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SEEDLING AGE AND NITROGEN RATES AFFECT HYBRID RICE (*ORYZA SATIVA* L.) PRODUCTIVITY

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ABSTRACT

Hybrid rice (cv. Arize H-64) was tested using four seedling ages (10, 20, 30 and 40 days old) and five nitrogen levels (0, 100, 135, 170 and 205 kg/ha) in a field experiment conducted at Agronomic Research Area, University of Agriculture, Faisalabad, during the year 2013. The results revealed that both parameters significantly affected plant height, crop growth rate, leaf area index and duration, number of productive tillers per meter, number of non-bearing tillers per meter, number of spikelets per panicle, number of filled grains per panicle, paddy yield, straw yield, biological yield and harvest index. Maximum paddy yield (7487.7 kg/ha) was observed when 10 days old seedlings were transplanted against minimum paddy yield (4735.9 kg/ha) in 40 days old seedlings. Yield and yield components were also higher in 10 days old seedlings. Both 170 and 205 kg N resulted in maximum (7863.8 and 7899.7 kg/ha) paddy yield while minimum (3197.9 kg/ha) paddy yield was obtained in control (no nitrogen fertilization). This study explores hybrid rice technology in Pakistan.

KEYWORDS: ***Oryza sativa;*** **rice; seedling age; nitrogen rates; biological yield; crop growth rate; leaf area index; yield; Pakistan.**

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INTRODUCTION

Rice (*Oryza sativa* L.), an important cereal crop and staple food, fulfills the food requirement of more than 50 percent of the world's population (24). It is estimated to increase by 9-11 billion by 2025, 4.3 billion of whom will depend on rice as their basic staple food (10). Pakistan has a population of 186 million making it the sixth most populous country in the world; this is expected to increase to 226 million by 2025 (7). Thus, rice yield will need to be enhanced to meet increasing food demand.

In Pakistan, rice is the second major food grain crop after wheat (*Triticum aestivum* L.) and is the third largest cultivated crop after wheat and cotton (*Gossypium hirsutum* L.) (6). Three types of rice are grown in Pakistan viz. basmati (aromatic), coarse (IRRI type) and hybrid rice. The yield of basmati and coarse rice is very low and has remained almost stagnant for several decades (6). Pakistan lacks arable land to further extend the area for rice cultivation. Hence, there is no chance of increasing the acreage under rice cultivation in future. Consequently, rice has to be produced more in a smaller area using limited resources. Obulamma *et al*. (33) reported cultivation of hybrid rice which is a new strategy to increase production per unit area to meet the food requirement of increasing populations. Metwally *et al.* (30) reported that hybrid rice can yield 15-20 percent more than commercial high yielding varieties. Yang and Sun (48) explained that higher yield by rice hybrids is due to their vigorous and extensive root system. Ehsanullah *et al*. (15) mentioned that proper sowing date, seedling age for transplantation, optimum spacing for maximum tillering, balanced fertilization, weed control and water management (i.e.improved cultural practices) are crucial for good vegetative growth as well as high yield.

Seedling age influences tiller production, grain formation and other yield contributing parameters in rice (8,17, 18) and is the main factor contributing to uniform stand establishment (19). Tillering is

largely dependent on seedling age at the time of transplanting as mentioned by Pasuquin *et al.* (34). Mobasser *et al.* (31) noted optimum seedling age and transplanting at the right time favours good growth and enhances the tillering capacity of rice. Cai *et al*. (12) explained that nitrogen is required in large amounts during rice production and is an essential component of cellular and biochemical components. The level of nitrogen fertilizer affects rice yield and quality (29) so the optimum use of fertilizer is required for obtaining higher grain yield (26) and to minimize the negative impact on the environment. Vennila *et al*. (47) and Kaushal *et al*. (25) studied that increase in nitrogen can increase panicle length, number of productive tillers, 1000-kernel weight, straw yield and number of filled grains per panicle leading to increased paddy yield.

This study aimed to determine the optimal nitrogen rate for hybrid rice transplanted at different seedling ages under the climatic conditions of Faisalabad.

