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EVALUATING THE ROLE OF SEED PRIMING IN IMPROVING THE PERFORMANCE OF NURSERY SEEDLINGS FOR SYSTEM OF RICE INTENSIFICATION

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There is a dire need to explore the potential of seed priming in different aged rice nursery seedlings under system of rice intensification. The field experiment was executed to evaluate the role of seed priming in improving the performance of nursery seedlings for system of rice intensification during the 2nd week of June, 2010 and 2011 at Agronomic Research Area, University of Agriculture, Faisalabad, Pakistan. The experiment was laid out into randomized complete block design with split split plot arrangement having three replications. The experimental treatments were comprised of two rice varieties (Super Basmati and Shaheen Basmati), three seedling ages (2, 3 and 4 weeks old) and seed priming (non-primed seeds; control and primed with 1.5% solution of $CaCl_2$). The results showed that rice cultivars, seedling age and seed priming significantly improved the leaf area index, crop growth rate, leaf area duration and net assimilation rate during both the years. Two weeks old seedlings performed better than 3 and 4 weeks old seedling by improving tiller production, kernels per panicle, 1000 grain weight, kernel yield, straw yield and harvest index. Two weeks old seedlings raised from seeds osmoprimed with $CaCl_2$ improved kernel quality and remained best by giving higher net benefits (Rs. 136124 & 144933) and marginal rate of return (35 & 39) during the year 2010 and 2011.
Keywords: SRI, intensification, $CaCl_2$, seedling age, oryza sativa

INTRODUCTION

Rice is the most important cereal crop and around 3 billion people, half of the world's population, depend on rice for survival (Khush, 2004). More than 90% of the rice in the world is grown in Asia (FAO, 2009) which accounts for 35-75% of total calorie intake (Khush, 2004). Rice ranks as second after wheat among the most staple food grain crops in Pakistan. The geographical area of Pakistan is 79.61 million hectares and its total cropped area is 22.51 million hectares (Govt. of Pakistan, 2005). Rice sowing area is estimated as 2.79 million hectares with production of 6.80 million tons during the year 2012-13 in Pakistan. Rice accounts 3.1% of the value added in agriculture and 0.7% of the GDP (Govt. of Pakistan, 2014). The total quantity of rice (rice milled equivalent) exported was 3.41 million tons and the export value was 2.06 billion US dollars during the year 2011 (FAO, 2013).
Rice is an excellent food source as it has been found easy in digestion and has high nutritional contents. The energy needs obtained from rice accounts 80% for more than 2 billion peoples in Asia as it contains 80% starchy carbohydrate, 7 to 8 % protein contents, 3% fat, and 3% fiber (Juliano, 1985). Until recently, rice was considered only a starchy food with abundant quantity of carbohydrates and some amount of protein (Umadevi *et al*., 2012). Though rice contains small amounts of protein even then it is of high nutritional value (Chaudhary and Tran, 2001). A campaign organized by FAO under the motto "Rice is Life" reveals the importance of rice as primary source of food and it focus on an understanding that rice based systems are necessary for food security, poverty alleviation and better livelihoods.
The system of rice intensification (SRI) originated from the uplands of Madagascar during 1980s and the originator was a French Priest Henri de Laulanie. Initially this system has faced many controversies ever since the effectiveness of its methods was confirmed in China and Indonesia seven years ago (Wang *et al*., 2002; Gani *et al*., 2002). It is not necessary that rice produces more under flooded conditions (Hatta, 1967). Other studies which have been conducted to evaluate the manipulation of depth and interval of irrigation has shown that rice does not necessarily need a continuously submerged conditions for high yields (Guerra *et al*., 1998).
System of rice intensification has been supported as a set of agronomic management practices for the cultivation of rice from more than a decade as that it offers high yield (Namara *et al*., 2008; Zhao *et al*., 2009), decreases the irrigation requirements (Satyanarayana *et al*., 2007), enhances the productivity of inputs (Sinha and Talati, 2007), is handy for smallholders (Stoop *et al*., 2002). In case of SRI intermittent irrigation is carried out to keep the soil just moist or saturated while organic matter application is carried out rather using inorganic fertilizers which reflects SRI is more favorable for the environment (Uphoff, 2003).

Seed priming is a technique in which seeds are soaked partially in water or salt solution to initiate metabolic processes related its germination before radical emergence (Bradford, 1986). Seed priming usually increases rate of germination. During imbibitions these alterations in seed physiology greatly contribute towards the metabolic repair (Burgass and Powell, 1984; Bray et al., 1989), a buildup of metabolites that promotes germination (Farooq et al., 2006a) and osmotic adjustment (Bradford, 1986). In addition seed priming has been reported to enhance seedling establishment, allometry and yield under field sown rice (Farooq et al. 2006b).

Seed priming with $CaCl_2$ has shown promising results in improving the stand establishment, growth and yield of rice (Farooq *et al*., 2005 & 2006 a,b). Much of the work has been carried out for evaluating the role of osmopriming under direct seeding and transplanting technique for rice cultivation. However, less attention has been given to explore the performance of rice cultivars under SRI management practices when osmoprimed with $CaCl_2$. The objective of the current study was to evaluate the performance of different aged nursery seedlings of rice cultivars when osmoprimed with $CaCl_2$ using two fine rice cultivars under SRI.

