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Impact of weed management and row spacing on growth attributes of aerobic rice, weed density, dry matter and nutrient uptake

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Abstract
A field experiment was conducted during *Kharif* season of 2017 in D_2 block at Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar to find out the impact of weed management practices and row spacing on the growth attributes of direct seeded rice, dry matter accumulation of weeds and nutrient uptake by them. Row spacing recorded the non-significant difference in plant height at all growth stages. Pendimethalin 1kg /ha *fb* penoxsulam 22.5 g/ha recorded the highest plant height which was at par with the weed free and with cyhalofop-butyl + penoxsulam (Readymix) 150g/ha at 80 DAS and at maturity. Row spacing of (25 cm) recorded highest number of shoots which was at par with (20) row spacing and significantly higher than the (30 cm) row spacing at 60, 80 DAS and at maturity. Pendimethalin 1kg/ha *fb* Penoxsulam 22.5 g/ha recorded significantly maximum number of shoots per square metre over all the other treatments at all crop growth stages. The highest total dry matter accumulation of weeds at 60 DAS was under the spacing of 30cm which was at par with the other two row spacings. The highest uptake of nitrogen (26.12 kg/ha), phosphorous (5.47 kg/ha) and potassium (52.82 kg/ha) by weeds was recorded in weedy check. Treatment pendimethalin @1kg a.i/ha *fb* penoxsulam @ 22.5 g/ha recorded lowest uptake of nutrients (N, P and K).

Keywords: Growth, herbicides, pendimethalin, penoxsulam, rice, row spacing, weed

Introduction

Aerobic" rice-rice that grows well under dry conditions in the absence of flooding-offers a promising means to combat the looming water crisis. Farmers can use 30 to 40% less irrigation water by growing aerobic rice; however, this savings typically comes with a yield penalty of 10 to 25%, which discourages many rice growers in the tropics from adopting the new technology (https://www.agronomy.org/science-news/managing-aerobic-rice-higher-yields). Aerobic rice is a resource conservation practice which has got high water use efficiency by cutting down the water losses caused due to the seepage and percolation. Weed management is one of the most important aspects which affect the growth and productivity of aerobic rice. Hence, proper management of weeds is the need of the hour to sustain the productivity of aerobic rice. On the other hand, row spacing also plays a significant role for adopting the weed management practices and also decides the plat population which in turn affects the final grain yield. Therefore, it is imperative to assess the effect of weed management practices with different row spacings on aerobic rice and associated weeds.

Materials and Methods

A field experiment was conducted during *Kharif* season of 2017 in D_2 block at Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar with a view to find out the efficacy of different pre and post-emergence herbicides for controlling the weeds and also their effect on direct (dry) seeded rice in three planting geometries. Three planting geometries (S1-20 cm, S2- 25 cm and S3- 30 cm) in main plots and four weed management practices (W1- Weedy check, W2- Pendimethalin @ 1kg/ha *fb* Penoxsulam @ 22.5 g/ha, W3- Cyhalofop-butyl + Penoxsulam @ 150 g/ha, W4- weed free) in sub plots were studied in a split plot design (SPD), with four replications.
Seeds of "Pant dhan 18" were sown in lines at seed rate of 40 kg/ha with different row spacing of 20cm, 25cm and 30cm apart manually in all plots. Pendimethalin on the next day of

sowing and post emergence herbicides penoxsulam and cyhalofop-butyl at 20 DAS were applied using 500 litres of water by using knapsack sprayer fitted with flat fan nozzle. The plant height was recorded from randomly selected 5 tagged plants from one meter row length marked in each plot at 20, 40, 60, 80 DAS and at maturity of the crop. It was measured from ground level to the tip of the longest leaf or to the tip of panicles after heading with the help of meter scale. The mean height of all five shoots was reported in cm. Total number of shoots was counted from sampling area of one meter row length marked in each plot for observation at 40, 60, 80 and at maturity of the crop. The mean of number of shoots in one meter row length was computed to number of shoots per square metre. All plants falling within the quadrate (50 cm x 50cm) were cut close to the ground surface and air dried first (4-5 days) separately and then dried in a hot air oven maintained at 70ºC±5^{0}C temperature till constant dry weight was attained. It was observed at 20, 40, 60, 80 and at maturity of crop and dry matter of crop was expressed as gram per square metre area. The number of weeds in each plot was counted by using quadrate of 50cm x 50cm from area marked for observation at 20, 40, 60 and 80 DAS and at the maturity of crop. The count of weeds was computed as number of weeds per square metre. All the weed species falling within the quadrate (50 cm x 50cm) were cut close to the ground surface and air dried first (4-5 days) separately and then dried in a hot air oven maintained at 70ºC±5^{0}C temperature till constant dry weight attained. Weed dry matter was observed at 40, 60 and 80 DAS and at the maturity of crop and expressed as gram per square metre area. In weeds nitrogen, phosphorous and potassium content was estimated by modified micro kjeldahl procedure (Jackson, 1973) [1], Vanado-molybdophosphoric yellow colour method (Jackson, 1973) [1] and flame photometry method (Jackson, 1973) [1] respectively. Nutrient removal by weeds was calculated by using the following formula.

