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Chemical composition, milling and cooking quality of mechanically transplanted rice in relation to seedling age and plant population

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ABSTRACT

New ways of rice growing like direct seeding, bed planting and mechanical transplanting are being advocated to reduce fuel and labour costs and increase profitability. Little information is available on how these practices affect grain quality of rice, the latter one in particular. Different parameters associated with grain quality (nitrogen, protein, amylose, amylopectin content, milling and cooking quality) of rice transplanted mechanically with Japanese transplanter by using seedlings (rice cv. PR-115) of different age (3, 4 and 5 weeks old) and at different plant population levels (21, 24 and 28 plants m^{-2}) were studied. The nitrogen content in grains decreased significantly with increasing age of seedlings and decreasing plant population levels, which led to the corresponding decline in the protein content in the grains. Similar trend was noticed for amylose content; however, it was opposite in case of amylopectin. Non-significant differences in milling quality (brown rice, white rice, head rice and broken grains) were observed in seedlings of different age and plant population levels tested. Cooking time showed positive correlation with protein content (At p d" 5, r = 0.97 and 0.99 for age of seedlings in 2010 and 2011, respectively and 0.99 for plant population levels in both the years). The length: breadth ratio of cooked rice and cooking co-efficient increased with seedling age and plant population levels.

Key words: *mechanically transplanted rice, protein, milling, cooking, quality*

Manual transplanting of paddy seedlings is the common method of crop establishment in irrigated rice systems of Asia, but it is labour intensive (30 person ha^{-1} day^{-1}) process. Agriculture in Indian Punjab is highly dependent on the migrant labourers. The availability of labour for rice transplanting has reduced over the years which results in delay in transplanting and consequently reduced yield. Mechanical transplanting is the most viable option in these situations as it results in 66 per cent saving of cost over the manual transplanting and requires only 7 per cent of time for transplanting as compared to the manual transplanting (Sharma *et. al.,* 2002). Numerous studies have been conducted to compare the grain yield and to determine the physiological and morphological traits that explain their yield differences in context to age of seedlings and plant population in mechanically transplanted rice (Kim *et. al.,* 1999; Shen *et. al.,* 2006; Peng *et. al.,* 2006; Yuan *et. al.,* 2007). However, there is no information available on the effect of age of seedlings and plant population on milling, physico-chemical and cooking characteristics of mechanically transplanted rice. This information is of paramount importance while shifting from traditional manual transplanting to mechanical transplanting, so the present study was undertaken.

MATERIALS AND METHODS

The field experiment was conducted at Student's Research Farm, Punjab Agricultural University (PAU), Ludhiana, during wet season of 2010 and 2011 (May-October). The site (30^o 56' N, 72^o 52' E) is 247 m above sea level and is a part of the Indo-Gangetic plains. The climate is characterized by hot summers and very cold winters. The soil of the experimental site is loamy sand in texture with normal soil reaction (pH 8.0) and electrical conductivity (0.21 dS m^{-1}), medium in organic carbon (0.43 %), available N (341.2 kg ha^{-1}), P (18.5 kg ha^{-1}) and K (230.0 kg ha^{-1}). The total precipitation in the growing season was 651.8 mm and 1190.2 mm in 2010 and 2011, respectively.

Three , four and five week old seedlings of the rice cv. PR 115 were evaluated at three plant population levels *viz*. 28 plants m^{-2} (D_1 : 30 cm × 12 cm), 24 plants m^{-2} (D_2 : 30 cm × 14 cm) and 21 plants m^{-2} (D_3 : 30 cm × 16 cm) in a factorial randomized block design with four replications. PR 115 is characterised by short stature (about 100 cm), stiff straw with maturity period of 125 days. The mat type nursery was raised in the appropriate frames of size 58 cm × 28 cm × 2 cm. The sowing of nursery was done on 13th, 20th and 27th May in 2010 and on 16th, 23rd and 30th May in 2011 to have seedlings of age 3, 4 and 5 weeks old respectively, at the time of transplanting. The crop was transplanted on 17th June 2010 and 21st June 2011 by the Japanese mechanical transplanter in puddle plots at spicing as per the treatment.