MATERIALS AND METHODS

General experimental details: The field experiment was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (30.35-31.47° N & 72.08-73.40° E), Pakistan, during the year 2010 and 2011, respectively. The experimental soil was sandy loam having pH (8.3 & 8.6), electrical conductivity (0.37 & 0.33 dS m^{-1}) and organic matter (0.87 & 0.83%) during the year 2010 and 2011, respectively.

Meteorological data were collected from the Department of Crop Physiology (agro meteorological cell) University of Agriculture, Faisalabad, Pakistan. The average minimum and maximum air temperature during the entire crop season was 22.5 ℃ and 34.2 ℃, respectively and total precipitation 591.9 mm, with most of the rain during July and August in year 2010. However, in the year 2011, the average minimum and maximum air temperature during the crop season was 17.0 ℃ and 29.7 ℃, respectively and total precipitation was 507 mm, with most of the rain during the months of July, August and September during the same year.

Experimental design and treatments: The experiment was executed in randomized complete block design with split split plot arrangement and experimental units were repeated three times. Net plot size was 3m x 6m. The treatments include two rice cultivars (Main plots) viz. Super Basmati and Shaheen Basmati, three seedling ages viz. 2, 3 and 4 weeks old in sub plots and osmopriming with $CaCl_2$ (1.5% slon.) with untreated seeds used as control in sub sub plots. Seed were osmoprimed with $CaCl_2$ (1.5 % soln.) for 46 hours and then primed seeds were subjected to drying with forced air before sowing. For seed priming the ratio of seed weight to solution volume was 1:5 (Farooq et al., 2006c).

Land preparation and fertilizer application: Wetland preparation method was adopted where three cultivations were carried out followed by two plankings to achieve the desirable soil structure. Fully decomposed farmyard manure (5 t ha^{-1}) was applied after completion of puddling, leveling and draining off excess water. Chemical fertilizer was applied to provide 75 kg N, 45 kg P and 35 kg K and 10 kg Zn ha^{-1} in the form of Urea (46%), single super phosphate (18% P_2O_5), sulphate of potash (50% K_20) and zinc sulphate (35% Zn). All the P, K, Zn and half of the N was applied at the final land preparation time as basal dose. The rest of the N was applied in two equal splits each at tillering and panicle initiation stage.

Seedling transplantation and irrigation: Nursery seedlings were transplanted in a wider square pattern of 30cm x 30cm by keeping the transplanting time same for all the seedling age. Single seedling per hill was transplanted. The field was irrigated by applying alternate wetting and drying (AWD) with the interval of 6-7 days for each.

Crop growth and development: Leaf area was measured with the help of leaf area meter (Licor, Model 3100). Leaf area index was calculated as the ratio of leaf area to land area (Watson, 1947). Leaf area duration, crop growth rate and net assimilation rate were determined by using the formulas given by Hunt (1978).

Phenology, growth and yield components : Emergence to heading and heading to maturity was recorded by counting the number of days taken from emergence to 50% heading and heading to maturity. All the other growth and yield contributing attributes were recorded by using the standard agronomic methods.

Kernel quality attributes: Protein contents were determined by Micro-Kjeldahl digestion and ammonia distillation. Amylose contents were determined by following the procedure reported by Juliano (1971). Kernel water absorption ratio was measured as a ratio of cooked rice to raw rice according to the formulae reported by Juliano et al. (1965). Chlorophyll contents were determined according to the methodology described by Yoshida et al. (1976).

Statistical analysis: Data collected were subjected to statistical analysis by using Fisher's analysis of variance technique and treatments' means were compared by using least significant difference (LSD) test at 5% probability level (Steel et al., 1997). The data was taken in two consecutive years and means of years were pooled as year effect was not significant. Economic analysis was carried out by using the MSTATC ECON menu which utilizes the methodology suggested by CIMMYT (1988).

RESULTS AND DISCUSSION

Allometry and crop growth: Among seedling age and osmopriming, maximum leaf area was recorded in 2 weeks old seedlings of both the cultivars osmoprimed with $CaCl_2$ in both years. However, the least leaf area index was recorded in non-primed 4 weeks old seedling of both the cultivars during both the years (Fig. 1 a,b). Among seedling age higher leaf area duration was recorded in 2 weeks old seedlings than that of 3 and 4 weeks old seedlings in both the cultivars during the year 2010 (Fig. 3 a) and similar trend was also recorded during the year 2011 (Fig. 3 b). For interaction of seedling age with osmopriming indicated that higher crop growth rate was recorded in 2 weeks old seedling osmoprimed with $CaCl_2$ in both cultivars during the year 2010 (Fig. 2 a) and similar trend was also recorded during the year 2011 (Fig. 2 b).

