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INFLUENCE OF CROP-WEED COMPETITION PERIOD AND GENOTYPE ON MILLING, GRAIN AND BIO-CHEMICAL CHARACTERISTICS OF DIRECT SEEDED RICE (*Oryza sativa* L.)

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Direct seeded rice (DSR) is fast emerging rice crop establishment method in Asia due to its higher resource efficiency as compared to transplanted rice. It is reported that as compared to puddled transplanted rice (PTR), DSR provides saving of 12-60 per cent of irrigation water, 8-60 per cent in labour, reduction in global warming potential by 32-44 per cent, saving cost of cultivation by INR 6436-7950 ha^{-1} and results in better wheat yield (8-10 per cent more) than PTR (Basavalingaiah *et al*., 2020). High weed pressure prevails under DSR as compared to transplanted rice systems and weeds are the foremost barrier in enhancing the yield and quality of direct seeded rice (Shekhawat *et al*., 2020). Studies by Farooq *et al*. (2011) revealed higher grain length along with better amylose and protein concentration under weed free treatments as compared to weedy treatment. Likewise, Ottis *et al*. (2005) found that red rice due to its competitiveness reduced the milling quality of rice. Genotype is the primary factor affecting the rice nutritional qualities as quality traits are under strong genetic control (Das *et al*., 2020). Present studies were therefore planned with the objective to evaluate the effect of different crop-weed competition periods and genotypes on milling, grain and bio-chemical characteristics of direct seeded rice.

A field experiment was conducted during *kharif* 2020 at the Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana, India [30°56' N latitude; 75°52' E longitude; 247 m altitude]. Climate of experimental site is characterized as subtropical, semi–arid with an annual rainfall of 733 mm, out of which about 80% is received from June to September. Rainfall, maximum and minimum temperatures were measured at agro–meteorological observatory of PAU, Ludhiana situated at 200 m from the experimental site. Rainfall received during the crop growth period was 400.8 mm. During the crop season, maximum temperature varied from 32.6 to 37.6 ^{0}C, minimum temperature from 15.9 to 26.5 ^{0}C. The mean relative humidity during June, July, August, September and October was 51.9%, 70.7%, 74.9%, 70.7% and 57.8%, respectively. The experimental site was sandy–loam in texture, low in available N (265.0 kg ha^{-1}), high in available P (31.9 kg ha^{-1}) but medium in available K (136 kg ha^{-1}) and organic carbon (0.42%). The soil pH and electrical conductivity were within the normal range.

The experiment was laid out in split plot design replicated thrice keeping four crop-weed competition period *viz*; weedy throughout crop growth period (WT), weed free up to 15 days (WF15), weed free up to 30 days (WF30) and weed free throughout (WF-Th) in main plots; and eight genotypes (RYT 4004 (PAU 6456-8-2-1-1-1), RYT 4005 (PAU 6456-8-2-1-1-2), RYT 4079 (PAU 5533-21-1-1-1-1-1-2), RYT 4080 (PAU 6456-8-1-1-1-1), RYT 4081 (PAU 6453-8-2-2-1-1), PR 120, PR 126 and SAVA 134 (Two-line hybrid from Savanah Seeds Pvt. Ltd.) in sub plots.Seeds were sown in proper moisture conditions (locally known as *vattar* DSR method or soil mulch DSR). Pre-sowing irrigation was applied in a well prepared soil followed by shallow tillage when field reached *vattar* (field capacity) condition and then rice sowing was done by *pora* method on June 15, 2020 at row spacing of 20 cm using a seed rate of 20 kg ha^{-1} in plots measuring 12 meter square. Weedy conditions were simulated by sowing of *purple rice* as surrogate weed as suggested by Bastiaans *et al.* (1997). To provide uniform competition in all plots, 100 viable seeds of *purple rice* per square metre area were sown at 0 DAS in case of WT 15 DAS in case of WF15 and 30 DAS in case of WF30 treatment in inter row space. All other weeds were eliminated by frequent hand weeding or hand pulling. Besides, stale seed bed method was adopted to exhaust the weed seed present in the field. After sowing, first post-sowing irrigation was applied 15 days after sowing. Subsequent irrigations were scheduled as per the crop demand at weekly interval. All other production and protection technologies were followed as per recommendations of Punjab Agricultural University. Recommended dose of fertilizer (N @ 150 kg/ha and $ZnSo_4$ Heptahydrate @ 25 kg/ha) was applied to the crop. Nitrogen was applied through urea in three equal splits at 30, 45 and 63 days after sowing (DAS). Whole of $ZnSo_4$ was applied before sowing. Owing to sufficient level of available P and K, these nutrients