A total of 30 kg P_2O_5 ha^{-1} through single super phosphate, 30 kg K_2O ha^{-1} through muriate of potash and 62.5 kg ha^{-1} zinc sulphate tetrahydrate were applied before the last puddling. Apart from this, 125 kg N ha^{-1} in the form of urea was applied in three equal splits after one week, three weeks and six weeks from the date of transplanting, respectively. All other production and protection technologies were followed as per the recommendations of PAU, Ludhiana. Harvesting was done on 7th October in 2010 and 8th October in 2011.

Around 1000 g grains were obtained for quality evaluation from each plot and stored at room temperature for 3 months to ensure stable grain quality (Perez *et. al.*, 1996). It is reported that 3-4 months aged milled rice has higher volume expansion and water absorption and less dissolved solids on cooking, and the cooked grain is more flaky (Villarial *et. al.*, 1976). Paddy samples (100 g, moisture content 13.5 – 14.5 %) were shelled in the laboratory sheller (Satake Rice Sheller, Satake Engg. Co. Japan) equipped with rubber rolls. Brown rice samples were milled (polished) in Mc Gill Miller No. 2 (U.S.A.) to remove the bran layer. Grain length, grain breadth, L/B ratio, hulling percentage, milling percentage, water uptake, volume expansion ratio and kernel elongation ratio were determined as per Shouichi *et al*., 1976. Protein and amylose content of rice was determined in laboratory with Zx 800 Near Infrared Grain Analyzer (Zeltex Inc.). Amylopectin content in rice grains was determined as per Low (1994). The cooking time, water absortption ratio and grain elongation ratio were calculated as per the methodology given by Juliana and Bechtel (1985).

To test the significance of results and draw valid conclusions, the data collected on various parameters under study were subjected to statistical analysis as per procedure given by Cochran and Cox (1967) and adapted by Cheema and Singh (1991). All the comparisons were made at 5 per cent level of significance.

RESULTS AND DISCUSSION

The data recorded on nitrogen concentration in the paddy grains revealed that nitrogen concentration in grain decreased with the increase in seedling age from 3 weeks to 5 weeks (Fig. 1a and 1b). During 2010, highest nitrogen content was recorded with 3 weeks-old seedlings which were 4.10 and 7.63 per cent higher than 4 week-old and 5 week-old seedling, respectively. Similar results were recorded during 2011, where 3 weeks-old seedlings recorded 4.07 and 7.56 per cent higher nitrogen content in paddy grains than 4 weeks-old and 5 weeks-old seedling, respectively. The higher N content in grains of 3 weeks-old seedlings might be attributed to the significantly longer crop duration as compared to 4 weeks-old and 5 weeks-old seedling (data not shown). Nitrogen content in paddy grains increased significantly with increasing planting densities (Fig. 1c and 1d). During 2010, planting density of 28 plants m^{-2} recorded highest nitrogen content in paddy grains which was 4.96 and 7.63 per cent higher than wider planting densities of 24 plants m^{-2} and 21 plants m^{-2}, respectively. Corresponding increase in 2011 was 3.32 and 6.72 per cent, respectively. It could be attributed to the significantly lower weed dry matter in closest planting density of 28 plants m^{-2} (data not shown) over the wider planting densities which might have resulted in more nutrient absorption by the crop.

The highest protein content (7.89 % in 2010, 8.22 % in 2011) was recorded in the milled grains of crop planted with 3 weeks-old seedlings (Fig 1a and 1b). It declined progressively with the increasing age of seedlings. Plant population had significant influence on the protein content in the milled rice (Fig. 1c and 1d). During 2010, highest protein content was recorded in milled rice of 28 plants m^{-2} (8.11 %) which was significantly higher than that in 24 plants m^{-2} (7.67 %)

