 to 40 quintal jute fibre/ ha, 4.5 to 5 tonnes of upland and transplanted land rice, 3.0 to 4.5 tonnes of wheat and 15 q mustard/ha under farmers' field and at ICAR-CRIJAF in different years. It increases soil aeration (Oxygen diffusion rate, ODR: 303 µg O_2 m^{-2} sec^{-1}), keeps the soil cooler (1-5^{0}C) and improves soil moisture (4-15%) by soil mulching in drier months and improves jute fibre yield (10-20%) and its water productivity. Till now around 55000 numbers of "Agricultural Weeder with Nail assembly" have been distributed to the jute farmers of West Bengal by Department of Agril. Govt. of WB. Due to its low draft (8-15 kg only at FC), women, youngsters and aged persons can also operate the tool easily in different crop round the year.

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Keywords: Manual weeder; weed control; soil moisture; soil air; economics; adoption.

1. INTRODUCTION

In field and horticultural crops, about 30% to 40% of the total cost of cultivation is usually drained in manual weeding process alone and it minimises the net return from crop husbandry. Weeds also compete with main crops for water, space and nutrients for its survival. With the advancement of time, quick spread of rural education, rise of standard of living and availability of other drudgery free remunerative jobs include 100 days jobs in MGNREGA, man power availability during peak weeding hours becoming scarce in agricultural sector. The environmental concern of chemical weed control in agriculture is also well known to all. Agricultural weeder with nail assembly can be used both for line sown and broadcast crops. Using this tool, simultaneous weeding, thinning, line arrangement and soil mulching can be created in broadcast crop. The fine nails pulverizes the soil and conserve more soil moisture (5-15%) and saves the crop form long drought spells and increases water productivity under limited irrigation. It keeps the soil cooler by 1-5^0 C and increases soil aeration [1]. Additional components, like scrapper helps to weed out established weeds and tines supplied with it can be used for line making after final soil preparation. In prepared soil the tool is helpful to mix seeds and fertilizer in field for proper germination and better nutrient use efficiency. In jute, it saves up to 100-135 man days/ha depending on weed densities. Reducing manpower requirement in manual weeding, the net return from crop husbandry is also increased [2]. Clean environment in crop field also helps to keep the insect and pests at low ebb. It minimises dependence on manpower requirement. Addition of a boat replacing its front wheels and two conical rotors in the main frame, make it suitable to control weeds in transplanted rice field also [3,4]. Thus the tool can be used round the year by small and marginal farmers. This tool is suitable for operation in all field (cereals, pulses and oilseeds) and horticultural crops (flower, fruits and vegetable Photo 3-8). Looking into its advantages, this tool was used in different weed control experiments at ICAR-CRIJAF, WB and it was validated across jute growing states of the country from 2009 to 2022.

2. MATERIALS AND METHODS

Repeated field experiments were conducted from 2009 to 2022 at ICAR-CRIJAF, Barrackpore, WB, in randomized block design replicated thrice, with a combination of 10 to 11 treatments, to test the relative weed control ability of Agricultural weeder with nail assembly over other weed control practices in vogue. The experimental soil was sandy clay loam in texture, with 44 per cent sand, 28 per cent silt and 28 per cent clay. Its available nitrogen, phosphorus & potassium contents were 175, 32 and 130 kg/ha, respectively. The individual plot size was 4 m X 2 m. Efficacy of Agricultural weeder with nail assembly for composite weed control was tested against different pre emergence herbicides (Butachlor 50 EC, Pretilachlor 50 EC, Ipfencarrbazone etc) and post emergence herbicides (Quizalop Ethyl 5 and 10 EC, Propaquizafop 10 EC), Glyphosate 41% SL using CRIJAF herbicide applicator, jute and green gram intercropping, manual weeding twice and control in different years. The experimental results were validated across jute growing states of the country in AICRP JAF from 2012 to 2022.