Nutrient uptake (kg/ha) = Nutrient content (%) / 100× Dry matter of weeds (kg/ha)

Results and Discussion

Plant height

While considering the plant height (Table 1) of rice crop at various growth stages (20, 40, 60, 80 DAS and at maturity), the different row spacings recorded the non-significant difference in plant height. Numerically the highest plant height was observed under row spacing of 25 cm. Among the herbicidal treatments pendimethalin 1kg /ha *fb* penoxsulam 22.5 g/ha achieved significantly superior height being at par with cyhalofop-butyl + penoxsulam 150 g/ha and with the weed free at 20 DAS. Plant height in the plots pendimethalin 1kg/ha *fb* penoxsulam 22.5 g/ha was statistically at par with the weed free at 40 DAS. While at 80 DAS and maturity, pendimethalin 1kg /ha *fb* penoxsulam 22.5 g/ha recorded the highest plant height which at par with the weed free and with cyhalofop-butyl + penoxsulam (Readymix) 150 g/ha. Plant height in pendimethalin 1kg /ha *fb* penoxsulam 22.5 g/ha applied plots was at par with the weed free at 60 DAS. Significantly lowest plant height was observed under weedy plot as weeds were dominating which competed with the rice crop for natural resources and checked the growth of the crop because of which height was reduced.

Plant density

Number of shoots per square metre (Table 2) enhanced with the advancement of growth up to 80 DAS in all treatments but after 80 DAS, reduction in number of shoots per square metre was observed under different treatments due to the competition. 25 cm row spacing recorded highest number of shoots *fb* 20 cm row spacing which was at par to 30 cm spacing at 40 DAS. Row spacing of (25 cm) recorded highest number of shoots which was at par with (20 cm) row spacing and significantly higher than the (30 cm) row spacing at 60, 80 DAS and at maturity. This result was in accordance with Singh *et al.* (2011) [4]. Under different weed management practices, all the weed control measures significantly influenced the number of shoots at all crop growth stages. Pendimethalin 1kg/ha *fb* Penoxsulam 22.5 g/ha recorded significantly the maximum number of shoots per square metre over all the other treatments at all crop growth stages. Minimum number of shoots recorded in weedy condition. High tillering is not so desirable in DSR aerobic rice because panicle number (m^2) depends largely on the main culm rather than the tillers. Increasing in plant spacing is associated with increase in number of tillers because the plant has more area to draw nutrients required for tiller formation Munyithya *et al*. (2017) [6].

Dry matter accumulation of crop

The dry weight (Table 3) increased with the advancement of crop growth and highest dry weight was obtained at harvest stage. Considering the dry matter accumulation of rice crop at various growth stages (20, 80 DAS and at maturity), the different row spacings recorded the non-significant difference in dry matter accumulation of crop while at 40 and 60 DAS row spacing of 20 cm recorded the maximum dry matter accumulation which was significantly higher with the other two spacings, which were found to be at par with each other.

Irrespective of the weed management practices, crop dry matter production increased with advancement in crop age. All the weed management practices produced significantly higher crop dry matter than weedy check at all stages (20, 40, 60, 80 DAS and at maturity). Crop dry matter accumulation weed free treatment was at par with pendimethalin 1kg/ha *fb* penoxsulam 22.5 g/ha and significantly higher over the other treatments at 20 and 60 DAS, while, at maturity weed free was at par with pendimethalin 1kg ai/ha *fb* penoxsulam 22.5 g/ha and cyhalofop-butyl + penoxsulam (Readymix) 150g/ha. Crop dry matter accumulation with pendimethalin 1kg/ha *fb* penoxsulam 22.5 g/ha being at par with the weed free was significantly higher than the cyhalofop-butyl + penoxsulam (Readymix) 150g/ha at 40 and 80 DAS. The effective weed control due to both pre and post herbicide which controlled weeds at both early and later stage in the treatment resulted in optimum tiller density (m^2), more number of grains/panicle and hence more population of rice in closer spacing which resulted in more total dry matter production **(**Hasanuzzaman *et al*. 2008) [2].

