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Crop-weed competition in aerobic rice (*Oryza sativa*) — serious concern in nitrogen fertilizer management

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ABSTRACT

Aerobic rice (*Oryza sativa* L.) is a climate resilient agro-technology thriving over the threats of looming water scarcity. However, severe crop-weed competition is the crux of the problem affecting N use efficiency that could result in drastic grain yield reduction. Thus, what would be the efficient weed management minimizing crop-weed competition for higher grain yield was studied at farmer's fields under ICAR-NRRI, Cuttack and GBPUAT, Pantnagar during 2015–16 and 2016–17. Results showed that maintaining crop-weed competition during initial 75, 60 and 45 days crop growth accelerated N uptakes at 106.0 to 106.6 kg/ha, 105.5 to 105.8 kg/ha and 100.0 to 101.2 kg/ha enhancing grain yield by 5.25 to 5.56 t/ha, 5.0 to 5.4t/ha and 4.7 to 5.15 t/ha respectively. Corresponding weedy crop stands produced 0.90 to 1.35 t/ha, 1.10 to 1.48 t/ha and 2.45 to 2.86 t/ha grain yields only. Thus, average N gain of 0.22 and 0.17% were attributed to initial 75 and 60 days weed-free stands over initial soil N. While, N losses were maximum of 25.36, 24.56 and 22.32% at initial 60 and 75 days weedy stands and initial 15 days weed free stands respectively. Minimum N losses of 1.26 and 1.63% were at initial 15 days weedy crop or initial 45 days weed-free stands respectively. Therefore, on-farm validation at farmer's fields could imply significance of declining crop-weed competition preferably up to initial 30-45 days promoting N use efficiency for higher aerobic rice production.

Keywords: Aerobic rice, Crop-weed competition, Grain yield, Nitrogen utilization, Weed management

Rice (*Oryza sativa* L.) is ostensibly a water-guzzling crop; thus, balancing a trade-off between crop and water productivity called for growing rice at tropical aerobic situation without compromising the potential grain yield. Although, actual productivity happens to be much lower, largely due to inefficient weed management (Zhao *et al.* 2007). The projected regions of aerobic rice cultivation are rainfed favorable uplands and water deficient irrigated medium land situations in states namely, Odisha, West Bengal, Bihar, Uuuar Pradesh, Jhrakhand, Chhattisgarh, Punjab, Tamil Nadu and Karnataka with a potential yield of 4.0-4.5 t/ha (Ghosh *et al.* 2018). Aerobic soil environment usually experiences a transitional phase between dry and wet moisture regime creating a congenial soil environment facilitating emergence and severe growth of complex weed flora in different flushes. Although, germinations of both rice and weed seeds occur concurrently, initial weed pressure becomes severe due to delay in 'head start' of rice seed over weeds (Rahman *et al.* 2017). While, varying crops and growing ecologies determines N removal estimating around 95.0-100 kg N/ha (Yadav *et al.* 2019). This is the major concern while understanding the complex relationship between crop-weed competition and N utilization pattern in aerobic rice cultivation. As considerable proportion of applied N remains unutilized on account of inefficient weed management, which is evident more in this aerobic soil environment (Belder *et al.* 2005). Therefore, crop-weed competition is presumed to decline NUE, which is however governed by varying schedules of weed management.

Adequate research information is yet to establish a better understanding of schedules of weed management *vis-à-vis* N budgeting in aerobic rice cultivation. Thus, our intensive study intended to investigate the consequences of inverse relationship between crop-weed competition and N utilization dynamics at the target environment. Therefore, it was expected that the current study could help us derive a logical conclusion advocating optimum period of weed free situation for higher NUE and aerobic rice productivity.