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were not applied to the experiments crop.

For calculating 1000 seed weight of paddy, brown rice and milled rice, 100 seeds were counted and weighed from each treatment and multiplied by ten to determine its 1000-grain weight. For assessing milling quality weighed samples (125g) of clean paddy with a moisture content of 13-14%, were dehusked in a Satake Rubber Roll Laboratory Sheller (Satake Engineering Co., Japan) and the shelled rice (brown rice) samples were milled (McGill Miller No.2, USA) and following indices were calculated.

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100$$

$$\text{Milling (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100$$

$$\text{Head rice recovery (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of rough rice}} \times 100$$

$$\text{Head yield (\%)} = \frac{\text{Head rice recovery}}{\text{Milling recovery}} \times 100$$

Length and breadth of grains was measured using vernier caliper in millimeter (mm) and expressed as L/B ratio. The chemical parameters such as amylose content (Juliano, 1971) and total soluble protein content (Lowry *et al.*, 1951) in milled rice were analyzed. Crude protein was analysed by kjeldhal's method (Kjeldahl, 1883) and crude protein yield was calculated by multiplying grain yield with milling (%) and then with crude protein content and expressed in q/ha. Data were subjected to analysis of variance (ANOVA) using statistical software (SAS 9.3.). Treatment means were compared using Tukey's test at $p \le 0.05$.

Data in Table 1 indicated that 1000-grain weight of white rice could not vary significantly due to crop-weed competition periods. But 1000-grain weight of paddy and brown rice were found to be the highest in WF-Th, which was statistically similar to WF15 and WF30, while WT recorded significantly the least value for these parameters. There were also marked differences in 1000-grain weight of different genotypes. It was found that different genotypes recorded 1000-grain weight of paddy, brown rice and white rice in the range of 22.5-27.2 g, 18.6-21.9 g and 17.1-20.4 g, respectively (Table 1). RYT 4004, RYT 4005 and RYT 4080 recorded the highest 1000-grain weight of paddy, brown rice and white rice respectively, which were statistically similar among themselves except for 1000-grain weight of white rice, where significant differences existed with RYT 4005.

Table 1. Effect of crop-weed competition period and genotype on 1000- grain weight, grain length, breadth and length: breadth ratio (L:B) of rice crop

Treatment	1000 grain weight (g)			Grain length (mm)	Grain breadth (mm)	Grain L:B
	Paddy	Brown rice	White rice			
Crop-weed competition period						
Weedy throughout (WT)	23.8	18.0	18.3	6.94	1.82	3.85
Weed free up to 15 days (WF15)	25.1	20.5	18.5	6.96	1.84	3.79
Weed free up to 30 days (WF30)	25.1	20.6	18.5	6.95	1.85	3.79
Weed free throughout (WF-Th)	25.2	20.7	18.6	6.97	1.85	3.78
SEm$\pm$	0.1	0.1	0.1	0.013	0.005	0.014
CD (p = 0.05)	0.3	0.2	NS	NS	0.02	NS
Genotypes						
RYT 4004 (G_1)	27.2	21.7	20.0	6.99	1.96	3.56
RYT 4005 (G_2)	26.8	21.9	19.7	6.83	1.89	3.62
RYT 4079 (G_3)	23.6	18.6	17.4	6.70	1.90	3.53
RYT 4080 (G_4)	26.8	21.7	20.4	7.11	1.99	3.59
RYT 4081 (G_5)	24.5	19.3	17.8	7.22	1.81	4.02
PR 120 (G_6)	24.0	19.1	18.3	7.00	1.80	3.90
PR 126 (G_7)	22.5	18.7	17.1	6.73	1.66	4.11
SAVA 134 (G_8)	22.9	18.7	17.2	7.05	1.72	4.10
SEm$\pm$	0.14	0.12	0.13	0.014	0.012	0.030
CD (p = 0.05)	0.4	0.3	0.4	0.04	0.04	0.08