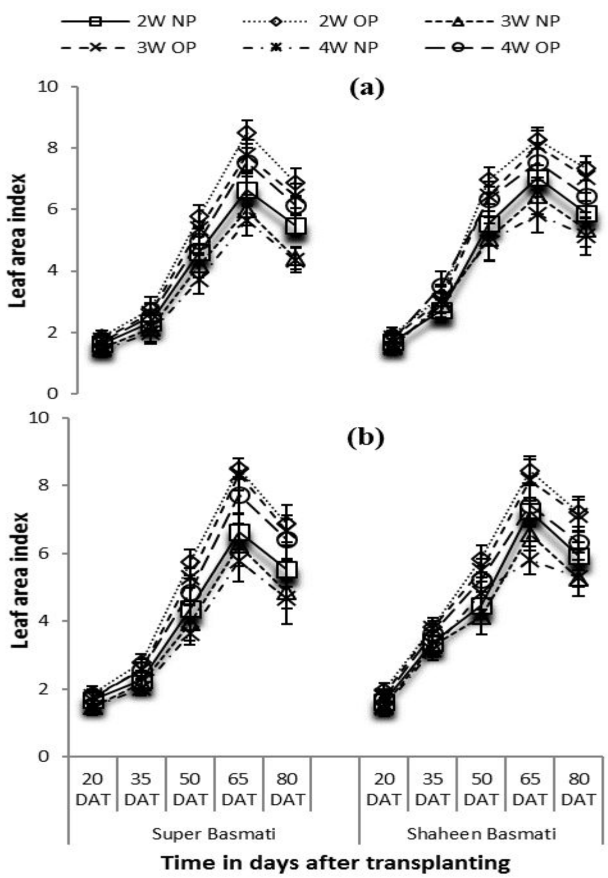

Figure 1. Influence of seedling age and osmopriming on leaf area index of fine rice cultivars during the year (a) 2010 (b) 2011. W = weeks old seedlings, NP = non primed, OP = osmoprimed with $CaCl_2$

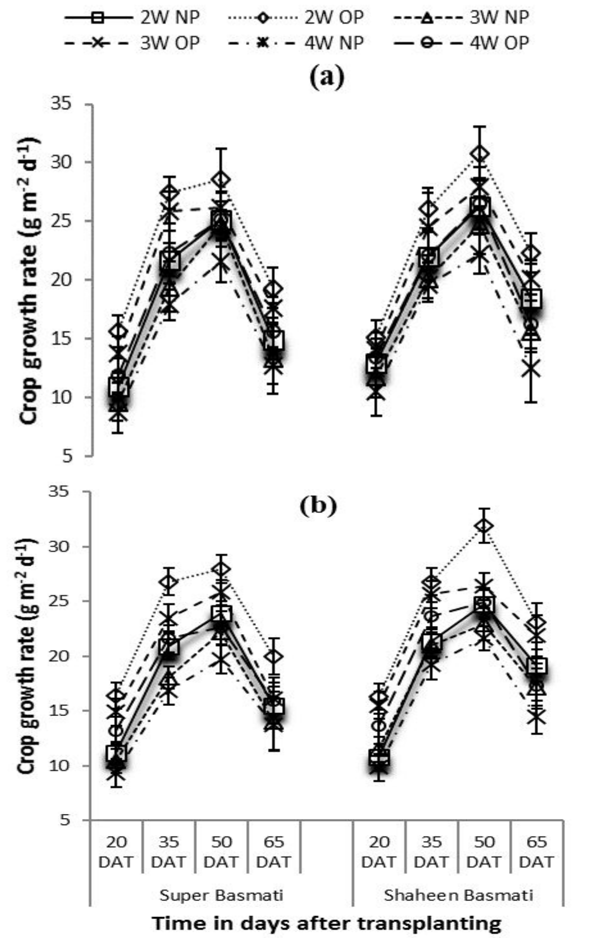

Figure 2. Influence of seedling age and osmopriming on crop growth rate of fine rice cultivars during the year (a) 2010 (b) 2011. W = weeks old seedlings, NP = non primed, OP = osmoprimed with $CaCl_2$

A decreasing trend was recorded with increase in seedling age in both cultivars for net assimilation rate during both years. The least net assimilation rate was recorded in untreated seeds of 4 weeks old seedlings in both cultivars during both years (Fig. 1 a,b). Improvement in growth rate in younger seedlings seems to be the result of accelerated growth due to increased tillering and shortened phyllochron (Nemato et al., 1995) than that of older seedlings of 3 and 4 weeks. The younger seedlings retrieved earlier and faced less effect of transplanting shock (Stoop et al., 2002) than that of older seedlings and this might have resulted in improved growth rate, leaf area index and net assimilation rate. Improvement in allometry and crop growth rate due to osmopriming with $CaCl_2$ seems to be the result of earlier and uniform seedling stand establishment that gave a healthier and energetic start (Farooq et al., 2006a).