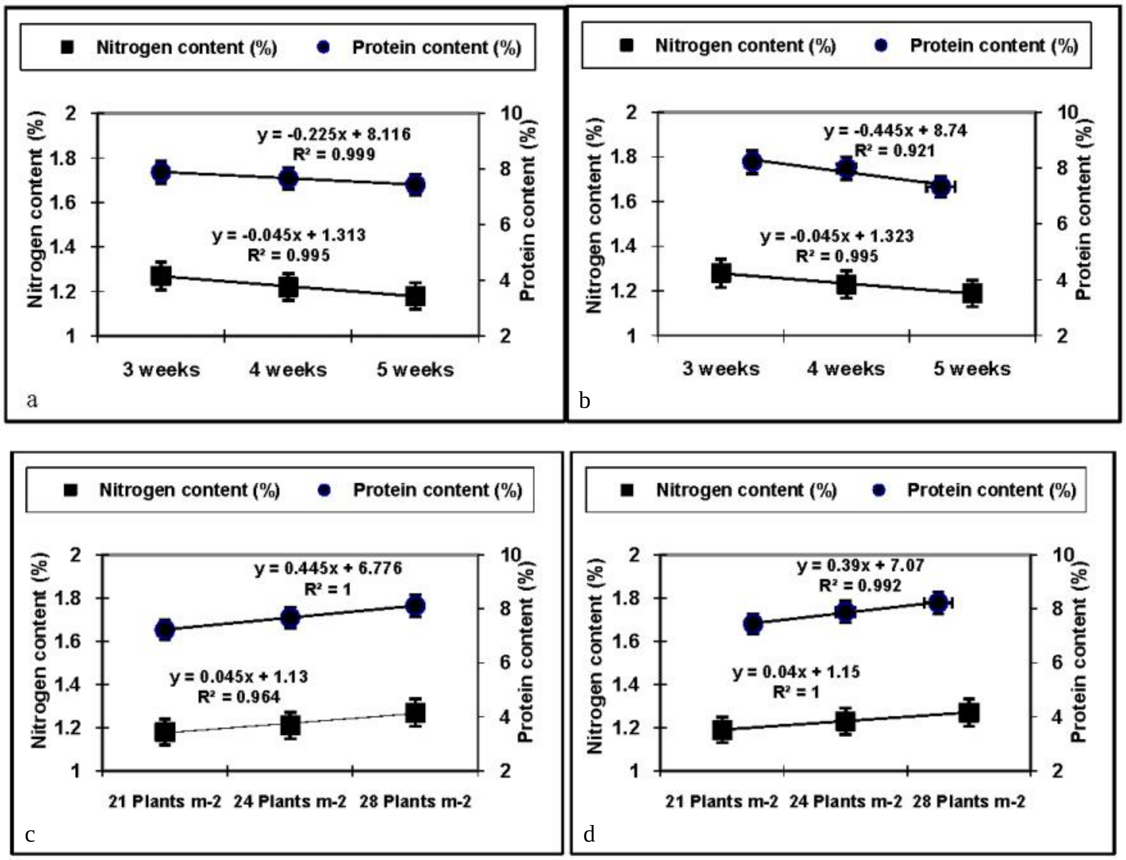

Fig. 1. Relationship of nitrogen content and protein content in grain for different age of seedlings and plant population in 2010 (a and c) and 2011 (b and d). Error bars represent standard error of mean.

and 21 plants m^{-2} (7.22 %). Similar results were also recorded during 2011, where, planting density of 28 plants m^{-2} resulted in 0.33 and 0.78 per cent higher protein content than that in 24 plants m^{-2} and 21 plants m^{-2}, respectively. The nitrogen content in grains had a direct bearing on the protein content in the grains. The increase in nitrogen content in grains with decrease in seedling age and plant population resulted in significant improvement in protein content in grains (Fig. 1c and 1d). These results are supported by Xu *et. al.* (2008) who reported that increasing planting density from 24 plants to 36 plants m^{-2} increased the protein content in grains.

Many of the cooking and eating characteristics of the milled rice are influenced by amylose content in the grains. Amylose is the linear fraction of the starch and correlates negatively with taste panel scores for cohesiveness, tenderness, colour and gloss of the boiled rice. It is evident from the results (Table 1) that during 2010, 3 weeks-old seedlings showed highest amylose content (16.15 %) which was statistically at par with 4 weeks-old seedlings (16.08 %) however, both 3 and 4 weeks-old seedlings had significantly higher amylose content than 5 weeks-old seedlings (14.84 %), respectively. Similar results were observed in the second year where 3 and 4 weeks-old seedlings produced 1.16 and 1.06 per cent higher amylose content than 5 weeks-old seedlings. The amylose content increased significantly with the successive increase in the planting density from 21 plants m^{-2} to 28 plants m^{-2} (Table 1). During 2010, plant population of 28 plants m^{-2} showed 3.37 and 7.75 per cent higher amylose content than plant population of 24 plants m^{-2} and 21 plants m^{-2}, respectively, while during 2011, the corresponding increase was 3.33 and 6.68 per cent, respectively.