2.1 Brief Description of the Tool

The tool contains the main frame (made of M S angle 25 mm x 25 mm x 5 mm x 307 mm long) that holds the nail assembly and wheel assembly, a handle and the fixing bracket - nail assembly (Photo 1). The nail assembly consists of nail assembly fixing bar, nails, shaft nail assembly, holding bracket nail assembly. The replaceable nails are attached to the nail assembly fixing bar by nuts. The nails are uniformly spaced at 30 mm intervals. The retainer nail assembly is attached to the shaft nail assembly at one end and pivoted with the main frame through pivot bracket-retainer. Draw bar handle i.e. handle fixed to the main frame at pivot bracket handle and its height is adjusted with the help of angular-bracket-handle to suit height adjustment as per operators' suitability. The retainer helps to absorb a part of the draft generated at the nails in maintaining stability and rigidity of the nails. The angular orientation of the nails helps it to penetrate easily for desired weed control. Thus the draft requirement of the implement is lesser than prior weeders. Provisions have been made here two attach ii) one scrapper and iii) one tine iv) two conical rotors and v) one boat for its use in upland and in transplanted rice fields. Single wheel "Agricultural weeder with nail

assembly" has also been developed to operate it in between very close spaced crops like onion etc (Photo 2). Raw materials required are M.S. angle, M.S. rod, M.S. Tubular pipe, M.S. flat of different dimensions, fixing bolts and nuts etc. The experimental data were analysed following standard statistical procedure.

Photo 1. Agricultural weeder with nail assembly, Design registration no. 289754 in class 15-03, dt. 13-09-2019, Patent Office Kolkata, Govt. of India

Photo 2. Agricultural Weeder with Nail Assembly having single front wheel and addition of conical rotors and boat for operation in transplanted rice (from left)

Photo 3. Simultaneous weeding, thinning, line arrangement, soil aeration and soil mulching in broadcast jute using agricultural weeder with nail assembly

Photo 4*. Trianthema spp* control at early stage by agricultural weeder with nail assembly

Photo 5. Weed control "within rows" in sunnhemp by agricultural weeder with nail assembly opening its central nail

2.2 Time of Application, Precautions and Procedure of Use of the Tool

For composite weed control at emerging stage, the tool with its nails has to be operated with to and fro movement at field capacity stage of soil (5-7 DAE, days after emergence of crops, photo 3 &4). The operating depth should be 3-4 cm on an average. Opening the central nail, the tool can be operated over crop rows (10 cm tall) and the weeds within the rows can be controlled (Photo 5). For controlling established weeds in between rows the scrapper has to be fitted behind the tool and can be operated since 15 days on wards. Single wheel arrangement has also been made for weed control in close growing crops (like onion, jute, rice etc), To operate the tool in transplanted rice the front wheels and the nail assembly should be removed and conical rotors and the boat has to be fitted. This can be operated in transplanted rice field since 8-10 days after transplanting (Photo 2). For flexibility in use, scrappers, tines, conical rotors and boats can be fitted with the tool using nut and bolts [5]. Operating the tool at field capacity, keeping 7-10 cm gaps in between two successive runs, simultaneous weeding, thinning, line arrangement and soil mulching is done in broadcast jute, mesta, mustard and, sesame etc (Photo 3). The "Nail assembly" is used for early weed control and mud stirring in transplanted rice field, fitting it with 3- 4 feet long bamboo/wooden handle.

Soil moisture conservation capacity after nail weeder operation was measured gravimetrically or by using moisture meter. Soil aeration was measured by Oxygen Diffusion Rate meter (ODR meter, Eijkellkamp, The Netherlands), soil moisture tensions were recorded using tensiometer and soil temperatures were recorded using alcohol thermometers. The data were analysed following standard statistical packages.

3. RESULTS AND DISCUSSION

Major weed flora present in jute fields across jute growing states of India were i) Grasses: *Ecinocloa colonum, Cynodon dactylon, Brachiaria mutica etc' Digittaria spp, Elusine indica; ii)* Broad leaved weeds*: Trainthema spp, Physalis minima, Digera arvensis and Alternanthera spp etc ;)* and *iii*) Sedges: *Cyperus rotundus, Ceperus dformis, Cyperus iria etc*.