Table 1. Influence of seedling age and osmopriming on phenology, tiller production, kernels per panicle, yield and yield contributing attributes of fine rice cultivars grown under system of rice intensification

	Pooled means of year 2010 and 2011									
	Super Basmati		Shaheen Basmati		Means	Super Basmati		Shaheen Basmati		Means
	NP	OP	NP	OP		NP	OP	NP	OP	
Seedling age	**Days to heading**					**Heading to maturity (days)**				
2 weeks old seedlings	84	81	71	59	73.9 C	37	34	24	28	30.75
3 weeks old seedlings	93	87	78	64	80.9 B	38	32	23	29	30.83
4 weeks old seedlings	99	86	81	69	84.2 A	37	34	24	28	31.00
Means	92.44A	85.00 B	76.89 C	64.33 D		37.67 A	33.44 B	24.00 D	28.33 C	
	LSD_{PYM} (A) = 3.03, LSD_{PYM} (V × P) = 3.26					LSD_{PYM} (V × P) = 1.88				
	Plant height at maturity (cm)					**No. of kernels per panicle**				
2 weeks old seedlings	122	120	145	152	137 A	84	88	102	115	98 A
3 weeks old seedlings	119	125	141	145	133 AB	79	83	109	118	98 A
4 weeks old seedlings	116	123	137	142	130 B	77	81	98	103	90 B
Means	122 B		144 A			80 D	84 C	103 B	113 A	
	LSD_{PYM} (A) = 4.60					LSD_{PYM} (A) = 2.96, LSD_{PYM} (V × P) = 2.77				
	Productive tillers (m^2)					**Unproductive tillers (m^2)**				
2 weeks old seedlings	425	477	430	479	453 A	106	91	103	82	96 C
3 weeks old seedlings	363	413	368	389	384 B	126	106	119	101	113 B
4 weeks old seedlings	360	406	351	401	380 B	137	127	126	116	127 A
Means	383 C	432 A	383 C	423 B		120 A		104 B		
	LSD_{PYM} (A) = 4.22, LSD_{PYM} (V × P) = 5.49					LSD_{PYM} (A) = 11.5, LSD_{PYM} (P) = 8.57				
	1000 kernel weight (g)					**Kernel yield (t ha^{-1})**				
2 weeks old seedlings	15.8	18.9	19.2	22.2	19.0 A	4.18	4.49	4.44	4.78	4.46 A
3 weeks old seedlings	15.2	16.2	17.7	21.2	17.6 B	3.86	4.08	3.94	4.21	4.00 B
4 weeks old seedlings	14.7	15.1	17	19.9	16.7 B	3.40	3.60	3.79	4.08	3.70 C
Means	15.3 D	16.7 C	17.9 B	21.1 A		3.94 B		4.21 A		
	LSD_{PYM} (A) = 1.17, LSD_{PYM} (V × P) = 1.0					LSD_{PYM} (A) = 0.05, LSD_{PYM} (V) = 0.18				
	Straw yield (t ha^{-1})					**Harvest index (%)**				
2 weeks old seedlings	13.7	13.9	13.6	14.0	13.8 A	30.4	31.8	32.6	34.1	32.2 A
3 weeks old seedlings	13.5	13.7	13.0	13.5	13.4 B	28.0	29.9	30.2	31.1	29.8 B
4 weeks old seedlings	12.8	13.2	12.9	13.2	13.0 C	25.8	27.3	29.4	31.0	28.4 C
Means	13.34	13.6	13.2	13.6		28.1	29.7	30.7	32.1	
	LSD_{PYM} (A) = 0.16					LSD_{PYM} (A) = 0.47				

NP = non primed, OP = osmoprimed with $CaCl_2$, LSD = least significance difference

NP = non primed, OP = osmoprimed with $CaCl_2$ (1.5% soln.)

Phenology: Two weeks old seedlings took less time to heading than 3 and 4 weeks old seedlings during both the years (Table 1). Osmopriming in Shaheen Basmati significantly lowered the time (days) taken to heading than that of non primed seeds of the same cultivar and higher time was taken where non primed Super Basmati during both years (Table 1). Non primed Shaheen Basmati took less time from heading to maturity followed by osmopriming in same cultivar while higher time was taken by non-primed Super Basmati during both the years.

The overall interaction of cultivars, osmopriming and seedling age was not significant regarding heading to maturity (Table 1). The difference in days to heading and heading to maturity between the rice cultivars is due to the genetic characteristics of the varieties. In Shaheen Basmati lower days to heading and heading to maturity might be due to short life cycle of the cultivar and it might accomplish all growth stages earlier as compared to long duration Super Basmati. Transplanting younger seedling significantly lowered the days taken to heading.

Reduction of time for phonological development due to seedling age is crucial. It seems due to more robust growth of rice cultivars when 2 weeks old seedlings were transplanted compared to 3 and 4 weeks old seedlings. The higher days taken to heading in lanky seedlings were perhaps due to more time for crop establishment and tardy root and shoot growth because of poor utilization of resources (Brar *et al.*, 2012). The older aged seedling required more time to heading and heading to maturity due to slow establishment of these seedlings in the field than that of younger seedlings (Reddy & Reddy, 1992). Lowering of time taken to heading might be the result of healthy and vigorous start of seedlings due to earlier and uniform germination (Basra *et al.*, 2004 & 2005; Farooq *et al.*, 2006a).