Amylopectin content is also an important component of milled rice which governs its cooking and eating quality. The amylopectin content was highest in

Table 1. Amylose content, amylopectin content and milling quality in milled rice as influenced by age of seedlings and planting densities

Treatment	Amylose content (%)		Amylopectin content (%)		Brown rice(%)		White rice(%)		Head rice(%)	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Age of seedling (weeks)										
3	16.15	16.36	60.46	60.08	79.80	78.72	68.05	65.68	56.43	53.86
4	16.08	16.26	61.05	61.02	79.90	80.42	68.75	68.08	56.42	55.21
5	14.84	15.20	62.21	61.96	78.77	79.20	68.47	67.40	56.33	54.83
CD (p=0.05)	0.36	0.30	0.35	0.75	NS	NS	NS	NS	NS	NS
Planting density										
30 cm × 12 cm	16.26	16.46	60.33	60.15	79.58	79.12	67.35	66.81	55.32	54.58
30 cm × 14 cm	15.73	15.93	61.21	60.93	79.78	79.90	69.18	67.78	57.11	55.26
30 cm × 16 cm	15.09	15.43	62.18	61.97	79.10	79.32	68.74	66.57	56.76	54.07
CD (P<0.05)	0.36	0.30	0.35	0.75	NS	NS	NS	NS	NS	NS

the milled grains of 5 weeks-old seedlings and was significantly higher than 3 and 4 weeks-old seedlings (Table 1). Amylopectin content was reduced significantly with increasing planting densities (Table 1). Milled rice quality is directly related to the price of the rice in the market (Conway *et. al.*, 1991). The seedling age and planting density did not affect brown rice yield, white rice yield, head rice recovery and broken grains (Table 1). These results are in conformity with the findings of Xu *et. al.* (2008) who also observed that planting density of rice had no effect on the white rice yield.

The age of seedlings and planting densities showed significant influence on the minimum cooking time of milled rice (Table 2). The milled rice produced in 3 weeks-old seedlings took highest minimum cooking time and it was statistically at par with 4 weeks-old seedlings. However, it was significantly higher than 5 weeks-old seedlings. Further, the milled rice produced in planting density of 28 plants m^{-2} took significantly higher minimum cooking time as compared to those of wider planting densities of 21 and 24 plants m^{-2} (Table 2). The increase in minimum cooking time of grains produced from the crop of 3 weeks-old seedlings as well as planting density of 28 plants m^{-2} might be due to the higher protein content (Fig 1c and 1d) in the grains. Proteins being harder in nature provide hardness to grain (Leesawatwong *et. al.*, 2005), therefore, harder

Table 2. Cooking quality of mechanically transplanted rice as influenced by age of seedlings and planting densities

Treatment	Minimum cooking time (minutes and seconds)		L:B ratio of cooked milled rice		Elongation ratio		Water absorption ratio		Cooking co-efficient	
	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
Age of seedlings (week)										
3	15.17	15.24	3.20	3.25	1.26	1.26	2.56	2.49	3.13	3.25
4	15.04	15.13	3.24	3.33	1.33	1.36	2.58	2.54	3.54	3.68
5	14.25	14.42	3.31	3.41	1.36	1.37	2.59	2.62	3.65	3.80
CD (p=0.05)	0.25	0.28	0.08	0.09	NS	NS	NS	NS	0.19	0.21
Planting density										
30 cm × 12 cm	15.42	15.41	3.07	3.23	1.25	1.27	2.45	2.43	3.29	3.42
30 cm × 14 cm	15.00	15.07	3.26	3.33	1.29	1.31	2.56	2.55	3.33	3.45
30 cm × 16 cm	14.04	14.32	3.42	3.44	1.40	1.40	2.72	2.68	3.71	3.89
CD (P<0.05)	0.25	0.28	0.08	0.09	0.12	0.10	0.14	0.13	0.19	0.21