3.1 Weed Control by Agricultural Weeder with Nail Assembly

This tool was operated over years at ICAR-CRIJAF and validated in different jute and mesta growing states across the country to weed out young composite weed flora including germinating ones mechanically, from line sown and broadcast field (jute, mesta, flax, sunnhemp, cereals, pulses, oilseeds) and horticultural crops (vegetables and flowers etc.) since 5-7 days of crop sowing at field capacity (Photo 3-8, [6,7] Ghorai et al*,* 2009-2014; [8,9]). In two operations, at 5 days interval since 5 DAE, it requires only 12-18 man days/ha. With the help of this tool, 85 to 90 per cent of composite weeds weeds can be controlled [10] (Ghorai et al, 2016). However, rest 10 - 15% of the weed flora has to be removed manually. It is cheaper (Rs.15000 to Rs.20000/ha) than conventional manual weeding. Over years, this tool produced jute fibre yield up to 39.5 q/ha, upland rice yield up to 45 q/ha and wheat yield up to 45 q/ha. It produced higher fibre yield by 10 - 20% over conventional weed control methods (Table 1 & 2). This tool recorded higher weed control efficiency (84 per cent), net return (Rs.65615/ha) and B:C ratio (2.07) over conventional manual weeding twice (63.62 per cent, Rs. 56192 and 1.80 respectively), Table 2, Ghorai et al, [11]. It minimizes the soil cracks (Photo 6, Ghorai et al, [1]) in jute field found 4-5 days after sowing and aerates soil by pulverizing it during its operation. Due to low draft (8-15 kg only at FC) women, youngsters and aged persons can also operate the tool easily (Photo 7).

Table 1. Effect of different weed management treatments on yield of jute-rice-vegetables/oilseeds/pulses cropping systems

Treatments	Fibre yield (q/ha)	Green gram /carrot yield (q/ha)	Rice yield (q/ha)	Pulses/oil seeds/veg (q/ha/nos./ha)
T1: NJ 7010+TMB 37 (1:1) Pretilachlor 50EC @ 0.9l/ha+1HW -Rice -Bottle gourd	29.46	9.08	31.5	60000/ha
T2: NJ 7010+TMB 37 (Mixed) Pretilachlor 50EC @ 0.9l/ha +1HW -Rice+Pumpkin (Gunny bag columns) +Spinach (Zero till paira)	29.13	7.20	34	100 q+ 40 q
T3: NJ 7010+Sukumar (1:1) Pretilachlor 50EC @ 0.9l/ha+1HW-Rice-Ash gourd (Gunny bag columns)+Khesari (Zero till paira crop)	29.48	7.41	33.33	25000 nos./ha
T4 : Ipfencarbazome@ 68.43 g/ha+1HW-Rice+Bitter gourd (Gunny bag columns)	32.48	-	35.33	12.70 q
T5: Ipfencarbazome@ 91.24 g/ha+1HW- Fenugreek (Zero till paira crop)	35.93	-	35.33	--
T6: Ipfencarbazome@ 114g/ha+1HW-Coriander (Zero till paira crop)	39.73	-	32.33	--
T7: Agricultural weeder with nail assembly +1HW –Rice- Bengal gram (Zero till crop)	39.42	-	32.67	-

Treatments	Fibre yield (q/ha)	Green gram /carrot yield (q/ha)	Rice yield (q/ha)	Pulses/oil seeds/veg (q/ha/nos./ha)
T8: Two manual weedings-Rice-Field pea (Minimum tillage by tines)	33.03	**-**	33.33	17.25 q
T9:NJ 7010+TMB 37 (Relay)-rice-Rice-Lentil (Zero till paira crop)	25.67	-	33.33	8.82 q
T10 : NJ 7010+ Carrot (1:1) 2HW-Rice-Khesari (Zero till paira crop)	24.67	25.0	32.33	16.66 q
T11: Control (no manual weeding)-rice-Mustard (Zero till paira crop)	19.53	-	35	15.91 q
S..Em (±)	1.95	-	1.60	-
C.D. 5%	5.74	-	NS	-

