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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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Agricultural weeder with nail assembly, popularly known as CRIJAF Nail Weeder, controls germinating and young weeds. It performs best at field capacity (FC) and has low draft (8–12 kg at FC) requirement. Its operation improves soil hydrothermal regimes and aeration (oxygen diffusion rate, 303 μg^{-2} O_2 m^{-2} s^{-1}). It has 5–6 detachable nails, each at 3 cm distance, and has option to attach one scrapper or one tine. Introducing a boat in place of its front wheels and addition of two conical rotors in the mainframe makes it suitable to control weeds in transplanted rice. It requires 12–18 man-days/ha for operation, controls 85–90% weeds, produced 33–40 q/ha jute fibre, 4.5–5 t/ha of upland and transplanted rice, 3.0–4.5 t/ha of wheat and 15 q/ha of mustard. More than 55,000 units have been distributed by the Department of Agriculture, Government of West Bengal.

Keywords: CRIJAF nail weeder, manual weeder, soil air, soil moisture, soil temperature, weed control.

In field and horticultural crops, usually 30–40% of the total cost of cultivation is consumed by the manual weeding process alone. Thereby it minimizes the net income from crop husbandry. Recently, new invasive weeds are creating newer concerns and their management is challenging. The environmental concerns about the use of herbicides in agriculture are well known. Mechanical control of weeds is a viable alternative in the long run. Currently, workforce availability is low during peak hours in the agricultural sector. Hence we have developed an agricultural weeder with nail assembly for simultaneous weeding, thinning, line arrangement and soil mulching in broadcast crops. The fine nails of the weeder scratch the upper surface of the soil and conserve soil moisture (5–15%). This saves the crops from long drought spells and increases water productivity under limited irrigation. It keeps the soil cooler by 1–5°C and increases soil aeration[1]. Using additional components like a scrapper helps weed out established weeds and tine helps in line-making after final soil preparation. Operating the weeder after seed sowing and fertilizer application is helpful in mixing seeds and fertilizers with the soil for proper germination and improving nutrient use efficiency. In jute, it saves up to 100–135 man days/ha depending on weed densities. Reducing workforce requirements in manual

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weeding, the net return from crop husbandry also increases. Clean environment in the crop fields helps keep insects and pests away. It minimizes dependence on workforce requirements. This weeder is suitable for all field crops (cereals, pulses and oilseeds) and horticultural crops (flowers, fruits and vegetables).

The main frame of the weeder (made of MS angle 25 mm × 25 mm × 5 mm × 307 mm long) holds the nail assembly and single or double wheel assembly, a handle and the fixing bracket – nail assembly (Figure 1). The nail assembly consists of a fixing bar, nails, shaft nail assembly and a holding bracket nail assembly. The nails are attached to the fixing bar using nuts. They are uniformly spaced at 30 mm intervals. The retainer nail assembly is attached to the shaft nail assembly at one end and pivoted to the main frame using a pivot bracket–retainer. The draw bar handle is fixed to the main frame at the pivot bracket handle and its height is adjustable with the help of an angular bracket handle according to operator suitability. The retainer helps absorb a part of the draft generated in the nails to maintain stability and rigidity of the nails. The angular orientation of the nails easily penetrates 2–4 cm soil depth for desired weed control. Thus the draft requirement of this weeder is less than other weeders. Provisions have been made to attach one scrapper, one tine, two conical rotors and one boat to use the weeder in upland and puddled rice fields. A single-wheel agricultural weeder with nail assembly has also been developed for operation in close-spaced crops like onion and garlic (Figure 2). Raw materials required are MS angle, MS rod, MS tubular pipe, MS flat of different dimensions, fixing bolts and nuts, etc.

For composite weed control at the emerging stage, the weeder has to be operated with to and fro movement at the field capacity stage of the soil (5–7 days after the emergence of crops). Opening the central nail, the weeder can be operated over crop rows (up to 10 cm plant height) to control weeds within the rows. For controlling established weeds between rows, the scrapper is fitted behind the weeder and can be operated from 15 days onwards. Single-wheel arrangement has also been made for weed control in close-growing crops (like onion, jute, rice, etc.). To operate the weeder in transplanted rice, the front wheels and nail assembly are replaced with conical rotors and a boat. For flexibility in use, scrappers, tines, conical rotors and boats can be fitted with the weeder using nuts and bolts[2]. By operating the weeder at field capacity, maintaining 7–10 cm gaps between two successive runs, simultaneous weeding, thinning, line arrangement and soil mulching can be made in broadcast crops like jute, mesta, mustard, sesamum, etc. The nail assembly is used for early weed control and mud stirring in a transplanted rice field by fitting it with a 3–4 ft long bamboo/wooden handle.