MATERIALS AND METHODS

This study was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (31.26 ºN, 73.06 ºE) during summer season 2013. The experiment was laid out in factorial arrangement, using RCBD replicated thrice. The soil texture was clay loam having pH 8.20, EC 2.22 dS/m, organic matter 1.19%, available nitrogen 0.06%, phosphorus 9.2 mg/l and potassium 140 mg/l. Hybrid rice (cv. Arize H-64) was tested using four nursery seedling ages (10, 20, 30 and 40 days) after transplanting and five levels of nitrogen (0, 100, 135, 170 and 205 kg/ha). Seeds were sown to raise the nursery using wet method at 10-day intervals on 20th May, 30th May, 10th June and 20th June. All seedlings of varying ages were transplanted at the same time on 30th June to hills (2 seedlings/hill) with a row spacing of 22.5 cm × 22.5 cm while maintaining plot size 6 m × 2.25 m. NPK fertilizers were applied in the form of urea, diammonium phosphate (DAP) and sulphate of potash (SOP). Phosphorus and potash fertilizers and one third of nitrogen were applied prior to transplanting of nursery as a basal dose. The remaining nitrogen doses were divided into two equal splits (after transplanting) and applied at two critical growth stages: first at tillering (35 days after transplanting) and second at anthesis (80 days after transplanting). Recommended doses of phosphorus and potassium were applied @ 115 and 60 kg per hectare as a basal dose, respectively. Water depth was maintained at 4-5 cm during transplanting and then raised gradually to about 5-7 cm one week after transplanting to avoid seedling mortality and to facilitate early rooting. Dead or uprooted hills were replanted during this period. Weeds were controlled with Butachlor (Machete 60 EC, CAS No. 23184-66-9, Shandong Qiaochang Chemical Co., Ltd. Jiangsu, China) applied @ 800 ml per hectare at 7 days after transplanting in standing water (41). Carbofuron (Furadan 3G, *CAS No.* 1563-66-2, FMC, PA, USA) was broadcasted at 25 kg per hectare at 55 days after transplanting to protect the crop from stem borers and leaf folders. When the crop showed signs of physiological maturity, irrigation was withheld to facilitate harvesting. Harvesting was performed manually when panicles were fully ripened (110-120 days after transplanting) and contained about 23-25 percent moisture, which was assessed with a moisture meter (Model No. PM 650, Kett, USA).

The crop was harvested 110-120 days after transplanting and data on the following parameters were recorded.

Plant height at maturity (cm): Plant height was measured precisely with the help of a meter rod. Ten primary tillers were selected randomly and properly ear marked in each plot from an area of 1 m^2. The pH was then measured from soil surface to the tip of flag leaf and averaged.

Number of tillers/m^2: Number of tillers was recorded at harvest from an area of 90 cm × 90 cm from three different places in each plot. The average number of tillers per meter square was then calculated.

Number of productive tillers/m^2: Panicle-bearing tillers were counted from an area of 90 cm × 90 cm, randomly selected and earmarked from three different points in each plot at the time

of maturity. The average number of productive tillers per meter square was then calculated.

Non-panicle bearing tillers/m²: Non-panicle bearing tillers were counted from an area of 90 cm × 90 cm, randomly selected and earmarked from three different points in each plot at the time of maturity. Average non-panicle bearing tillers per meter square was calculated per unit area per meter square

Panicle length (cm): Panicle length was measured with the help of a meter rod. The length of 10 primary tillers selected randomly and properly earmarked in each plot from an area of one meter square was measured and then averaged.

Number of spikelets/panicle: Five panicles of primary tillers were randomly selected from the earmarked area in each plot at harvest and saved in paper bags. Each panicle was placed on a sheet of white paper and total number of spikelets per panicle was counted and the average was calculated.

Number of filled grains/panicle: Five panicles of primary tillers were randomly selected from the earmarked area in each plot at harvest and saved in paper bags. Each panicle was placed on a white sheet of paper and total number of filled grains per panicle was counted and average was calculated.

1000-kernel weight (g): 1000-kernel weight of normal grains from each treatment was recorded using an automatic electric balance (AY 220, Shimadzu Corp., Japan) in the laboratory.

Paddy yield (kg/ha): After harvesting and threshing, the clean rough (paddy) rice was air-dried for ten days, bulked and weighed. Rice had approximately 13-15 percent moisture at the time of final weighing.

Biological yield (kg/ha): At physiological maturity, the crop was manually harvested with a sickle leaving non-experimental area. The harvested crop was tied into bundles and kept in respective plots for five days. Biological yield was calculated as the sum of grain yield and straw yield.

Straw yield (kg/ha): Straw yield per plot was determined after drying in the sun for one week and calculated by subtracting grain yield from biological yield.