Agronomic and yield related attributes: Higher plant height was recorded in Shaheen Basmati compared to Super Basmati during both the years (Table 1). Among seedling age, the plant height was higher in 2 weeks old seedling than 4 weeks old and was similar to 3 weeks old seedlings. The overall interaction of cultivars, seedling age and osmopriming was not significant regarding plant height. Among different seedling ages, 2 and 3 weeks old seedlings recorded statistically similar kernels per panicle and were superior than that of 4 weeks old seedlings (Table 1).

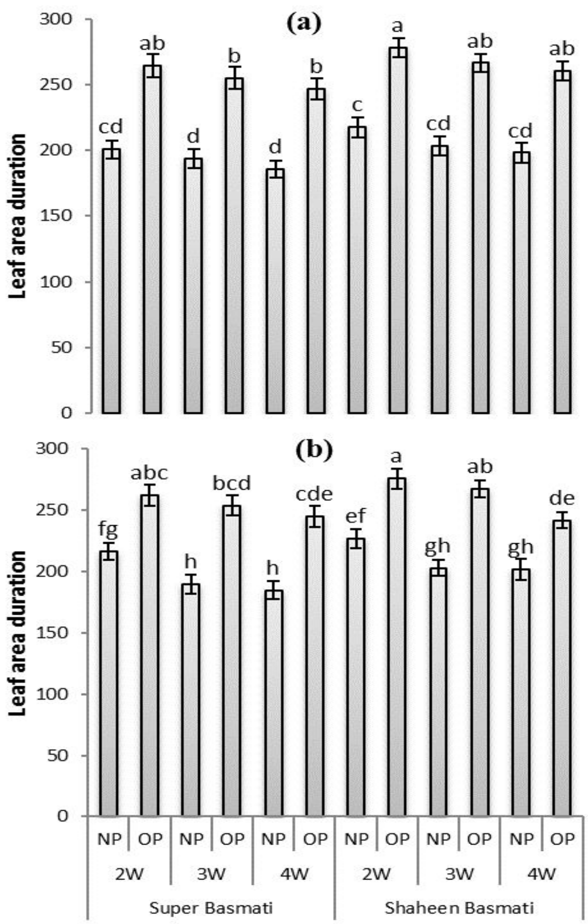

Figure 3. Influence of seedling age on leaf area duration of fine rice cultivars grown under system of rice intensification during the year (a) 2010 (b) 2011. W= weeks old seedlings, NP= non primed, OP= osmoprimed ($CaCl_2$)

The interaction of cultivars with osmopriming revealed that osmopriming in Shaheen Basmati produced higher number of kernels per panicle than that of non-primed both cultivars . Maximum productive tillers were produced by two weeks old seedlings of Shaheen Basmati primed with $CaCl_2$ than 3 and 4 weeks old seedlings while the later two seedlings were similar regarding tiller production. The interaction of cultivars with osmopriming indicated that osmopriming with $CaCl_2$ resulted in higher tiller production in both the cultivars than that of non-primed. However, the interaction among cultivars, seedling age and seed priming was not significant regarding productive tillers (Table 1). Rice cultivars differed significantly regarding unproductive tillers where least unproductive tillers were recorded in Shaheen Basmati than that of Super Basmati (Table 1). The least number of unproductive tillers were also recorded where 2 weeks old seedlings were transplanted than 3 weeks old seedlings while higher number of unproductive tillers were recorded in 4 weeks old seedlings during both the years. However the overall interaction of cultivars, seed priming and seedling age was not affected significantly for unproductive tillers.

Higher 1000 grain weight was recorded in 2 weeks old seedlings than that of 3 and 4 weeks old seedlings in both the years while 3 and 4 weeks old seedlings were at par statistically (Table 1). The interaction of cultivars with osmopriming resulted in significant improvement of 1000 kernel weight where higher weight was recorded in Super Basmati which was primed with $CaCl_2$ followed by non-primed with same cultivar and the least 1000 kernel weight was recorded in non-primed Shaheen Basmati during both years (Table 1). Between the rice cultivars, highest kernel yield was recorded in Shaheen Basmati than Super Basmati during both the years. In different seedling age, 2 weeks old seedling resulted in maximum kernel yield than 3 and 4 weeks old seedlings.

However, transplanting seedlings of 3 weeks old resulted in better kernel yield than 4 weeks old (Table 1). Seedling age affected straw yield significantly while all interactions were not significant. Maximum straw yield was recorded in 2 weeks old seedlings than that of 3 and 4 weeks old (Table 1). Seedling age significantly differed for harvest index. Maximum harvest index was recorded in 2 weeks old seedlings than that of 3 and 4 weeks old seedlings. Harvest index did not differed for the interaction of rice cultivars with seed priming (Table 1).