MATERIALS AND METHODS

Field studies were conducted at farmer's fields in coordination with ICAR-NRRI, Cuttack, and GBPAUT, Pantnagar during 2015–16 and 2016–17. Twelve schedules of weed management maintaining weed-free crop stands for initial 15, 30, 45, 60 and 75 days along with weedy

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and near weed-free check as control treatments. To comply 'Treatment' specification, weed management comprised with the application of pre-emergence herbicide, Pendimethalin @ 1.5 kg a.i. /ha at 3 days after sowing (DAS) followed by post-emergence herbicide, Bispyribac sodium @ 25 g a.i./ ha at 21 DAS and need based once/twice manual weeding maintaining near weed-free situations as per treatment. The experiment was arranged in a randomized complete block design at five farmer's fields as replication. The soils at experimental locations were medium to moderately coarse textured containing 0.79 and 0.68% organic carbon, 240.4 and 232.8 kg/ha available nitrogen, 19.9 and 27.0 kg/ha available phosphorus and 178.6 and 177.0 kg/ha available potassium with *p*H 7.3 and 6.9 respectively at Pantnagar and Cuttack.

Aerobic rice variety, CR Dhan 200, a medium duration (100-120 days), photo-sensitive, semi-tall rice genotype was dry drill sown in 25 m^2 plot at 15 cm × 20 cm spacing during 2nd week of January at a seed rate of 50 kg/ha. A recommended dose of fertilizer N, P_2O_5 and K_2O was applied at the rate of 120, 60 and 60 kg/ha, respectively; of which 50% N, 100% P_2O_5 and 75% K_2O were applied as basal; while 25% N was applied at active tillering stage, and remaining 25% N and 25% K_2O were applied at panicle initiation stage. A flush irrigation was applied soon after sowing facilitating uniform germination followed by subsequent irrigation maintaining 40 kPa soil moisture potential at 30 cm root depth. Soil moisture potential at the root depth was monitored throughout the crop growing period with a portable electronic tensiometer (SMS 2500S, No. 0660727, Eijkelkamp Agrisearch Equipment BV, The Netherlands). Two parameters namely N uptake by rice grain and straw, and residual soil N after the crop harvest were estimated. Soil N analyses were conducted following standard Kjeldahl method of N estimation in the ICAR-NRRI, Cuttack. As a result, N balance accounting apparent N gains and losses were also derived for better understanding of the N utilization pattern. Weed samples were collected at each 15 days interval since emergence of crop till harvest from unit area of one m^2 in each treatment plot. Relative advantages of different schedules of weed management were derived following two important parameters namely weed control efficiency (WCE) and weed index (WI) following numerical derivation;

WCE (%) = Dry biomass of weeds in (weedy plot-treated plot) × 100

Dry biomass of weed in weedy plot

WI (%) = Grain yield in (weed free plots- treated plot) × 100

Grain yield in weed free plot

Crop was harvested from 5 m^2 areas in each plot at physiological maturity recording grain yield at 14% moisture content.

The data were subjected to ANOVA using standard statistical procedure where treatment differences were compared following least significant difference (LSD) tests at $P<0.05$ level of significance.

RESULTS AND DISCUSSION

Prevalence of weed flora: Complex weed flora comprised major grassy weeds namely *Echinochloa colona, Echinochloa crus-galli, Dactyloctenium aegypticum* and *Eleusine indica;* sedges namely *Cyperus iria, Cyperus rotundus, Fimbristylis milliaceae,* and broad leaf weeds namely *Amarenthus spinosus* and *Alternanthera sessilis, Eclipta alba, Eclipta prostrate, Commelina benghalensis, Portilaca oleracea, and Euphorbia hirta.* Among three categories of weed flora, population of grassy weeds was predominant during initial 21 days, while prevalence of sedges and broad leave weeds was pronounced more during next 15 days.

Determination of weed biomass and weed growth parameters: Completely weedy and near weed-free situations recorded fresh weed biomasses of 650.10 and 692.05 g/m^2, and 67.50 and 80.15 g/m^2 respectively across the year. While, fresh weed biomass declined significantly during initial 15 days weedy stands and initial 60-75 days of near weed-free stands accounting 82.75 and 100.10, 105.60 and 150.82, 165.20 and 210.72 g/m^2 respectively during consecutive year. In contrast, initial 15 days of near weed-free stands recorded significantly higher weed biomasses of 550.60 and 600.20 g/m^2, closely followed by that of 555.25 and 600.16 g/m^2 at stands remained weedy for initial 75 days.