This weeder was operated in jute and mesta-growing states across India to mechanically weed out young composite weed flora, including that germinating, from line sown and broadcast fields (jute, mesta, flax, sunnhemp, cereals, pulses, oilseeds) and horticultural crops (vegetables and flowers) after 5–7 days of crop sowing at field capacity[3–6]. In two operations, at five days interval since 5 days after emergence (DAE), it required only 12–18 man-days/ha. With the help of this weeder, 85–90% of composite weeds can be controlled[6,7]. However, rest (10–15%) of the weeds must be removed manually. It is cheaper (by Rs 15,000–20,000/ha) than conventional manual weeding. Over the years, this weeder has helped produce a jute fibre yield up to 45.8 q/ha, upland rice yield up to 45 q/ha and wheat yield up to 45 q/ha. It has also helped produce higher fibre yield (10–20%) compared to conventional weed control methods (Table 1). Higher weed control efficiency (84%), net return (Rs 65,615/ha) and B : C ratio (2.07) have been recorded using this weeder compared to conventional manual weedings (63.62%, Rs 56,192/ha and 1.80 respectively)[8] (Table 2). It minimizes the soil cracks in jute fields 4–5 days after sowing and aerates them by scratching 2–4 cm of the surface soil during its operation (Figure 3)[1]. Due to its low draft (8–12 kg at field capacity (FC)) women, youngsters and aged persons can also easily operate this weeder.

Soil moisture conservation capacity, soil moisture tension, soil temperature, aeration, water productivity and jute fibre production under limited irrigation/deficit rainfall over a

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

Figure 2. The weeder with a single front wheel and addition of conical rotors and boat for operation in transplanted rice (from left).

Table 1. Effect of different weed management treatments on yield of jute–rice–vegetables/oilseeds/pulses cropping systems (2017–18)

Treatment	Fibre yield (q/ha)	Green gram/carrot yield (q/ha)	Rice yield (q/ha)	Pulses/oilseeds/veg (q/ha/or nos/ha)
T1: NJ 7010 + TMB 37 (1 : 1) Pretilachlor 50EC @ 0.9 l/ha + 1 HW–rice–bottle gourd	29.46	9.08	31.5	60000 no
T2: NJ 7010 + TMB 37 (mixed) Pretilachlor 50EC @ 0.9 l/ha + 1 HW–rice + pumpkin (gunny-bag columns) + spinach (zero-till paira crop)	29.13	7.2	34	100 q + 40 q
T3: NJ 7010 + Sukumar (1 : 1) Pretilachlor 50EC @ 0.9 l/ha + 1 HW–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 + 1 HW–rice + bitter gourd (gunny-bag columns)	32.48	–	35.33	12.70 q
T5: Ipfencarbazome @ 91.24 g/ha + 1 HW–fenugreek (zero-till paira crop)	35.93	–	35.33	–
T6: Ipfencarbazome @ 114 g/ha + 1 HW–coriander (zero-till paira crop)	39.73	–	32.33	–
T7: Agricultural weeder with nail assembly + 1 HW–rice–Bengal gram (zero-till crop)	39.42	–	32.67	–
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) 2 HW–rice–khesari (zero-till paira crop)	24.67	25	32.33	16.66 q
T11: Control (no manual weeding) – rice–mustard (zero-till paira crop)	19.53	–	35	15.91 q
SEm (±)	1.95	–	1.6	–
CD (5%)	5.74	–	NS	–