The least 1000- grain weight of paddy and white rice was found in case of PR 126 while, RYT 4079 recorded the least 1000-grain weight of brown rice. The variation in 1000 grain weight of different genotypes can be ascribed to the genetic constitution of genotypes. None of the interactions were significant. Data also brings out that grain length (L) and length breadth ratio (L:B) was not affected by crop-weed competition period. But grain breadth (B) revealed significant differences due to crop-weed competition period (Table 1), which was higher in all weed free treatments (WF-Th, WF-30 and WF-15) while WT recorded the least grain breadth. Data further indicate significant variation in grain length, breadth and L:B under the influence of genotypes (Table 1). RYT 4081 recorded significantly the highest grain length followed by RYT 4080 followed by SAVA 134 followed by PR 120. The highest grain breadth was noted in RYT 4080, which was statistically similar to RYT 4004 while the higher L:B was recorded under PR 126, which was statistically similar to SAVA 134. The lowest grain breadth was noted in PR 126 while lowest grain length and grain length and breadth ratio was recorded in RYT 4079, which was statistically similar to PR 126 for grain length. Interactive effects were not significant.

Hulling and milling (%) did not vary significantly under the influence of crop-weed competition period. But head rice recovery and head yield were found to be the highest under the treatment of weed free throughout (WF-Th), which was statistically similar to weed free up to 15 days (WF15) and weed free up to 30 days (WF30) while weedy throughout (WT) recorded the least value for these parameters (Table 2). Milling characters also varied due to genotypes. RYT 4080 recorded the highest value for all milling characteristics and was significantly superior over rest of the genotypes. It was further observed that RYT 4081 recorded the lowest values for milling characteristics, but the lowest head yield was noted in case of SAVA 134. The differences in milling characteristics in response to crop-weed competition period can be ascribed to the uneven grain filling due to stress under WT treatment (Mutters and Thompson, 2009). Similarly, genotypic differences for milling characteristics is also reported by Koutroubas *et al*. (2004). All interaction effects were significant

Amylose content is an important factor for predicting processing, cooking and eating characteristics. Amylose and protein are the chemical components which influence the physical characteristics of cooked rice. The data on amylose, crude protein, crude protein yield and total soluble protein content presented in Table 3 revealed significant variation among different treatments. It is evident that the highest amylose content (18.2%) was recorded under WF-Th treatment. Conversely, the highest crude protein and total soluble protein content was recorded in WT treatment. All treatments showed amylose content in the range

Table 2. Effect of crop-weed competition period and genotype on milling characters of rice crop

Treatment	Hulling (%)	Milling (%)	Head rice recovery (%)	Head yield (%)
Crop-weed competition period				
Weedy throughout (WT)	79.9	70.4	54.4	75.7
Weed free up to 15 days (WF15)	79.9	70.5	55.2	78.9
Weed free up to 30 days (WF30)	79.9	70.5	55.5	79.0
Weed free throughout (WF-Th)	80.2	70.6	55.7	79.1
SEm$\pm$	0.19	0.19	0.18	0.20
CD (p = 0.05)	NS	NS	0.6	0.7
Genotypes				
RYT 4004 (G_1)	80.4	72.0	61.0	85.0
RYT 4005 (G_2)	80.4	72.5	60.1	82.9
RYT 4079 (G_3)	79.9	70.4	50.2	72.4
RYT 4080 (G_4)	80.9	72.8	62.9	87.2
RYT 4081 (G_5)	78.1	64.4	46.2	71.6
PR 120 (G_6)	79.5	70.9	56.0	79.3
PR 126 (G_7)	80.2	71.4	55.0	76.7
SAVA 134 (G_8)	80.2	69.7	50.3	70.5
SEm$\pm$	0.15	0.21	0.42	0.24
CD (p = 0.05)	0.4	0.6	1.2	0.7