In this study, WCE was higher ranging from 85.54 to 87.27% at initial 15 days weedy stands, which was nearly similar to that of 88.42 to 89.62% at weed-free situations (Fig 1). Significantly higher WCE accounting 69.66 to 74.59% and 78.21 to 83.76% were also derived in those stands remained weed-free for initial 60 and 70 days, respectively over the years. While, lower WCEs of 13.27 to 15.30% and 13.28 to 14.59% were derived at the stands remained weed-free for initial 15 days and weedy for initial 75 days respectively in successive year. While, WI was less accounting 4.47 to 6.36 % and 7.22 to 9.09% at weed- free stands for initial 60 and 75 days, respectively over the years, followed by that of 11.51 to 14.54% at weed-free for initial 45 days in successive year (Fig 1). However, higher WI of 74.91 to 81.81%, 74.57 to 80.00% and 76.80 to 83.64% were recorded across the year in weed-free stands for initial 15 days or weedy for first 60 or 75 days. Thus, crop growth within 30 to 45 DAS could be considered most critical taking account optimum value of WCE and WI derived during these periods (Fig 1).

Determination of grain and straw yield: Stands remained nearly weed-free during initial 75 days produced significantly higher mean grain yield of 5.4 t/ha ranging from 5.56 to 5.25 t/ha, which was comparable with those of 5.2 and 4.9 t/ha ranging from 5.0 to 5.40 and 4.70 to 5.15 t/ha grain yield respectively at near weed-free stands for initial 60 and 45 days across the locations (Table 1). While, initial 15 days weedy stands produced significantly mean

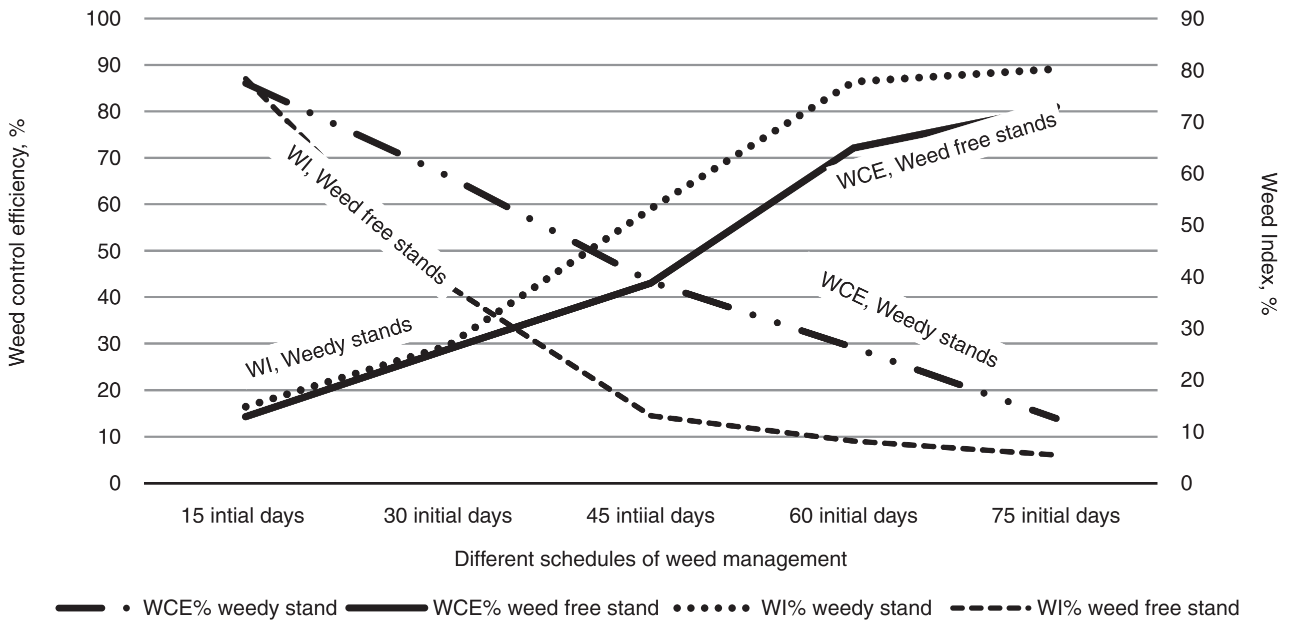

Fig 1 Weed control efficiency and weed index at different schedules of weed management in aerobic rice cultivation during 2015-16 and 2016-17 (mean of two years).