Total weed density

Density of total weed species (Table 4) owing to different row spacing was not significant at (40 and 80 DAS), whereas, total weed density was significantly higher in 30 cm wider row spacing over 20 and 25 cm row spacing at 60 DAS. Numerically, the highest total weed density was recorded in the wider row spacing of 30 cm. Among the various weed management practices, weedy recorded the highest total weed density. The weed density and weed dry matter were significantly higher in non-weeded control treatment as reported by (Prakash *et al.,* 2013). whereas, the cyhalofop-butyl + penoxsulam (Readymix) 150g/ha resulted in significantly higher total weed density than pendimethalin 1kg ai/ha *fb* penoxsulam 22.5 g/ha at 40 DAS, whereas, the herbicidal treatments pendimethalin 1kg/ha *fb* penoxsulam 22.5 g/ha and cyhalofop-butyl + penoxsulam (Readymix) 150 g/ha were found at par with each other in recording the total weed density at 60 DAS and 80 DAS. Total weed density increased up to 60 DAS and declined thereafter. This may be due to coverage of crop canopy at latter stage may smothered weeds.

The total weed density was reduced with crop growth stages also because of the action of different weed management practices follows. Table 4-14 on different weed densities reveal that weed management practices follows in direct seeded rice crop has great influence on reducing their respective densities; hence the total weed density was also recorded lowest in the treatments.

Dry matter of total weed species

Dry matter accumulation of total weeds (Table 5) varied due to different row spacings at 60 DAS. There was no significant effect of row spacing at 40 and 80 DAS. The highest total dry matter accumulation of weeds at 60 DAS was under the spacing of 30cm which was at par with the other two row spacings. Numerically lowest dry matter of total weeds was recorded in the 25 cm row spacing.

Among the herbicidal treatments, pendimethalin 1kg/ha *fb* penoxsulam 22.5 g/ha and cyhalofop-butyl + penoxsulam (Readymix) 150g/ha were found at par with the weed free at 40 and 60 DAS and at 80 DAS. The use of any single strategy cannot provide effective, season-long weed control as different weeds vary in their dormancy and growth habit. So there is a need to integrate different weed management, such as the use of agronomic practices (by altering row spacing followed by the use of pre- and post-emergence herbicides) (Chauhan, 2012) [5].

Nutrient content and uptake by the weeds

Different row spacings of rice had significant effect on nutrients (N, P and K) uptake (Table 6) by weeds at 80 DAS. The highest uptake of nitrogen (11.8kg/ha), phosphorous (2.90 kg/ha) and potassium (22.2 kg/ha) was recorded under the spacing of 30 cm. Nutrient uptake by weeds was the manifestation of weed biomass in the field (Payman and Singh, 2008) [3]. Nutrient uptake (N, P and K) by weeds, a function of dry matter and was recorded to be maximum under the row spacing of 30 cm at 80 DAS accounted to maximum dry matter production by weeds.

Weed management practices also affected nutrient uptake significantly at 80 DAS of crop growth stage. The highest uptake of nitrogen (26.12 kg/ha), phosphorous (5.47 kg/ha) and potassium (52.82 kg/ha) by weeds was recorded in weedy check. Treatment pendimethalin @1kg a.i/ha *fb* penoxsulam @ 22.5 g/ha recorded lowest uptake of nutrients (N, P and K). Weed free treatment resulted significantly lowest nutrient uptake as compared to all other treatments and this was attributed to lesser weed dry matter production. Results clearly showed that major parts of the nutrient are utilized by the weeds which create major competition between crop and weeds.

Table 1: Effect of different row spacing and WMP on plant height (cm) at different stages of crop growth

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Maturity
Row spacing(cm)					
20	23.2	39.0	73.1	90.5	94.1
25	23.5	39.4	76.9	91.7	94.7
30	22.5	38.7	73.6	91.2	94.2
SEm	0.60	1.00	1.57	2.06	2.04
C.D at 5%	NS	NS	NS	NS	NS
Weed management practices					
Weedy	20.3	35.3	65.4	83.9	87.7
Pendimethalin@1kg /ha *fb* Penoxsulam @22.5 g/ha	24.7	40.9	80.9	94.4	96.8
Cyhalofop-butyl + Penoxsulam @ 150g/ha	23.1	38.9	74.0	92.3	94.9
Weed free	24.3	41.3	77.7	94.1	97.9
SEm±	0.65	0.78	1.35	1.35	1.26
CD at 5%	1.90	2.30	4.86	3.95	3.70

Table 2: Effect of different row spacing and WMP on the number of shoots/ m^2) at different stages of crop growth

Treatments	40 DAS	60 DAS	80 DAS	Maturity
Row spacing(cm)				
20	200	228	242	227
25	206	231	243	229
30	196	223	236	223
SEm±	1.51	0.95	0.99	1.43
C.D at 5%	5.35	3.37	3.55	5.04
Weed management practices				
Weedy	99	126	138	125
Pendimethalin@1kg/ha*fb* Penoxsulam @22.5 g/ha	256	283	295	280
Cyhalofop-butyl + Penoxsulam @ 150g/ha	241	270	283	272
Weed free	205	231	245	229
SEm±	2.18	2.19	2.59	2.59
CD at 5%	6.38	6.40	7.58	7.57

