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Management of weedy rice (*Oryza sativa* f. *spontanea*) by enhancing rice competitiveness

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ABSTRACT

Of late, weedy rice (Oryza sativa f. spontanea) has emerged as a major weed in the traditional and nontraditional rice belts of Kerala. The objective of the study was to investigate the possibility of increasing crop competitiveness to weedy rice by adopting high seed rates of 100,120 and 140 kg ha^{-1}along with two priming techniques viz., water and 2.5% KCl. Among the priming methods tested, hydropriming showed superiority over hardening with 2.5% KCl. Number of grains panicle^{-1}, chaff percentage, grain and straw yield were significantly influenced by high seed rate (100 or 120 kg ha^{-1}) along with hydropriming. Seed rate of 100 kg ha^{-1} along with hydropriming recorded the highest number of grains (120.02 and 121.76 respectively) per panicle followed by seed rate of 120 kg ha^{-1} with hydropriming. Better crop stand from hydroprimed seeds sown at 120 kg ha^{-1}resulted in rapid canopy development and gave preliminary advantage to rice plants over weedy rice.Weedy rice count and dry weight showed a decline on sowing of hydroprimed seeds at 100 or 120 kg ha^{-1}, with weed control efficiencies of 52 and 51per cent respectively. The study revealed a positive relation between rice competitiveness and hydropriming of seeds upto 120 kg ha^{-1}. While yield increase of 10 per cent was recorded for hydroprimed seeds at 120 kg ha^{-1}, yield reduction of 39 per cent was recorded at 140 kg ha^{-1}. Hydropriming of seeds at a rate of 100 or 120 kg ha^{-1} followed by pregermination could be recommended as one of the management practices for enhancing rice competitiveness to manage weedy rice infestation in wet seeded rice.

***Keywords*:** Competitiveness, hydro priming, seed rate, weedy rice and wet seeded rice

To cope up with the problems associated with labour shortage and water scarcity, farmers are forced to shift from puddled transplanted rice to direct seeded rice (DSR). Though DSR has many benefits like early and easy crop establishment, lower water requirement and less labour requirement, one of the major threats that has evolved by continuous adoption of this system is the emergence of one of the most invasive weeds in rice field *i.e*. weedy rice (*Oryza sativa* f. *spontanea*). It is similar to cultivated rice in most of the attributes and very difficult to identify during the initial stages. Weedy rice is regarded as the most problematic weed of 21st century and has already invaded the major rice growing states of the country with an infestation level of 5 to 60 per cent (Varshney and Tiwari, 2008). Of late, the weed has become a serious threat in the major rice growing tracts of Kerala like Palakkad, Kuttanad and Kole lands. Abraham and Jose (2014) reported non-recognition of weedy rice biotypes or hybrids in the crop field during the early stage of infestation due to its close similarity with cultivated rice as the primary reason for its alarming spread.

Weedy rice shares traits of both cultivated as well as wild rice types as it is a conspecific taxon of the AA genome complex of rice. It usually flowers earlier than cultivated rice, has a pigmented caryopsis, pigmented hulls with or without awns and its grains shatter easily, thus enhancing the weed seed bank (Rathore *et al*., 2013). Hand weeding is practically not feasible in heavily infested fields and by the time of panicle initiation during which the morphological differences are clearly evident serious damage would have been occurred to the crop. Weedy rice has competitive advantage over cultivated rice as it grows taller and faster, tillers profusely and competes with cultivated rice for nutrients, light and space. Important traits for the success of weedy rice invasion are early shattering of the grains and variable seed dormancy (Chauhan, 2013).