higher grain yield of 4.8 t/ha ranging from 4.60 to 5.05 t/ha and weedy stands for initial 75 and 60 days produced the lowest mean grain yield of 1.1 and 1.3 t/ha, respectively across the locations. Stands remained either weedy or weed free for initial 30 days produced more or less similar mean grain yield of 3.0 to 3.5 t/ha, respectively over the year. Straw yields were significantly higher of 6.2, 6.5 and 6.9 t/ha at the stands remained weed-free for the initial 45, 60 or 75 days comparing with those of 6.6 t/ha at the stands remained weedy for initial 15 days.

Estimation of N uptake pattern: N estimation showed comparable mean N uptake of 101.4, 105.6 and 106.3 kg/ha respectively at weed-free stands for initial 45, 60 and 75 days over the year, which were significantly higher than those at other schedules. Comparable N uptake of 103.5 kg/ha was also estimated at weedy stands for initial 15

Table 1 Grain yield, yield attributes and N utilization under different schedules of weed management in aerobic rice cultivation during 2015 and 2016 (mean of two years)

Crop stand	Plant height (cm)	Panicle/ m^2	Panicle weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	N uptake (kg/ha) (i)	Residual N in soil (kg/ha) (ii)	N balance (kg/ha) (i+ii = B)	% apparent N Loss (-)/Gain (+) (A-B)
Weedy stands									
0 days	111	405	2.6	5.6	6.8	108.2	252.2	360.4	+1.09
Initial 15 days	108	350	2.5	4.8	6.6	103.5	249.6	352.1	-1.26
Initial 30 days	100	290	2.2	3.0	4.5	76.5	245.4	321.9	-9.53
Initial 45 days	97	275	2.0	2.6	3.8	30.4	242.8	273.2	-23.34
Initial 60 days	90	180	1.8	1.3	2.6	28.3	240.7	269.0	-24.56
Initial 75 days	87	150	1.7	1.1	2.4	26.5	239.7	266.2	-25.36
Weed free stands									
0 days	86	175	1.9	1.0	2.5	15.7	237.1	252.8	-29.11
Initial 15 days	89	165	1.8	1.2	2.6	35.2	241.8	277.0	-22.32
Initial 30 days	98	310	2.0	3.5	4.6	86.2	247.1	333.3	-6.53
Initial 45 days	108	370	2.5	4.9	6.2	101.4	249.4	350.8	-1.63
Initial 60 days	110	400	2.6	5.2	6.5	105.6	251.5	357.2	+0.17
Initial 75 days	112	410	2.8	5.4	6.9	106.3	251.1	357.4	+0.22
SEm ±	1.3	9.2	0.12	0.21	0.43	1.7	0.8	3.1	
CD (P=0.05)	4	28	0.33	0.62	1.10	5.2	2.8	9.5	

Initial available soil N (a)- 236.6kg/ha; Applied N (b)-120.0 kg/ha; Total available N (a+b = A)- 356.6 kg/ha days (Table 1). On the other hand, N uptakes were lower at the stands remained weedy for initial 75 and 60 days, respectively accounting average of 26.5 and 28.3 kg/ha over the year. Maximum mean N uptake of 108.2 kg/ha was estimated at the complete weed-free stands, ranging from 108.0 to 108.5 kg/ha across the locations.