Table 3: Effect of different row spacing and WMP on the crop dry matter accumulation (g/ m^2) at different stages of crop growth

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Maturity
Row spacing(cm)					
20	7.71	221	405.69	506.04	550.46
25	7.40	213.72	398.08	503.40	549.13
30	8.83	209.17	396.07	502.40	548.20
SEm±	0.51	1.68	1.84	2.33	2.16
C.D at 5%	NS	5.93	6.50	NS	NS
Weed management practices					
Weedy	5.73	112.77	132.79	157.81	201.93
Pendimethalin@1kg /ha *fb* Penoxsulam @22.5 g/ha	9.02	257.78	492.26	623.04	666.99
Cyhalofop-butyl + Penoxsulam @ 150g/ha	7.39	235.8	480.84	613.47	659.98
Weed free	9.8	252.23	493.9	622.23	668.16
SEm±	0.80	1.71	1.94	2.70	4.33
CD at 5%	2.33	5.00	5.68	7.89	8.60

Table 4: Effect of different row spacing and WMP on the total weed density (No./ m^2) of other weed species at different stages of crop growth

Treatments	40 DAS	60 DAS	80 DAS
Row spacing(cm)			
20	3.28(14.56)	2.79(8.59)	1.76(2.50)
25	3.22(13.25)	2.65(7.65)	1.75(2.42)
30	3.45(15.56)	3.78(17.14)	1.79(2.65)
SEm±	0.21	0.09	0.06
C.D at 5%	NS	0.33	NS
Weed management practices			
Weedy	6.11(36.91)	5.01(25.45)	2.53(5.46)
Pendimethalin@1kg/ha *fb* Penoxsulam @22.5 g/ha	2.52(6.66)	2.98(8.61)	1.65(1.86)
Cyhalofop-butyl + Penoxsulam @ 150g/ha	3.64(14.25)	3.07(9.36)	1.89(2.76)
Weed free	1 (0.00)	1 (0.00)	1 (0.00)
SEm±	0.28	0.25	0.09
CD at 5%	0.82	0.75	0.26

Original values are given in parantheses

Table 5: Effect of different row spacing and WMP on the dry matter (g/ m^2) of total weed species at different stages of crop growth

Treatments	40 DAS	60 DAS	80 DAS
Row spacing(cm)			
20	2.43(6.21)	3.05(10.59)	1.79 (2.61)
25	2.36(7.88)	2.71 (7.67)	1.73 (2.39)
30	2.96(14.54)	3.99 (19.52)	1.86 (3.18)
SEm±	0.27	0.04	0.03
C.D at 5%	NS	0.15	NS
Weed management practices			
Weedy	4.97(29.36)	5.36 (29.34)	2.71 (6.53)
Pendimethalin@1kg /ha *fb* Penoxsulam @22.5 g/ha	2.00(3.49)	3.28 (10.20)	1.60 (1.80)
Cyhalofop-butyl + Penoxsulam @ 150g/ha	2.35(5.33)	3.37 (10.83)	1.86 (2.58)
Weed free	1 (0.00)	1 (0.00)	1 (0.00)
SEm±	0.39	0.05	0.11
CD at 5%	1.13	0.16	0.32

Original values are given in parantheses

Table 6: Effect of treatments on nutrient content and uptake (kg/ha) by weeds at 80 DAS

Treatments	Nitrogen content	Nitrogen	Phosphorous content	Phosphorous	Potash content	Potash
Row spacing(cm)						
20	0.8	9.71	0.1	2.60	0.4	22.1
25	0.8	11.2	0.1	2.22	0.4	21.9
30	0.9	11.8	0.1	2.90	0.4	22.2
SEm±	0.01	1.00	0.009	0.30	0.01	1.96
C.D at 5%	NS	3.47	NS	1.04	NS	6.78
Weed management practices						
Weedy	1.2	26.12	0.3	5.47	0.6	52.82
Pendimethalin@1kg/ha *fb* Penoxsulam @22.5 g/ha	1.1	7.49	0.2	2.22	0.5	14.76
Cyhalofop-butyl + Penoxsulam @ 150g/ha	1.2	10.02	0.2	2.61	0.6	20.89
Weed free	0.00	0.00	0.00	0.00	0.00	0.00
SEm±	0.01	1.26	0.01	0.25	0.01	3.10
CD at 5%	0.04	3.67	0.03	0.76	0.03	9.00

Original values are given in parantheses

Conclusion

On the basis of the present investigation it was concluded that among the three planting geometries, row spacing (25cm) along with sequential application of pre-emergence pendimethalin 1kg/ha *fb* post-emergence application of penoxsulam 22.5g/ha was found most effective in reducing the density as well as dry matter accumulation of weeds. Yield attributing characters was also found maximum with the above treatment.

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