Table 2. Weed control efficiency of agricultural weeder with nail assembly (pooled) with other weed control processes

Treatments imposed:	Fibre equivalent yield (inclusive of jute stick and pulse waste) (q/ha)	Weed control efficiency (%)	Net return (Rs./ha)	Benefit cost ratio
1.Jute (30 cm) + PM-4 + Butachlor 50 EC @1kg /ha +1HW	49.51	71.61	90401	2.25
2. Jute (35 cm) + PM-5 + Butachlor 50 EC @1kg /ha +1HW	48.08	68.04	86814	2.23
3. Jute (30 cm) + Sukumar + Butachlor 50 EC @1kg /ha +1HW	47.07	82.19	840273	2.19
4. Jute (25cm) + RMG-62, Butachlor @50 EC 1kg /ha +1HW	52.64	69.27	102213	2.46
5. Jute (25 cm)+ Agricultural weeder with nail assembly (5-21 DAS) on broadcast jute for simultaneous weed control, line arrangement and soil mulching +1HW	39.15	84.33	65615	2.07
6. Open furrow (25cm) sowing of jute+Butachlor 50 EC @1kg +1HW	35.89	57.19	52422	1.83
7. Butachlor 50 EC @1kg /ha + Glyphosate 0.8 kg SL/ha at 21 DAS +1HW (25 cm)	37.66	82.19	62742	2.06
8. Two manual weeding in jute (25 cm), 15 and 21 DAS	38.97	63.62	56192	1.80
9. Jute + Okra (cv. Shakti) [(2:1, 25 cm, okra sown 3rd week of Nov). Jute sown on 22nd March +2HW	56.70	81.93	105766	2.31
10. Unweeded control (25 cm)	13.02	0	-19453	0.69
11. Glyphosate 1.23 l SL/ha by CRIJAF herbicide	40.79	81.93	75464	2.28

Treatments imposed:	Fibre equivalent yield (inclusive of jute stick and pulse waste) (q/ha)	Weed control efficiency (%)	Net return (Rs./ha)	Benefit cost ratio
applicator at 20 DAS +1HW (25 cm)				
C.D. (5%)	2.10	15.25	11873	0.262

3.2 Soil Water Conservation in Jute Field under Deficit Rainfall Using "Agricultural Weeder with Nail Assembly"

Soil moisture conservation capacity, soil moisture tension, soil temperature, aeration, water productivity and jute fibre production under limited irrigation/deficit rainfall over long term average (40 per cent from 15th March to 15th June) were determined through field experiments at ICAR-CRIJAF and Amadalavalasa, AP (2008-2016). The results were validated in large scale in farmers' field and ICAR-CRIJAF, till 2021. Operation of agricultural weeder with nail assembly in jute at 4-6 days after emergence controlled germinating weeds, created soil mulch pulverizing the top soil (4-5 cm), increased soil aeration [ODR: Oxygen diffusion rate, 303 µg O_2 m^{-2} sec^{-1} under soil mulch over only 140 µg O_2 m^{-2} sec^{-1} in non-mulch soil, Chakraborty et al, [12], minimised soil cracks those developed at early stages (Photo 6), maintained low soil moisture tension (Fig. 1, Ghorai et al, [13]), 4-15 per cent more soil moisture in different situations over no nail plots and kept the soil cooler (by 1-5 degree Celsius) at 5 to 10 cm soil depth. In 2016-17, the crop did not receive any rain till 30 days following its sowing with a pre-sowing irrigation. Weed free environment, better hydro thermal regime of soil and good aeration helped the young jute seedlings to escape early drought stress. This environment produced active, taller (23 cm) and deep rooted jute plants over stunted and lanky jute seedlings (11 cm) with shallow roots under prolonged drought (Photo 6). It saves one irrigation by maintaining better soil moisture through soil mulching.