Estimation of residual soil N: Comparing average initial soil status (i.e. 236.6 N kg/ha,) in two locations, marginal increase in residual soil N increased marginally accounting average of 251.1 and 251.5 kg/ha at the weed-free stands for initial 75 and 60 days, comparable with that of 252.2 kg/ha at completely weed-free stands; which was, however, significantly higher than other schedules (Table 1). Such a nominal increase might be accountable for uncontrolled N losses through other avenues mostly, leaching, volatilization, denitrification, etc, which were not estimated in the study. While, weedy stands for initial 15 days and also initial 45 and 30 days weed free stands showed considerably higher residual soil N of 249.6, 249.4 and 247.1 kg/ha over the year. On the other hand, stands remained weedy for initial 75, 60 and 45 days recorded mean lowest residual soil N accounting 239.7, 240.7 and 242.8 kg/ha respectively over the year.

Prevalence of grassy weeds was pronounced more at the beginning of the growing season constituting 75-80% population density; while sedges and broadleaf weeds were vigorous at the later stages of crop growth (Zhao *et al.* 2007). Such an unusually higher weed pressure of all three species was ascribed with the prevalence of transitional soil water regime that appeared to become conducive for severe weed flush (Mishra and Singh 2008). Crop-weed competitions under different schedules of weed management were determined considering the period and stage of the crop remained under either weedy or weed-free situation. As a result, WCE varied taking account not only the stage of weeding but the period of the stand remained weed free, too. Concurrently, magnitude of crop-weed competition governed the depletion trend of available plants nutrients in the soil. Evidently, such a stressful situation deprived the plant with adequate resources required for adequate growth and development (Dixit and Varshney 2008).

Significantly higher grain yield at the stands remained weed-free for the initial 75 days was attributed to the decline in weed intensity accounting 4.50% less than that in completely weed-free stands. This was also corroborated with corresponding WI, which established an inverse relationship with grain yield. In cognizance with such situations, lesser crop-weed competition substantially promoted better crop growth and vigor substantiated with adequate nutrient resources to achieve significantly higher grain yield (Saito *et al.* 2010). While, severe crop-weed competition at the stand remained weedy for initial 60 and 75 days accentuated adequate nutrient losses that resulted in poor grain yield (Payman and Singh 2008). Even, crop performance was also severely affected at the stand remained weed-free for initial 15 days. Therefore, it could be established that whether the stand remained weedy or weed-free may not help us derive any logical inference; the duration *vis-a-vis* crop growth stage when such situations could prevail, needs to be specified critically for a better understanding of the circumstantial impact on crop performances and productivity ultimately.

Critical analyses showed reduction in crop-weed competition either at weed-free stands for initial 75 and 60 days or even weedy stands for initial 15 days stimulated N uptake accelerating crop vigor for higher grain yield, which closely followed the weed-free stands for entire growth periods. It was also evident that better crop vigour assimilated higher N within the plant, which was attributed to higher residual soil N at the stands remained weed-free for initial 45 to 75 days and also weedy for initial 15 days (Mahajan and Timsina 2011). Critical review of the situations revealed two situations of apparent N gain, attributed to less crop-weed competition at weed-free stands for initial 75 days and 60 days accounting average of 0.22 and 0.17% N gain in successive years over those of initial soil N status, respectively in successive year of study (Table 1). While, apparent N losses occurred higher due to severe crop-weed competitions at weedy stands for the initial 75, 60, 45 days and also at weed free stands for initial 15 days accounting average of 25.36, 24.56, 23.34 and 22.32% respectively in successive years over those of initial soil N status. On the other hand, comparatively lower apparent N losses varying from around 1.26 to 9.73% were estimated over initial soil N status at the situations of weedy for first 15 or 30 or weed-free for initial 30 and 45 days. As a result, a lesser crop-weed competition ensured better crop growth and vigor attributed with absolute N gains or restricted N losses. In contrast, a severe crop-weed competition was also visualized where intense weed pressure suppressed crop growth that resulted in varying degree of N losses depending on different magnitude of crop-weed competitions.

Therefore, the study established an inverse relationship between crop-weed competition and N utilization having been attributed to different magnitude of yield penalties in aerobic rice cultivation. Lesser crop-weed competition was visualized responsible for greater ability of plant promoting NUE for higher grain yield and *vice versa*. Therefore, keeping crop-weed competition at minimum level attributed to near weed-free situations within 30 to 45 days of crop growth could be suggested for efficient N utilization and optimum grain yield of aerobic rice.

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