Improvement in plant height due to osmopriming seems to be the result of earlier, uniform and vigorous seedlings that gave an energetic start (Farooq *et al*., 2006b & 2007; Basra *et al*., 2004). The strong and vigorous seedlings resulted in higher number of productive tillers per m^2 (Reddy, 2004). Among other factors that influenced the growth and yield of rice under SRI, the seedling age has an important role as it has tremendously affected the plant height, tiller production, kernels per panicle and other yield contributing attributes. More tillers (Table 1) in 2 weeks old seedlings indicate that younger seedlings received shorter phyllochron duration which resulted in enhanced tiller production. It is evident that tiller production could be optimized by using younger seedlings than direct seeding or using seedlings of older age

(Pasuquin *et al.*, 2008) due to the inverse relation between tiller production and length of phyllochron (Nemato *et al.*, 1995). In the current study it is obvious that transplanting younger seedlings has consistently improved the grain yield due to increased tiller production, kernels per panicle and 1000 kernel weight (Table 1) as younger seedlings took longer growth period over 3 and 4 weeks old seedlings. Similar trend was also recorded by Brar *et al*. (2012) who reported that transplanting younger seedlings significantly improved yield and yield contributing attributes.

Improved kernel and straw yield and greater harvest index due to the age of seedlings might be result of improved nutrient supply by promoting shorter phyllochron and greater tiller production (Nemato *et al*., 1995). These results are in accordance with the findings of Nayak *et al*. (2006) who also reported greater number of tillers in younger seedlings than that of older seedlings which ultimately resulted in increased yield. Improved growth and yield characteristics due to the younger age seedlings might be due to their ability to retrieve the transplanting shock as during transplanting minimal disturbance to smaller roots of younger seedlings occur than that of larger roots of older seedlings (Yamamoto *et al*., 1995). The less transplanting shock received by the younger seedlings is due to faster resumption of the rate of phyllochron development. McHugh et al. (2002) also reported improvement in yield due to positive correlation between younger seedling age and grain yield.

Rice grain quality attributes: Between rice cultivars, higher grain protein contents were recorded in Shaheen Basmati than that of Super Basmati (Table 2). Among different seedling age, 2 weeks old seedlings yielded maximum protein contents than that of 3 and 4 weeks old seedlings (Table 2). Both cultivars and seedling age significantly affected regarding grain amylose contents.

The least amylose contents were recorded in 2 weeks old seedlings followed by 3 weeks old while the higher amylose contents were recorded in 4 weeks old seedlings (Table 2). Between rice cultivars, the lower amylose contents were recorded in Super Basmati than that of Shaheen Basmati while the interactions were not differed significantly. The overall interaction among cultivars, seedling age and osmopriming indicated that higher grain water absorption ratio was recorded in osmopriming with $CaCl_2$ in 2 weeks old seedlings of Super Basmati and non-primed Shaheen Basmati with same seedling age followed by non-primed Super Basmati and osmprimed Shaheen Basmati with same seedling age in both years (Table 2). The least grain water absorption ratio was recorded in non-primed 4 weeks old seedlings of Super Basmati and Shaheen Basmati during both year (Table 2). Similarly among seedling age, higher grain water absorption ratio was recorded in 2 weeks old

Table 2. Influence of seedling age and osmopriming on grain quality attributes of fine rice cultivars grown under system of rice intensification

	Pooled means of year 2010 and 2011									
	Shaheen Basmati		**Super Basmati**		**Means**	**Shaheen Basmati**		**Super Basmati**		**Means**
	NP	**OP**	**NP**	**OP**		**NP**	**OP**	**NP**	**OP**	
Seedling age	**Grain protein contents (%)**					**Grain amylose contents (%)**				
2 weeks old seedlings	8.06	8.37	8.1	8.38	8.23 A	22.8	24.8	24.0	26.4	24.5 C
3 weeks old seedlings	7.42	7.79	7.84	8.17	7.81 B	23.3	26.1	25.1	26.4	25.2 B
4 weeks old seedlings	7.26	7.63	7.49	7.91	7.58 C	26.6	28.6	26.1	29.0	27.6 A
Means	7.76 B		7.98 A			25.4 B		26.2 A		
	LSD_{PYM} (A) = 0.10, LSD_{PYM} (V) = 0.11					LSD_{PYM} (A) = 0.60, LSD_{PYM} (V) = 0.37				
	Grain water absorption ratio					**Chlorophyll a contents (mg g^{-1} fresh weight)**				
2 weeks old seedlings	4.27 BC	4.50 A	4.35 AB	4.28 BC	4.35 A	2.89	3.22	3.22	3.49	3.21 A
3 weeks old seedlings	3.78 FG	4.05 DE	3.94 EF	4.36 AB	4.03 B	2.60	2.92	2.87	3.31	2.93 B
4 weeks old seedlings	3.61 G	3.85 F	3.80 F	4.13 CD	3.85 C	2.11	2.46	2.41	2.88	2.47 C
Means	3.88	4.13	4.03	4.25		2.53	2.87	2.83	3.23	
	LSD_{PYM} (A) = 0.09, LSD_{PYM} (V × A × P) = 0.18					LSD_{PYM} (A) = 0.07				
	Chlorophyll b contents (mg g^{-1} fresh weight)					**Total chlorophyll contents (mg g^{-1} fresh weight)**				
2 weeks old seedlings	1.33 C	1.90 A	1.37 C	1.88 A	1.62 A	4.22	5.12	4.58	5.37	4.83 A
3 weeks old seedlings	1.09 D	1.61 B	1.38 C	1.67 B	1.44 B	3.69	4.53	4.25	4.98	4.37 B
4 weeks old seedlings	0.91 E	1.35 C	0.82 E	1.31 C	1.10 C	3.02	3.8	3.23	4.18	3.56 C
Means	1.11	1.62	1.19	1.62		4.07 B		4.44 A		
	LSD_{PYM} (A) = 0.08, LSD_{PYM} (V × A × P) = 0.11					LSD_{PYM} (A) = 0.11, LSD_{PYM} (V) = 0.05				