Harvest index (%): Harvest index was calculated using following formula:

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Leaf area index: Leaf area index is the ratio of leaf area to ground area (23). It was measured with a portable leaf area meter (Li-3000, Licor Inc., NE, USA). The following equation was used for LAI measurements (23):-

$$\text{Leaf area index (\%)} = \frac{\text{Leaf area}}{\text{Land area}} \times 100$$

Leaf area duration: Leaf area duration was determined as recommended by Hunt (22):-

$$\text{Leaf area duration} = \frac{(LAI1 + LAI\,2)}{2} \times (T2 - T1)$$

LAI_1 and LAI_2 are the leaf area indices at time T_1 and T_2, respectively.

Crop growth rate: Crop growth rate is defined as the rate at which the crop grows per day and expresses as dry matter accumulation (g/m²/day). It was calculated as proposed by Hunt (23):

$$\text{Crop growth rate} = \frac{W2 - W1}{t2 - t1}$$

Here W_1 is the first measurement of dry weight, W_2 is the second measurement of dry weight, T_1 is first sampling date of dry weight and T_2 is the second sampling date for dry weight, with 15-day interval between T_1 and T_2.

Statistical analysis: Data were analyzed by analysis and randomness between variables was assessed by Fisher's exact test (47). Statistical differences between treatment means were compared using least significant difference (LSD) test at 5 percent probability level using Statistic 8.1 software.

RESULTS AND DISCUSSION

Leaf area index (LAI)

The data (Table 1) revealed that 10 days old seedlings gave significantly higher LAI (6.28) than other seedling ages. Minimum LAI (5.02) was observed in 40 days old seedlings. Salem *et al.* (40) studied the influence of seedling age on inbred and hybrid rice varieties at three seedling ages (20, 30 and 40 days) and concluded that transplanting 20 days old seedlings gave the highest LAI value. Thuwe (45) noted that different seedling ages (8, 15 and 20 days) affected LAI significantly which increased significantly in 15 days old seedlings in three rice varieties (PSB Rc 18, PSB Rc 72 H and Dinorado).

Table 1. Influence of seedling age and nitrogen rates on leaf area index and leaf area duration of hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Leaf area index (%)				
0	5.75	5.22	4.84	4.13	4.98 C
100	6.05	5.85	5.12	4.82	5.46 B
135	6.23	6.14	5.67	5.20	5.81 AB
170	6.51	6.15	5.96	5.27	5.97 A
205	6.87	6.56	5.98	5.69	6.27 A
Means	6.28 A	5.98 A	5.51 B	5.02 C	
LSD 5%	S=0.41, N= 0.46, S×N=0.188				
	Leaf area duration (Days)				
0	253.54	231.91	197.79	145.66	207.22 C
100	270.10	241.30	207.04	195.59	228.51 B
135	277.20	261.84	235.64	206.23	245.23 B
170	287.16	283.26	258.94	238.06	266.85 A
205	298.90	284.14	273.74	255.96	278.19 A
Means	277.38 A	260.49 A	234.63 B	208.30 C	
LSD 5%	S=18.07, N=20.20, S×N= 365.01				

Means sharing the same letters are statistically similar at P ≤ 0.05

Campbell (13) and Grigg *et al*. (14) reported maximum LAI values ranging from 5.0 to 7.0 for rice. Ahmad *et al.* (4) noted that early transplanting (1st week of July) enhanced LAI more than late transplanting (3rd week of July) reaching maximum values of 7.79, 6.70 and 5.33 at three different locations. The average value of three locations was 6.60 and 4.85 in early and late transplanting, and with maximum LAI values of 6.24 and 6.15 for Super Basmati and Basmati-2000, respectively. In this study N @ 205 kg gave highest LAI (6.27) among all nitrogen treatments while minimum LAI (4.98) was observed in control (Table 1). Similar results were observed by Abou-Khalifa (3) who studied five genotypes (Sakha 106, Sakha 105, GZ. 7565, GZ. 9075 and GZ. 9362) at five nitrogen levels (0, 55, 111, 165 and 220). He found that average maximum LAI (5.35) was observed at the highest nitrogen level (220 kg/ha) compared to control. Ahmad *et al.* (4) noted that LAI reached a maximum value (5.86) with a split nitrogen application (1/3 at transplanting + 1/3 at 30 DAT + 1/3 at 50 DAT) whereas 1/3 at transplanting+ 1/3 at 30 days after transplanting (DAT) resulted in a LAI of 5.92. The control, which was full nitrogen, showed a mean LAI of 5.64 (4).