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

Treatment	Fibre equivalent yield (inclusive of jute stick and pulse waste) (q/ha)	Weed control efficiency (%)	Net return (Rs/ha)	Benefit–cost ratio
Jute (30 cm) + PM-4 + Butachlor 50 EC @1 kg/ha + 1 HW	49.51	71.61	90401	2.25
Jute (35 cm) + PM-5 + Butachlor 50 EC @1 kg/ha + 1 HW	48.08	68.04	86814	2.23
Jute (30 cm) + Sukumar + Butachlor 50 EC @1 kg/ha + 1 HW	47.07	82.19	840273	2.19
Jute (25 cm) + RMG-62, Butachlor @50 EC 1 kg/ha + 1 HW	52.64	69.27	102213	2.46
Jute (25 cm) + weeder (5–21 DAS) on broadcast jute for simultaneous weed control, line arrangement and soil mulching + 1 HW	39.15	84.33	65615	2.07
Open furrow (25 cm) sowing of jute + Butachlor 50 EC @ 1 kg + 1 HW	35.89	57.19	52422	1.83
Butachlor 50 EC @ 1 kg/ha + glyphosate 0.8 kg SL/ha at 21 DAS + 1 HW (25 cm)	37.66	82.19	62742	2.06
Two manual weeding in jute (25 cm), 15 and 21 DAS	38.97	63.62	56192	1.8
Jute + okra (cv. Shakti) [(2 : 1, 25 cm, okra sown in the third week of November), jute sown on 22 March 2011, 2012, 2013] + 2 HW	56.7	81.93	105766	2.31
Unweeded control (25 cm)	13.02	0	–19453	0.69
Glyphosate 1.23 l SL/ha by CRIJAF herbicide applicator at 20 DAS + 1 HW (25 cm)	40.79	81.93	75464	2.28
CD (5%)	2.1	15.25	11873	0.262

long-term average (40% from 15 March to 15 June during 2008–16) were determined through field experiments at ICAR-Central Research Institute for Jute and Allied Fibres, Kolkata and Amadalavalasa, Andhra Pradesh. The results were validated in large-scale farmers' fields till 2021. Operation of this weeder in jute at 4–6 DAE controlled germinating weeds, created soil mulch by scratching the top surface soil (2–4 cm), increased soil aeration (ODR: oxygen diffusion rate, 303 μg O_2 m^{-2} s^{-1} under soil mulch over only 140 μg O_2 m^{-2} s^{-1} in non-mulch soil)[9], mitigated soil cracks developed at early stages, maintained low soil moisture tension[10] (Figure 4), conserved 4–15% more soil moisture in different situations over no nailed plots and kept the soil cooler (by 1–5°C) at 5–10 cm soil depth. In 2016–17, the crops did not receive any rainfall till 30 days following sowing with a pre-sowing irrigation. Weed-free environment, a better hydrothermal regime of the soil and good aeration helped the young jute seedlings escape early drought stress. The nail weeder operation created an environment to produce active, taller (23 cm) and deep-rooted jute plants over stunted and thin jute seedlings (11 cm) with shallow roots under prolonged drought (Figure 3). It saved one irrigation by maintaining better soil moisture through soil mulching.