Yield loss under weedy rice infestation ranged between 60 to 80 per cent under moderate (15-20 weedy rice panicles m^{-2}) to high (21-30 panicles m^{-2}) infestation (Azmi and Karim, 2008). Yield of tall and short rice cultivars are reduced by 60 and 90 per cent respectively by weedy rice densities of 35 to 40 plants m^{-2}, indicating greater loss associated with weedy rice than other grassy weeds (Kwon *et al*., 1991). High seeding rates improve the ability of crop to suppress weeds more effectively by facilitating quick canopy closure (Chauhan and Johnson, 2011). Seed priming is expected to improve the competitive ability of crop against weeds with faster emergence and increased vigour which are the key factors for weed suppression. In this backdrop, the present investigation was undertaken to study the combined effect of high seed rate and seed priming on enhancing rice competitiveness for management of weedy rice.

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MATERIALS AND METHODS

Weedy rice management by enhancing rice competitiveness in terms of high seeding density and seed priming was evaluated by raising cultivated rice and most common weedy rice morphotype in microplots of size 1 m^2 during 2014-15(December 2014 to March 2015)in the wetlands of the Instructional Farm, College of Agriculture, Vellayani, Kerala. The field experiment was subsequently repeated in heavily weedy rice infested farmer's field at Nemom block during 2015-16 (December 2015 to March 2016) in plot of 20 m^2 for confirmation of results. The experimental field was located at 8^0 25' N latitude and 76^0 39' E longitudes at an altitude of 29 m above the mean sea level. The experiments were laid out in Randomized Block Design with nine treatments and three replications. The seed rates followed were 100,120,140 kg ha^{-1} with two different treatments *viz*., hydropriming and hardening with 2.5% KCl. The experimental area was ploughed twice, leveled, weeds and stubbles were removed. Weighed quantities of rice seeds of variety *Uma* as per treatments were subjected to hydropriming and hardening after conducting germination test. In hydropriming, seeds were soaked in water for 48 h and dried back to original moisture content. In hardening, seeds were dipped in 2.5% KCl solution for 18 hours and dried back to original moisture content (Sheela, 1993). Simultaneously, the seeds of most common weedy rice morphotype of the locality were allowed to germinate in petridishes after breaking dormancy by subjecting them to low temperature of 22^0C for 48 hours (Jose, 2015). Hydro primed seeds after germination were used for broadcasting under wet sown condition. Rice seeds were broadcasted in each plot as per treatments and in microplot study, after a week of rice establishment, one week old weedy rice seedlings were randomly transplanted in the field so as to maintain a standard weedy rice population of 7 plants $metre^{-2}$. The crop was fertilized with 90, 45, 45 of N, P_2O_5, and K_2O kg ha^{-1}. Half the dose of N, K and full P were applied at 15 DAS and remaining N and K at 55 DAS. All other agronomic measures were adopted as per the Package of Practice Recommendations of Kerala Agricultural University (KAU, 2011). Weeds other than weedy rice were removed as and when appeared in the field. After panicle emergence weedy rice plants were bagged separately to prevent the shattering of grains. Observations on weed count were recorded using quadrat (0.25 m × 0.25 m) placed randomly at two representative sites in each plot. Yield attributes like grains per panicle and1000 grain weight were recorded at harvest for both rice and weedy rice from 10randomly selected hills. The net plot area was harvested separately, threshed, winnowed and weight of grains and straw from individual plots were recorded. Weedy rice and cultivated rice were harvested separately and yield was recorded at 13 per cent moisture. In the confirmatory trial taken up during next year with plot size of $20m^2$, all the cultural practices were followed as in first experiment including removal of weeds other than weedy rice. The data was analyzed using ANOVA and the least significant difference (LSD) values at 5% level of significance were calculated to test significant difference between treatment means.