3.3 Irrigation Management under Deficit Rainfall Using Agricultural Weeder with Nail Assembly

In the year 2014-15, the rainfall deficit from 15th March to 15th June was 40 per cent over long term average, which primarily helps in initial establishment of jute crop. One irrigation in flat bed method of sowing at recommended fertilizer dose (RDF: N:P:K::60:30:30), could produced 25.6 q jute fibre /ha. At RDF and one flood

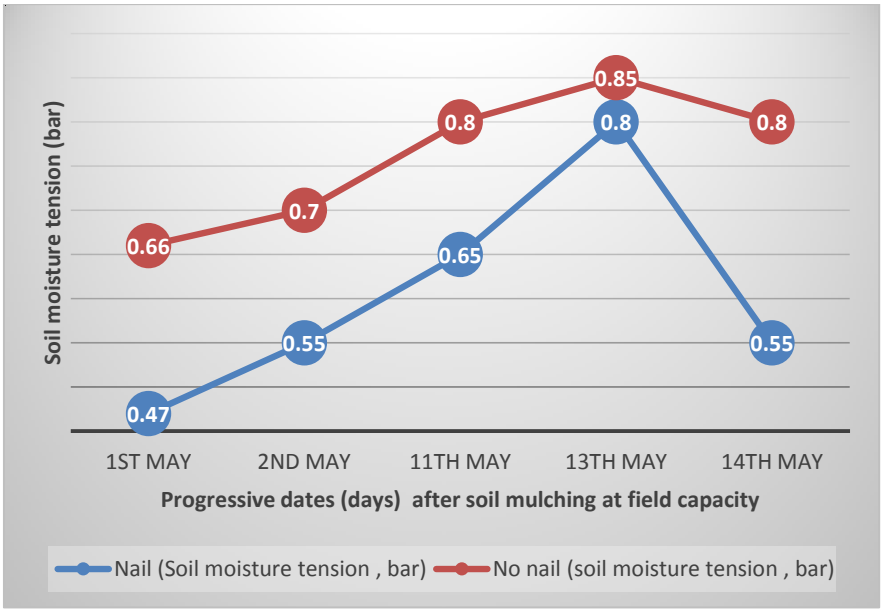

Fig. 1. Soil moisture tension due to operation of " agricultural weeder with nail assembly " in jute field at field capacity (bar)

irrigation followed by soil mulching (at field capacity) by CRIJAF nail weeder produced 28 q jute fibre /ha and is 2.35 over traditional flood irrigation system. Soil mulching by nail weeder maintained 4-5 per cent more soil moisture over no nail plots and maintained lower soil moisture tension before drying the soil. The water productivity and rain water use efficiency of Agricultural weeder with nail assembly operated plots was higher (1942 lit water/kg fibre, 2.598 Kg fibre/ha/mm**)** over no nailed plots (2120 lit water/kg fibre, 2.381 Kg fibre/ha/mm**),** Table 3 [13]. In other year, the soil mulch by Agricultural Weeder with Nail Assembly yielded 34.18 q jute fibre/ha (32.50 q/ha in control) with water productivity of 1284.62 litre water/kg fibre over 1351.5 litre water/kg fibre from no mulch traditional system.In roselle similar yield improvement was reported from Amadalavalasa, Andhra Pradesh (Table 4). Framers of jute growing districts could harvest 2-3 q more fibre using this technique under limited irrigation. Under limited moisture supply, it produces 10-20 per cent more fibre yield over conventional practice in different years from 2009-2020.