NP = non primed, OP = osmoprimed with $CaCl_2$, LSD = least significance difference seedlings than that of 3 and 4 weeks old during both the years.

Seedling age significantly differed regarding chlorophyll a contents where maximum chlorophyll a contents were recorded in 2 weeks old seedlings than that of 3 and 4 weeks old seedlings while 3 weeks old seedlings were superior than 4 weeks old (Table 2). However, the overall interaction of cultivars, seedling age and osmopriming was not affected chlorophyll a contents significantly. Similarly, the overall interaction of cultivars, seedling age and osmopriming significantly affected chlorophyll b contents. Maximum chlorophyll b content was recorded in both cultivars whose seeds were primed with $CaCl_2$ followed by 3 and 4 weeks old seedlings of both cultivars with same priming treatment (Table 2). The least chlorophyll contents were recorded in 4 weeks old seedlings whose seeds were not primed. Among seedling age, higher chlorophyll b contents were recorded in 2 weeks old seedlings than that of 3 and 4 weeks old seedlings (Table 2).

Rice cultivars differed significantly for total chlorophyll contents where higher total chlorophyll contents were recorded in Shaheen Basmati than that of Super Basmati. However, for seedling age, higher total chlorophyll contents were recorded in 2 weeks old seedlings than that of 3 and 4 weeks old seedlings while the interaction were not differed significantly (Table 2). Improvement in grain attributes due to age of seedling and osmopriming might be the result of improved nutrients and moisture supply which consequently resulted in reduced sterile spikelets due to enhanced fertilization (Thakuria and Choudhary, 1995). This might have resulted in improved grain protein contents and lowered amylose contents due to greater partitioning and assimilation of photosynthates towards the panicle.

Seedling age and osmopriming significantly improved grain water absorption ratio, grain protein and amylose contents (Table 2). Improvement in grain water absorption ratio, protein contents and chlorophyll contents due to younger seedlings and osmopriming seems to be the result of improved net assimilation rate (Fig. 4 a,b) that resulted in better translocation of photo assimilates towards the grains. Improvement in grain water absorption ratio seems to be the result of improved grain dimension and protein contents. Improvement in grain quality due to osmopriming is also supported by the findings of Thakuria & Choudhary (1995) and Zheng *et al*. (2002) who reported improved grain quality due to osmopriming under direct seeding and flooded conditions, respectively. The improvement in plant height, kernel yield and chlorophyll contents was also reported by Kadiri and Hussaini (1999) when seeds were primed with $CaCl_2$ or KNO_3 in a solution of 100 mg per liter than that of untreated seeds. In another study a significant improvement in chlorophyll contents was recorded in rice when osmoprimed with KNO_3 and PEG solutions (Esmeili & Heidarzade, 2012).

Economic and marginal analysis: Osmopriming with $CaCl_2$ in 2, 3 and 4 weeks old seedlings of both cultivars increased the net benefits than that of non primed seeds during both the years. However, maximum net returns or field benefits were obtained from 2 weeks old seedlings of Shaheen Basmati whose seeds were osmoprimed with $CaCl_2$ followed by non-primed same seedlings of the same cultivar and then Super Basmati of same seedling age osmoprimed with $CaCl_2$ during both the years (Table 3).