RESULTS AND DISCUSSION

Growth and yield attributes of rice

Higher seed rates had positive effect on Leaf Area Index while, priming methods showed no influence on enhancing LAI (Table 1) as the effect of priming was limited to the initial growth phase of two weeks. High seed rate of 140 kg ha^{-1} recorded high LAI, obviously due to the high plant population per unit land area. LAI values above the optimum indicate an excessive number of leaves per unit area leading to shading of lower leaves adversely affecting photosynthesis. Among the priming methods tested, hydropriming showed superiority over hardening with 2.5% KCl producing vigorous and fast growing seedlings during the initial stages. Seed priming lead to partial hydration of seeds without radicle emergence resulting in activation of most of the physiological processes and such seeds imbibe and revive metabolic activities soon after sowing (Farooq *et al.*, 2009). The superiority of hydropriming methods in improving germination attributes was reported by Juraimi *et al.* (2013)where hydropriming recorded twice higher Germination Index and reduced mean germination time while unprimed control exhibited inconsistent germination, poor crop stand establishment and less weed competitiveness resulting in poor yield.

Among various yield attributes, number of grains per panicle[1], chaff percentage, grain and straw yields were significantly influenced by higher seed rates (100 and 120 kg ha^{-1}) with hydropriming. However, still higher seed rate of 140 kg ha^{-1} (T_7, T_8 and T_9) recorded lower number of grains, which might be due to the greater competition for various growth factors under increased plant population. Yoshida (1972) also observed reduction in number of spikelets beyond an optimum plant density. Seed rate beyond an optimum would lead to an increase in leaf area resulting in increased respiratory rates and in turn reduction in the number of grains (Harris and Vijayaragavan, 2015). Seed rate of 100 or 120 kg ha^{-1} with hydropriming recorded high grain yield and lower unfilled grains, while unprimed or primed at 140 kg ha^{-1} (T_7, T_8 andT_9) recorded high sterility percentage and low grain yield. It could be inferred that seed rate of 140 kg ha^{-1} had negative effect on number of filled grains per panicle and poor weed competitiveness.

The study conducted in micro plots revealed that an increase in seed rate upto 120 kg ha^{-1} with hydropriming increased the grain yield upto 13 per cent and further

Table 1: Effect of treatments on vegetative and yield characters of rice at harvest (microplot study)

Treatments	Plant height (cm)	Days to 50% flowering (Days)	LAI	No. of grains panicle^{-1}	Chaff percentage	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
T_1 - seed rate of 100 kg ha^{-1} + without priming	108.33	80.82	2.81	105.90	14.87	22.92	3.55	6.04	0.37
T_2 - seed rate of 100 kg ha^{-1} + hydropriming	125.58	81.61	2.98	120.02	10.40	22.89	4.44	6.72	0.40
T_3 - seed rate of 100 kg ha^{-1}+ hardening with 2.5 % KCl	125.88	80.87	2.50	112.89	12.83	23.29	4.00	5.77	0.41
T_4 - seed rate of 120 kg ha^{-1} + without priming	110.28	81.08	4.86	112.74	12.73	23.56	3.64	6.19	0.37
T_5 - seed rate of 120 kg ha^{-1}+ hydropriming	120.45	80.90	2.90	119.81	11.58	23.46	4.07	6.37	0.39
T_6 - seed rate of 120 kg ha^{-1}+ hardening with 2.5 % KCl	117.33	81.25	4.22	116.73	12.12	23.26	3.80	5.70	0.40
T_7 - seed rate of 140 kg ha^{-1} + without priming	121.67	81.45	5.44	99.77	16.92	23.22	2.60	4.16	0.38
T_8 - seed rate of 140 kg ha^{-1} + hydropriming	125.64	80.99	4.85	106.33	16.05	23.29	2.72	4.03	0.40
T_9 - seed rate of 140 kg ha^{-1} + hardening with 2.5 % KCl	139.43	81.31	2.85	105.29	15.79	23.32	2.70	4.34	0.38
SEm (±)	**7.51**	**0.45**	**0.35**	**1.36**	**0.12**	**0.39**	**0.09**	**0.29**	**0.04**
LSD (0.05)	**NS**	**NS**	**1.05**	**4.08**	**0.37**	**NS**	**0.25**	**0.85**	**NS**