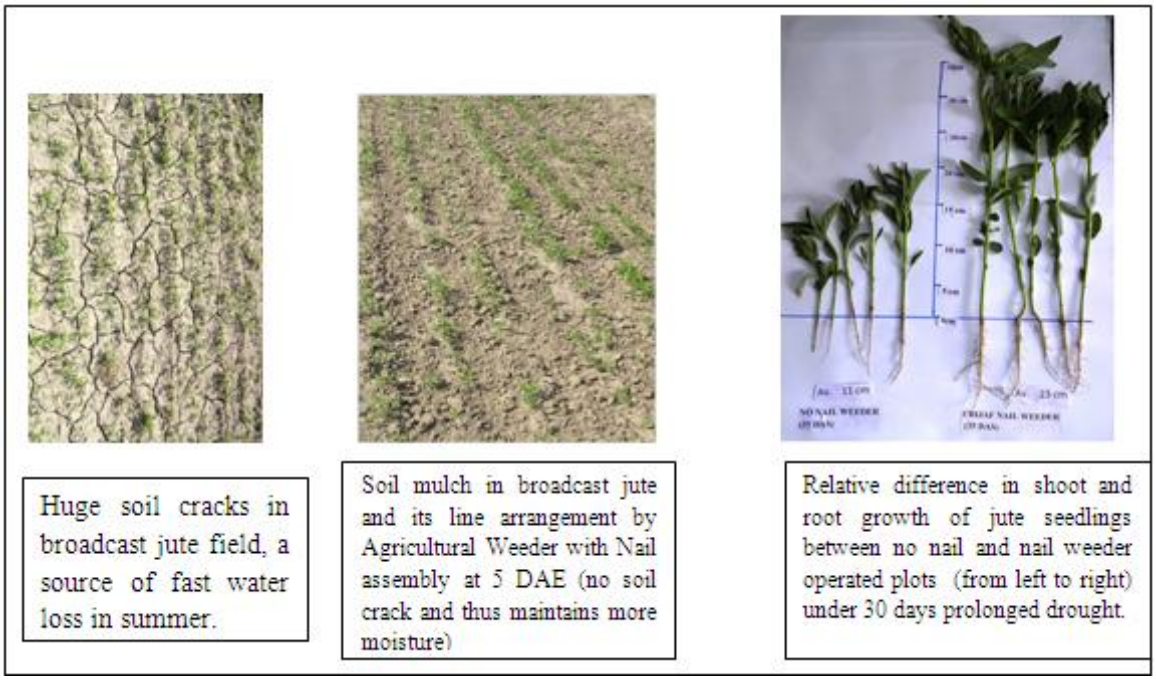

Photo 6. Soil crack reduction and moisture conservation in jute field by Agricultural Weeder with Nail assembly

Photo 7. Women working with Agricultural Weeder with Nail assembly in jute and mustard

a) Mechanical weeding in upland direct seeded rice (DSR) and transplanted rice

b) Mechanical weeding in wheat

c) Onion

d) Chili

e) Bengal gram (Chick pea)

f) Coverage of Agricultural Weeder with Nail Assembly in farmers field by Bengali leading newspaper "Ananda Bazar Patrika"

Photo 8. Agricultural Weeder with Nail assembly in other field and horticultural crops

Table 3. Yield and water productivity of jute under limited water supply using agricultural weeder with nail assembly

Treatment	Fibre yield (Kg/ha)	Total rain (mm) received in growth period	Irrigation water (mm)applied	Total water received (mm)in growth period	Rain water use efficiency (Kg fibre/ha/mm)	Water productivity (lit water/kg fibre)*
1. Flat bed sowing, N:P:K:: 60:30:30 & one irrigation + 2 manual weedings	25.6	1027	50	1077	2.381	2120
2. Flat bed sowing, N:P:K:: 80:40:40 & one irrigation + 2 manual weedings	28.0	1027	50	1077	2.599	1941
3. Flat bed sowing, N:P:K:: 60:30:30 & one irrigation &Agricultural Weeder with Nail assembly at 5 DAE	28.0	1027	50	1077	2.598	1942
4. Flat bed sowing, N:P:K:: 80:40:40, one irrigation & nail weeder at 5 DAE + 2 manual weedings	28.5	1027	50	1077	2.649	1905
5. Open furrow sowing, N:P:K:: 60:30:30 &one irrigation + 2 manual weedings	26.7	1027	30	1057	2.522	2039
6. Flat bed sowing, N:P:K:: 60:30:30 &2 irrigations + 2 manual weedings	28.75	1027	100	1127	2.55	1890
7. Flat bed sowing, N:P:K:: 80:40:40 &2 irrigations + 2 manual weedings	27.95	1027	100	1127	2.48	1945
8. Flat bed sowing, N:P:K:: 60:30:30 & two irrigations & nail weeder twice after each irrigation + 2 manual weedings	28.87	1027	100	1127	2.56	1883
9. Flat bed sowing, N:P:K::	29.2	1027	150	1172	2.48	1861