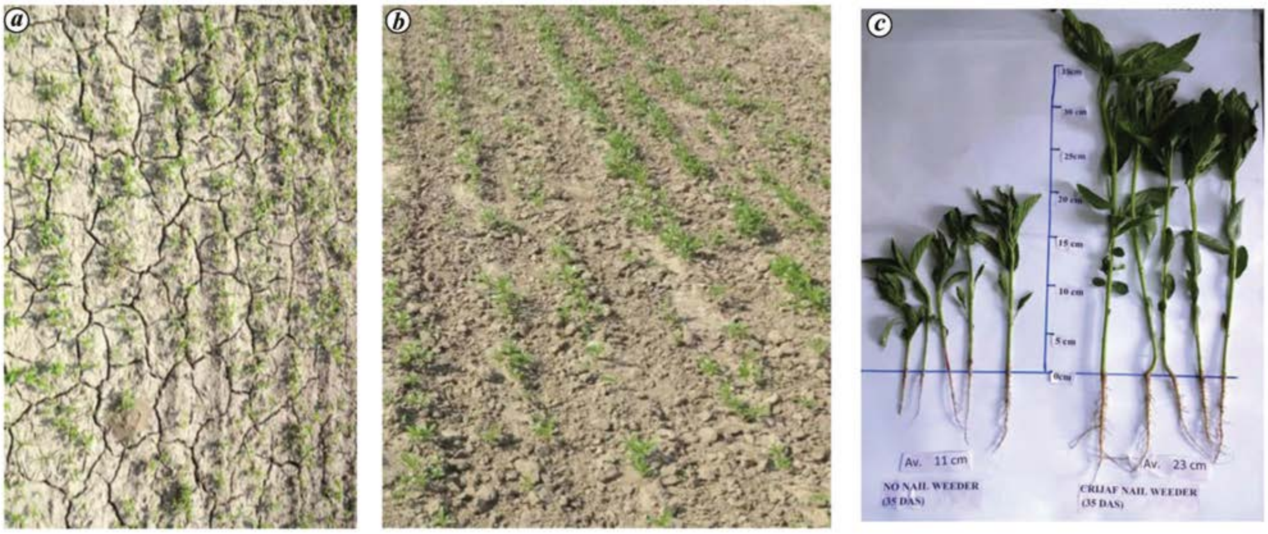

Figure 3. ***a***, Huge soil cracks in broadcast jute, a usual source of fast water loss from jute fields in summer. ***b***, Soil mulch in broadcast jute and its line arrangement by the weeder at 5 DAE (no soil crack and thus maintains more moisture). ***c***, Soil mulching by the weeder with nail assembly (5 and 8 DAE) maintained 5–6% more moisture, kept the soil cooler (by 1–3°C) at 5–10 cm soil depth and helped the jute seedling escape early drought stress (no rainfall till 30 days after sowing)[1].

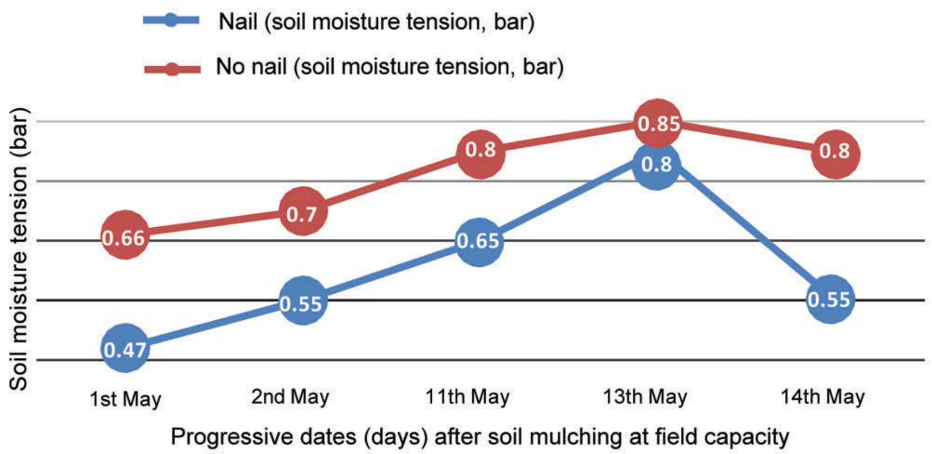

Figure 4. Soil moisture tension due to operation of agricultural weeder with nail assembly in jute field at field capacity.

In 2014–15, the rainfall deficit from 15 March to 15 June was 40% over the long-term average, which primarily helped in the initial establishment of the jute crop. One irrigation using the flat-bed method of sowing at recommended fertilizer dose (RDF: N : P : K::60 : 30 : 30) could produce 25.6 q jute fibre/ha. RDF and one flood irrigation followed by soil mulching (at field capacity) using the weeder produced 28 q jute fibre/ha, 2.40 q more than traditional flood irrigation systems. Soil mulching by the weeder maintained 4–5% more soil moisture over without nail applied plots and maintained lower soil moisture tension before drying the soil. The water productivity and rainwater use efficiency of the weeder operated plots were higher (1942 litre water/kg fibre, 2.598 kg fibre/ha/mm**)** over without nail application (2120 litre water/kg fibre, 2.381 kg fibre/ha/mm; Table 3)[10]. In 2015–16, the said system yielded 34.18 q jute fibre/ha (32.50 q/ha in control) with water productivity of 1284.62 litre water/kg fibre compared to 1351.5 litre water/kg fibre from no mulch traditional system. In roselle similar yield improvement was reported from Amadalavalasa, Andhra Pradesh (Table 4). Farmers of jute-growing districts could harvest 2–3 q/ha more fibre using this weeder under limited irrigation. Under limited moisture supply, it produced 10–20% more fibre yield than conventional weeder from 2009 to 2020.