Note: LAI: Leaf Area Index

increase (140 kg ha^{-1}+ hydropriming) resulted in reduction in yield upto 27 per cent. A similar trend was observed in confirmatory trial with yield increase up to 10 per cent for hydroprimed seeds at 120 kg ha^{-1} and 39 per cent yield reduction for hydroprimed seeds at 140 kg ha^{-1} (Table 2). The higher grain yield registered in these treatments corresponds to the lowest weedy rice population recorded in these treatments. High crop seeding rates of upto 120 kg ha^{-1} suppressed weedy rice population and hydropriming resulted in enhanced vigour of rice seedlings. It was observed that seed priming improved the competitive ability of crop against weeds and reduced the requirement of high crop seeding rates. Increased vigour of primed stand was the key factor for tolerating weeds. The synergistic effect of these two might have resulted in high competing ability of rice over weedy rice reducing its count. Better crop stand from hydroprimed seeds sown at 120 kg ha^{-1} resulted in rapid canopy development and gave preliminary advantage to rice plants over weedy rice. Although per plant yield was higher at the lowest seed rate this did not compensate for the contribution in terms of yield by more plants at the highest density. Above optimum LAI values recorded in treatments receiving higher seed rates (140 kg ha^{-1}) support these findings. Sreepriya and Girija (2018) reported improvement in weed competitiveness of primed stand of sesame due to enhancement in the early seedling vigour of the primed seeds.

The study revealed a positive relation between high seed rate and yield up to a certain level and beyond which it would start to decline because of severe competition for various growth factors. Ampong-Nyarko and De

Table 2: Effect of treatments on vegetative and yield characters of rice at harvest (confirmatory trial)

Treatments	Plant height (cm)	Days to 50% flowering (Days)	LAI	No of grains panicle^{-1}	Chaff percentage	1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
T_1 - seed rate of 100 kg ha^{-1} + without priming	91.17	80.34	3.98	107.64	14.50	22.40	3.88	6.61	0.37
T_2 - seed rate of 100 kg ha^{-1} + hydropriming	90.83	81.14	3.92	121.76	10.03	22.37	4.30	7.31	0.37
T_3-seed rate of 100 kg ha^{-1}+ hardening with 2.5 % KCl	91.80	80.41	3.55	114.63	12.45	22.77	3.94	6.71	0.37
T_4 - seed rate of 120 kg ha^{-1} + without priming	91.17	80.61	5.03	114.48	12.35	23.03	3.72	6.07	0.38
T_5 - seed rate of 120 kg ha^{-1}+ hydropriming	90.97	80.43	4.02	121.55	11.20	22.93	4.24	7.21	0.37
T_6 - seed rate of 120 kg ha^{-1}+ hardening with 2.5 % KCl	90.30	80.78	5.30	118.47	11.74	22.73	3.78	6.44	0.37
T_7 - seed rate of 140 kg ha^{-1} + without priming	93.34	80.99	6.11	101.51	16.54	22.70	2.57	4.28	0.38
T_8 - seed rate of 140 kg ha^{-1} + hydropriming	93.67	80.53	5.07	108.07	15.67	22.77	2.68	4.64	0.37
T_9 - seed rate of 140 kg ha^{-1} + hardening with 2.5 % KCl	91.87	80.82	5.26	107.03	15.42	22.80	2.74	4.76	0.37
SEm (±)	**1.42**	**0.63**	**0.56**	**1.93**	**0.27**	**0.56**	**0.14**	**0.26**	**0.05**
LSD (0.05)	**NS**	**NS**	**1.18**	**2.09**	**0.57**	**NS**	**0.33**	**0.78**	**NS**