Table 3. Effect of crop-weed competition period and genotype on amylose and protein content of rice crop

Treatment	Amylose (%)	Total soluble protein (mg/100mg sample)	Crude protein (%)	Crude protein yield (q/ha)
Crop-weed competition period				
Weedy throughout (WT)	16.2	16.23	6.16	1.79
Weed free up to 15 days (WF15)	16.2	14.36	6.07	3.02
Weed free up to 30 days (WF30)	17.2	14.31	5.86	3.22
Weed free throughout (WF-Th)	18.2	14.33	5.94	3.41
SEm±	0.02	0.158	0.027	0.057
CD (p = 0.05)	0.1	0.55	0.08	0.20
Genotypes				
RYT 4004 (G_1)	16.5	14.56	6.23	3.02
RYT 4005 (G_2)	17.3	14.00	5.65	2.48
RYT 4079 (G_3)	15.0	13.86	5.24	1.80
RYT 4080 (G_4)	16.8	13.90	6.56	3.12
RYT 4081 (G_5)	22.8	17.28	5.66	1.59
PR 120 (G_6)	15.7	15.57	6.51	3.56
PR 126 (G_7)	15.0	14.19	6.36	3.40
SAVA 134 (G_8)	16.2	15.13	5.85	3.94
SEm±	0.07	0.166	0.087	0.073
CD (p = 0.05)	0.2	0.47	0.25	0.21

16.2-18.2, crude protein content between 5.86-6.16% and total soluble protein content between 14.31-16.23 mg/100 mg sample. The lowest amylose content was recorded in WT and WF15. However, the lowest crude protein and total soluble protein content was recorded in WF30. The higher values of protein content in WT conditions can be explained in light of the inverse yield nitrogen law, which states that the power of growth or yielding ability of any crop is inversely proportional to the mean nitrogen content in dry matter (Wilcox, 1929). The grain and biological yield under this treatment was the least (data not presented). The highest crude protein yield was recorded under WF-Th which was statistically similar to WF30 treatment. However, WT recorded the least crude protein yield. Genotypic variation was also observed for amylose, crude protein and total soluble protein content (Table 4). The highest amylose and total soluble protein content were found in RYT 4081, whereas, RYT 4080 recorded the highest crude protein content, which was statistically similar to PR 126 and PR 120. But the lowest values for amylose content, crude protein content and total soluble protein content was noted in RYT 4079, which was statistically similar to PR 126 in case of amylose content. Crude protein yield was recorded to be significantly the highest in SAVA 134 than rest of the genotypes. However, the least crude protein yield was recorded under RYT 4081, which was statistically similar to RYT 4079. Grain quality attributes have been reported to vary among varieties and production environments (Fan *et al*., 1999). None of the interactions were significant

It can be concluded that keeping the direct seeded rice crop weed free up to 30 days resulted in higher head rice recovery, head yield, grain breadth and amylose content. Although crude protein and total soluble protein content was the highest in weedy treatment, but crude protein yield was the highest in weed free treatment on account of higher yield. Among genotypes, RYT 4080, RYT 4004 and RYT 4005 were found superior w.r.t. grain and milling quality characteristics but the highest amylose and total soluble protein content was recorded in RYT 4081. PR 126, PR 120 and RYT 4080 were found superior w.r.t. crude protein content.

Authors' contribution

Conceptualization and designing of the research work (BSD,TB); Execution of field/lab experiments and data collection (TB,BSD); Analysis of data and interpretation (TB,NS, BSD); Preparation of manuscript (TB,BSD,NS).

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