This ecofriendly weeder operates in different jute and mesta-growing states of India in different field and horticultural crops. During 2017–20 total area covered was around 20,000 ha and around 1 lakh farmers benefitted from this technology. Till now around 55,000 such weeders have been distributed to jute farmers by the Department of Agriculture, Government of West Bengal. It reduced the cost of

Table 3. Yield and water productivity of jute under limited water supply using the weeder

Treatment	Fibre yield (kg/ha)	Total rainfall received in the growth period (mm)	Irrigation water applied (mm)	Total water received in the growth period (mm)	Rainwater use efficiency (kg fibre/ ha/mm)	Water productivity (l water/kg fibre)
Flat-bed sowing, N : P :K :: 60 : 30 : 30 and one irrigation	25.60	1027	50	1077	2.38	2120
Flat-bed sowing, N : P :K :: 80 : 40 : 40 and one irrigation	28.00	1027	50	1077	2.60	1941
Flat-bed sowing, N : P : K :: 60 : 30 : 30, and one irrigation and the weeder at 5 DAE	28.00	1027	50	1077	2.60	1942
Flat-bed sowing, N : P : K :: 80 : 40 : 40, one irrigation and the weeder at 5 DAE	28.50	1027	50	1077	2.65	1905
Open-furrow sowing, N : P : K :: 60 : 30 : 30 and one irrigation	26.70	1027	30	1057	2.52	2039
Flat-bed sowing, N : P : K :: 60 : 30 : 30 and two irrigations	28.75	1027	100	1127	2.55	1890
Flat-bed sowing, N : P : K :: 80 : 40 : 40 and two irrigations	27.95	1027	100	1127	2.48	1945
Flat-bed sowing, N : P : K :: 60 : 30 : 30 and two irrigations and the weeder twice after each irrigation	28.87	1027	100	1127	2.56	1883
Flat-bed sowing, N : P : K :: 60 : 30 : 30 and three irrigations	29.20	1027	150	1172	2.48	1861
Flat-bed sowing, N : P : K :: 60 : 30 : 30 and one irrigation and mung waste (2 t/ha)	28.40	1027	50	1077	2.64	1921
CD	NS	–	–	–		

Table 4. Effect of water conservation methods and nutrients on rainfed roselle at Amadalavalasa, Andhra Pradesh

Treatment	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	29.9
80 : 40 : 40 kg/ha	366	2.05	27.85
SEm ±	6.342	0.0734	2.185
CD (5%)	13.165	0.114	4.23
Water conservation methods			
Rainfed sowing (W1)	355	1.81	26.33
Sowing in furrow (W2)	359	2.1	27.85
Rainfed sowing + soil mulch with weeder (W3)	373	2.54	30.36
CD (5%)	16.083	0.202	6.37
Interaction (N : P : K levels × water conservation methods)			
SEm ±	12.34	0.1454	4.8065
CD (5%)	25.857	0.331	9.237

weeding up to 90% (Rs 15,000–20,000/ha). In transplanted rice, it helped save 30 man-days/ha. It also helped save one irrigation by maintaining better soil moisture through soil mulching.

Farmers are using this low draft (8–12 kg) weeder for different crops. They have reported its usefulness in multiple crops, ease of operation and many other benefits. It helps save 60–90 man-days/ha in farmers' fields compared to manual weeding. In transplanted rice, it saves 30 man-days/ha. Farmers have been able to avoid herbicides to control weeds using this tool[11–13]. It has reduced dependence on the workforce during critical hours of weeding and increased self-reliance in crop weed management. Under limited irrigation/rainfed/deficit rainfall situation (45–50%), it helps improve jute fibre yield by up to 12%. It effectively scratches the surface soil (2–4 cm deep) and promotes aeration in soil for quick seedling establishment. It has helped to produce 33–40 quintal jute fibre/ha, 4.5–5 t/ha of upland and transplanted land rice, 3.0–4.5 t/ha of wheat and 15 q/ha of mustard in the farmers' fields and at ICAR-CRIJAF in different years.

Farmers have primarily adopted this weeder for weed control across the jute-growing states of India for field and horticultural crops. To date nearly 55,000 weeders have been distributed to farmers. The weeder has reduced the age-old drudgery of weed management operations due to its low draft (8–12 kg). This tool is eco-friendly and has minimized dependency on manual labour and chemical herbicides. It helps resource-poor farmers in reducing the cost of cultivation and improving crop yield.

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