Note: LAI: Leaf Area Index

Datta (1991) suggested that competition and yield reduction occurred when one of the limiting resources fell short of the combined requirements of crop and associated weeds. An inverse relationship was found between the grain yield of rice and weedy rice population present in respective treatments. Weedy rice count and dry weight were low in T_2 (seed rate 100 kg ha^{-1} + hydropriming) and T_5 (seed rate 120 kg ha^{-1} + hydropriming), with high weed control efficiencies of 51.85 and 50.82 per cent respectively (Table 3). Low seed rate resulted in poor crop densities and crop cover during the initial growth period leaving more resources available for the growth of weedy rice and enable them to establish quickly with its high innate competing ability. Arya and Ameena (2016) also reported that reduced crop density at the initial stages resulted in higher absolute density of weeds at the critical stages of growth. At above optimum crop density, canopy closes quickly and shade out the weedy rice plants. Such an advantage obtained during the initial stages will be reflected later as high yield. The study proved that in wet seeded rice, high seed rate favoured the competitiveness of rice plants in suppressing weeds compared to low seed rates. Primed seeds exhibited seedling vigour with uniform germination, increased germination rate, better allometric attributes and quick emergence of seedlings (Farooq *et al*., 2009), which improved the competitive ability of seedlings.

Reduction in grain yield was observed in treatments with an exceptionally high seed rate, which was directly correlated to the high weedy rice count recorded in the treatments. High weedy rice count was recorded in plots

Table 3: Effect of treatments on growth of weedy rice at harvest

Treatments	Microplot study (I year)					Confirmatory trial (II year)					Confirmatory trial			
	Plant height (cm)	Grains panicle^{-1} (number)	Sterility (%)	DW of grains (g m^{-2})	DW of straw (g m^{-2})	Plant height (cm)	Grains panicle^{-1} (number)	Sterility (%)	DW of grains (g m^{-2})	DW of straw (g m^{-2})	Leaf aream^{-2} (cm^2)	Weedy rice count (no. m^{-2})	DW of weedy rice (g m^{-2})	Weed control efficiency (%)
T_1	110.11	69.47	30.39	79.02	190.38	103.17	107.64	14.50	80.00	192.40	8906.12	5.18	121.73	34.91
T_2	113.50	67.07	30.94	48.83	119.00	109.67	121.76	10.03	46.46	113.05	4895.50	3.84	90.05	51.85
T_3	120.81	68.80	30.45	70.00	174.55	110.00	114.63	12.45	68.62	170.57	7685.51	5.53	132.77	29.00
T_4	106.85	68.93	31.39	75.24	171.32	110.35	114.48	12.35	75.05	171.12	7648.46	4.65	111.60	40.32
T_5	107.61	69.47	30.55	52.37	128.97	104.34	121.55	11.20	41.83	103.75	4049.45	3.85	91.98	50.82
T_6	102.96	68.70	31.05	50.84	126.33	111.20	118.47	11.74	50.72	125.30	4880.68	4.33	102.36	45.26
T_7	114.74	70.23	31.75	104.00	271.07	107.50	101.51	16.54	109.86	286.26	12223.96	7.75	187.01	0.00
T_8	116.88	67.90	31.15	91.42	0.29	106.50	108.07	15.67	104.73	0.29	10423.09	7.30	172.86	7.56
T_9	124.05	69.23	31.19	225.53	0.30	104.34	107.03	15.42	97.16	0.30	10806.00	7.37	175.77	6.01
SEm (±)	**2.69**	**0.84**	**1.00**	**0.10**	**0.04**	**3.13**	**1.93**	**0.27**	**0.05**	**0.03**	**79.63**	**0.12**	**3.11**	**1.73**
LSD (0.05)	**8.06**	**NS**	**NS**	**0.25**	**NS**	**NS**	**2.09**	**0.57**	**0.12**	**NS**	**284.65**	**0.29**	**6.60**	**3.67**