Treatment	Fibre yield (Kg/ha)	Total rain (mm) received in growth period	Irrigation water (mm)applied	Total water received (mm)in growth period	Rain water use efficiency (Kg fibre/ha/mm)	Water productivity (lit water/kg fibre)*
60:30:30 &3 irrigations + 2 manual weedings						
10. Flat bed sowing, N:P:K:: 60:30:30 & one irrigation and mung waste 2t/ha + 2 manual weedings	28.4	1027	50	1077	2.64	1921
C.D.	NS	-	-	-	SD±	SD±

Table 4. Yield improvement rain fed roselle *(Hibiscus Sabdarifa*) under limited irrigation at Amadalavalasa, AP, using Agricultural Weeder with Nail Assembly

Treatments	Plant height (cm)	Basal diameter (cm)	Fibre Yield (q/ha)
N:P:K levels			
60: 30:30 kg /ha	350	2.06	26.79
60: 30:30: kg /ha+ S 30 kg/ha	371	2.34	29.90
80 : 40:40 kg /ha	366	2.05	27.85
S.Em ±	6.342	0.0734	2.185
CD (5%)	13.165	0.114	4.23
Water conservation methods			
Rain fed Sowing (W1)	355	1.81	26.33
Sowing in furrow (W2)	359	2.10	27.85
Rain fed Sowing + Soil mulch with Agricultural Weeder with Nail assembly(W3)	373	2.54	**30.36**
CD (5%)	16.083	0.202	**6.37**
Interaction			
S.Em ±	12.34	0.1454	**4.8065**
CD (5%)	**25.857**	**0.331**	**9.237**

Framers' are using this low draft (8-15 kg) weed control tool round the years for different crops in their crop husbandry. It is used by youngsters, women (Photo 7) and aged persons also for its low energy requirement. It reduced the cost of weeding up to 90% (Rs.15000 to 20000/ha). It saves 60-90 man days /ha in farmer's field over manual weeding process. In transplanted rice it saves 30 man days/ha.The tool controlled composite weed flora (grass, broad leaves and. *Cyperus* spp.) in jute, mesta, sunnhemp, upland rice, different pulses, oil seed and other horticultural crops (Photo 8a to 8f). It saves one irrigation by maintaining better soil moisture through soil mulching. Farmers' have been able to avoid herbicide to control weeds using this tool. Under limited irrigation/rain fed/deficit rainfall situation (45-50%) it improves jute fibre yield up to 20%.

4. CONCLUSION

This eco-friendly weed control tool is operating in different jute and mesta growing states of the country in different field and horticultural crops (jute, mesta, sunnhemp, upland rice, different pulses, oil seed and other horticultural crops). Till date nearly 55000 pieces has already been sold for its distribution by Govt. of WB, Deptt. of Agriculture, NFSM-CC (Jute). It reduces the weeding cost by 85-90% (by Rs.15000 to 20000/ha), saves 60-90 man days per ha. The tool has reduced the age old drudgery of weed management operation due to its low draft (8-15 Kgs). Addition of a boat replacing its front wheels and two conical rotors in the main frame of the tool, make it suitable to control weeds in transplanted rice field also. It has minimized the dependency on manual labour and chemical herbicides and thus is an eco-friendly tool [14, 6,7]. Youngsters, ladies and aged persons can easily operate the tool. It reduces poverty of resource poor farmers by reducing cost of cultivation and improving crop yield. Increases crop yield under limited irrigation/deficit rainfall condition. It produced 33 to 40 quintal jute fibre/ ha, 4.5 to 5 tonnes of upland and transplanted land rice, 3.0 to 4.5 tonnes of wheat and 15 q mustard/ha under farmers field and at ICAR-CRIJAF in different years.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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