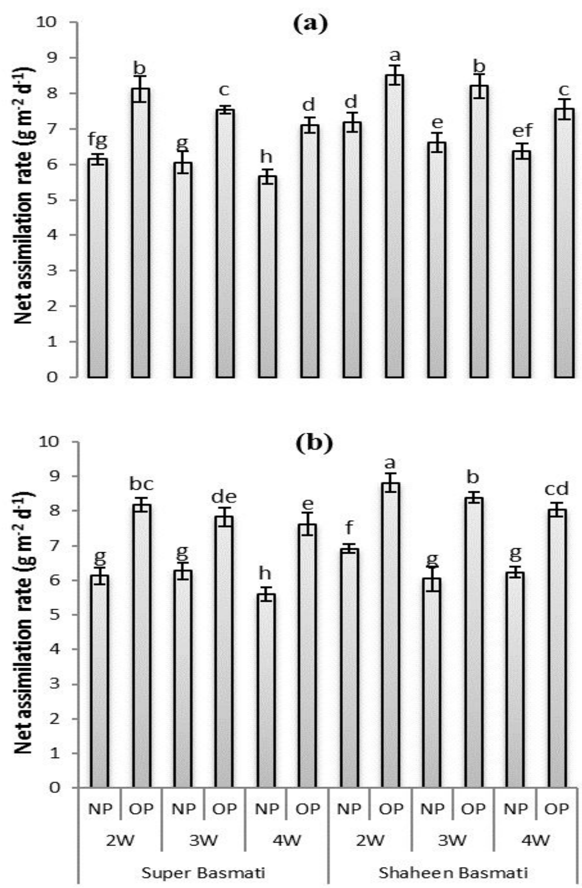

Figure 4. Influence of seedling age on net assimilation rate of fine rice cultivars grown under system of rice intensification during the year (a) 2010 (b) 2011. W= weeks old seedlings, NP= non primed, OP= osmoprimed with $CaCl_2$

Higher marginal rate of return was obtained in 2 weeks old seedlings of both the cultivars whose seeds were primed with $CaCl_2$ during both years (Table 4) followed by 3 weeks old seedlings of Super Basmati and 4 weeks old seedlings of Shaheen Basmati with same priming treatment and the least marginal rate of return was recorded in 4 weeks old

Table 3. Economic analysis of rice cultivars as affected by seedling age and osmopriming (Pooled data for the year 2010 & 2011)

	Super Basmati						Remarks
	2 weeks old		3 weeks old		4 weeks old		
	NP	OP	NP	OP	NP	OP	
Kernel yield	4.18	4.49	3.86	4.08	3.4	3.6	t ha^{-1}
Adjusted yield	3.76	4.04	3.47	3.67	3.06	3.24	10% less than actual
Value	126968	136384	117248	123930	103275	109350	Rs. 1350/40 kg
Gross benefits	126968	136384	117248	123930	103275	109350	Rs. ha^{-1}
Cost of $CaCl_2$	-	60	-	60	-	60	Rs. 100 kg^{-1}
Cost of priming	-	200	-	200	-	200	Aeration pump & container rent Rs. 50/ day each
Cost that vary	-	260	-	260	-	260	Rs. ha^{-1}
Net benefits	126968	136124	117248	123670	103275	109090	Rs. ha^{-1}
	Shaheen Basmati						
Kernel yield	4.44	4.78	3.94	4.21	3.79	4.08	t ha^{-1}
Adjusted yield	4.00	4.30	3.55	3.79	3.41	3.67	10% less than actual
Value	134865	145193	119678	127879	115121	123930	Rs. 1350/40 kg
Gross benefits	134865	145193	119678	127879	115121	123930	Rs. ha^{-1}
Cost of $CaCl_2$	-	60	-	60	-	60	Rs. 100 kg^{-1}
Cost of priming	-	200	-	200	-	200	Aeration pump & container rent Rs. 50/ day each
Cost that vary	-	260	-	260	-	260	Rs. ha^{-1}
Net benefits	134865	144933	119678	127619	115121	123670	Rs. ha^{-1}

Table 4. Marginal analysis of rice cultivars as affected by seedling age and osmopriming (Pooled data for the year 2010 & 2011)

Cultivars	Seedling age	Seed priming	Costs that vary (Rs. ha^{-1})	Marginal cost (Rs. ha^{-1})	Net benefits (Rs. ha^{-1})	Marginal net benefit (Rs. ha^{-1})	Marginal rate of return (%)
Super Basmati	**2 weeks old**	**NP**	0	-	126968	-	-
		OP	260	260	136124	9156	35
	3 weeks old	**NP**	0	0	117248	0	D
		OP	260	260	123670	6423	25
	4 weeks old	**NP**	0	0	103275	0	D
		OP	260	260	109090	5815	22
Shaheen Basmati	**2 weeks old**	**NP**	0	-	134865	-	
		OP	260	260	144933	10068	39
	3 weeks old	**NP**	0	0	119678	0	D
		OP	260	260	127619	7941	31
	4 weeks old	**NP**	0	0	115121	0	D
		OP	260	260	123670	8549	33

NP = non primed, OP = osmoprimed with $CaCl_2$ (1.5% soln.)

seedlings of Super Basmati and 3 weeks old seedling of Shaheen Basmati with same priming treatment.

Conclusion: Among rice cultivars, Shaheen Basmati remained superior to Super Basmati in growth and grain yield. Two weeks old seedlings whose seeds were osmoprimed with $CaCl_2$ (1.5% soln.) remained best and significantly improved the growth and yield of rice by increasing kernel yield of 12% and 20% than that of 3 and 4 weeks old seedlings, repectively. Two weeks old seedlings of Super Basmati and Shaheen Basmati primed with $CaCl_2$ also gave higher net benefits (Rs. 136124 & 144933) and marginal rate of return (35 & 39) than that of 3 and 4 weeks old seedlings, respectively.

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