Note: DW=dry weight

receiving higher seed rate without priming. This might be due to the severe competition set up among rice plants in which weedy rice took advantage of the situation. Chauhan (2013) opined that with each increase in weedy rice density, the grain yield of cultivated rice declines significantly. In a previous study, rice yield reductions were between 100 and 755 kg ha^{-1} for every weedy rice plant m^{-2} (Ottis *et al*., 2005). Economic analysis of the study indicated that T_2 (100 kg ha^{-1} + hydropriming) along with T_5 (120 kg ha^{-1} + hydropriming) turned out to be the most economic treatment registering B: C ratio of 1.68 and 1.64, respectively (Table 4). The most economic management practice was use of hydroprimed seeds at a rate of 100 kg ha^{-1} for suppression of weedy rice and improving competitive ability of rice. Wet seeding of pregerminated seeds after hydropriming at a seed rate of 100 or 120 kg ha^{-1} is found to enhance the competitive ability of rice against weedy rice.

Population and growth of weedy rice

Weedy rice plants were found to be taller at a high seed rate of 140 kg ha^{-1} in microplot while no such trend was observed in farmers' field (Table 3). Taller weedy rice plants would further add to its competitive ability by better interception of light. Taller weed plants are known to reduce crop yield more than shorter weed plants mainly by shading of crop plants (Chauhan, 2012). Seed rate of 140 kg ha^{-1} (T_7, T_8 and T_9) recorded high leaf area m^{-2} for weedy rice in both the situations which might be due to the high weedy rice count recorded from unit land area. Exceptionally high crop seeding rate generated severe competition among rice plants and weedy rice took advantage of the situation recording high weed densities. Taller weedy rice plants with higher leaf area at 140 kg ha^{-1} without priming(11651.17 and 12223.96 cm^2, respectively in microplot and farmers field) might shade rice plants. This indicated that grain production in rice is significantly affected by weedy rice densities and a decline was observed in no of grains per panicle with increment in weedy rice densities.

Weedy rice panicles contained more sterile and half filled grains with sterility percentage of 30 to 32, than cultivated rice (below 17 per cent) irrespective of the treatments. However, sterility percentage of weedy rice was lower in farmers' field (19 to 24). It could be observed that repeated back crossing between persistent weedy rice population and cultivated rice under farmers' field situation lead to more filling of weedy rice panicles. Seed production of weedy rice was high at crop seeding rates of 140 kg (T_7, T_8 and T_9) which was directly correlated to the higher weedy rice counts m^{-2} recorded in these treatments. This imply that under increased crop density, the crop fraction fared better with reasonable weed suppression till 120 kg ha^{-1} and beyond which weed fraction took upper hand.

The result suggest that adoption of higher seed rate of 120 or 100 kg ha^{-1} with hydropriming followed by

Table 4: Effect of treatments on economics of rice production (confirmatory trial)

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
T_1 - seed rate of 100 kg ha^{-1} + without priming	56,000	86830	30,830	1.55
T_2 - seed rate of 100 kg ha^{-1} + hydropriming	57280	96369	39,089	1.68
T_3 - seed rate of 100 kg ha^{-1}+ hardening with 2.5 % KCl	57325	88329	31,004	1.54
T_4 - seed rate of 120 kg ha^{-1} + without priming	56,800	83389	26,589	1.47
T_5 - seed rate of 120 kg ha^{-1}+ hydropriming	58080	95029	36,949	1.64
T_6 - seed rate of 120 kg ha^{-1}+ hardening with 2.5 % KCl	58125	84749	26,624	1.46
T_7 - seed rate of 140 kg ha^{-1} + without priming	57,600	57639	39	1.00
T_8 - seed rate of 140 kg ha^{-1} + hydropriming	58880	61009	2,129	1.04
T_9 - seed rate of 140 kg ha^{-1} + hardening with 2.5 % KCl	58925	60549	1,624	1.03

pregermination could be recommended as one of the management practices to be integrated with other agronomic practices for enhancing rice competitiveness to manage weedy rice infestation in wet seeded rice.

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