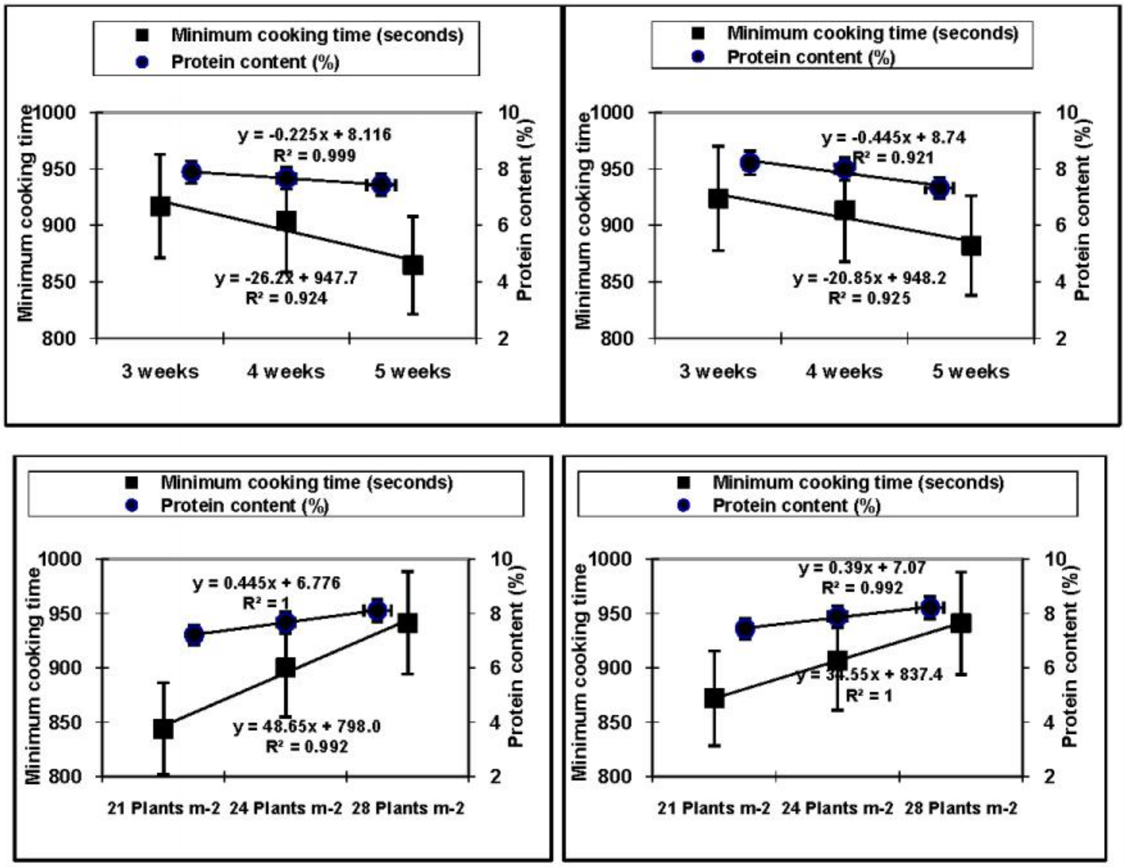

Fig. 2. Relationship of protein content and minimum cooking time of grains for different age of seedlings and plant population in 2010 (a and c) and 2011 (b and d). Error bars represent standard error of mean.

grains might have taken more time for cooking. Cooking time showed positive correlation with protein content (r = 0.97 & 0.99 and 0.99 in 2010 and 2011, respectively.

The results revealed that L:B ratio varied significantly due to different age of seedlings (Table 2). Highest L:B ratio was obtained with 5 weeks-old seedlings which was statistically at par with 4 weeks-old seedlings but significantly higher than 3 weeks-old seedlings. Further, mechanical transplanting at 21 plants m^{-2} resulted in highest L:B ratio. The L:B ratio decreased significantly with successive increase in the planting densities. The elongation ratio was statistically at par in mechanical transplanting of different age of seedlings (Table 2). The data further revealed that the lowest elongation was noticed in mechanical transplanting at 28 plants m^{-2}. It was statistically at par with 24 plants m^{-2} but significantly lower than 21 plants m^{-2}.

The seedling age had non-significant differences for water absorption ratio however, it was reduced significantly with each successive increase in planting density from 21 to 28 plants m^{-2} (Table 2). This might be attributed to higher carbohydrate content in milled rice of 21 plants m^{-2} which get gelatinised during cooking are responsible for higher water absorption during cooking. The cooking co-efficient was highest in 5 weeks-old seedlings which was statistically at par with that in 4 weeks-old seedlings but significantly higher over 3 weeks-old seedlings. The closest planting density of 28 plants m^{-2} recorded lowest cooking co-efficient and it increased with decreasing planting densities.

It can be concluded that although the results indicated statistical differences for some quality parameters due to variation in age of seedlings and plant population levels, the differences were small enough that they are unlikely to have a major impact on processing quality of rice grains, if co-mingled.

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