Leaf area duration (LAD)

The results (Table 1) showed that 10 days and 20 days old seedlings gave higher LAD (277.38 and 260.49 days) than two other seedling ages. Minimum LAD (208.30 days) was observed in 40 days old seedlings. Ahmad *et al.* (4) also observed that early transplanting significantly increased LAD at three different locations: being maximum LAD values (321.82 and 317.44) in Super Basmati and Basmati-2000, respectively. In this study, 205 kg N gave higher LAD (278.19 days) than other nitrogen rates. Minimum LAD (207.22 days) was observed in control (zero nitrogen). Ahmad *et al.* (4) also noted that a split nitrogen application did not affect LAD at two locations Faisalabad and Gujranwala. However, significant differences were found between nitrogen application treatments at Kala Shah Kaku, a third site where a split nitrogen application increased LAD by 9.92 percent (288 days vs 262 days) more than full nitrogen application treatment. Differences in LAD between two and three N split treatments were also significant: split nitrogen application (1/3 at transplanting+ 1/3 at 30 DAT) resulted in LAD of 298.96 whereas 1/3 at transplanting +1/3 at 30 DAT+1/3 at 50 days after transplanting (DAT) resulted in LAD of 298.96. In control, i.e. full nitrogen, mean LAD was 286.83 at transplanting over the three locations (4).

Crop growth rate (CGR)

Ten days old seedlings showed higher CGR (22.08 g/m/day) (Table 2). Minimum CGR (18.70 g/m/day) was observed in 40 days old seedlings. Ahmad *et al.* (4) noted that high CGR is usually dependent upon rapid expansion of LAI or LAD to intercept available radiation, especially early in the season. They observed that early transplanting (1st week of July) significantly increased mean CGR (13.43) than late transplanting (3st week of July) (13.04) at three locations; Super Basmati showed maximum CGR (14.93) at Faisalabad, minimum CGR at Gujranwala (12.15) mean CGR was 13.1 over the three locations; Basmati-2000 had a higher CGR (14.36) at Gujranwala and minimum CGR at Faisalabad (14.04) with a mean CGR value of 13.38 over all three locations. Thuwe (45) observed highest CGR in 15 days old seedlings.

Table 2. Influence of seedling age and nitrogen rates on crop growth rate (g/m²/d) of hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Crop growth rate (g/m²/d)				
0	20.03	18.93	17.66	16.67	18.32 C
100	21.71	20.34	20.21	18.12	20.09 B
135	22.48	21.45	20.48	18.87	20.82 AB
170	22.65	22.53	21.58	18.97	21.43 AB
205	23.54	22.26	22.03	20.88	22.17 A
Means	22.08 A	21.10 AB	20.39 B	18.70 C	

Means sharing the same letters are statistically similar at P ≤ 0.05

N @ 205 kg showed highest CGR (22.17 g/m/day) and minimum CGR (18.32 g/m/day) was observed in control (Table 2). CGR gradually increased as the level of nitrogen fertilizer increased, peaking (22.17 g/m/day) at 75 days after transplanting after which CGR decreased. Ahmad *et al.* (4) observed that a split nitrogen application significantly enhanced mean CGR more than full nitrogen application at two agro-ecological locations (Kala Shah Kaku and Gujranwala). Maximum mean CGR value (13.21) was observed when nitrogen was split as 1/3 at transplanting + 1/3 at 30 days after transplanting whereas the control, i.e., full nitrogen application at transplanting, resulted in a mean CGR value of 12.44 over both locations (4).

Plant height (PH)

Maximum PH (86.79 cm) was observed in 10 days old seedlings followed by 20 days old seedlings (86.40) while minimum PH (78.07 cm) was recorded in 40 days old seedlings (Table 3). Shrirame *et al*. (42) reported smaller leaf area might increase PH in younger seedlings due to better stand establishment and enhanced cell division. Sarkar *et al.* (41) noted taller plants (130.60 cm) in 25 days old seedlings and shortest

plants (127.54 cm) when 35 days old seedlings were transplanted. Prabha *et al*. (36) noted that 14 days old seedlings produced taller plants (89.50 cm) than 21 days old seedlings. In contrast, Ali *et al.* (5) found that in Boro rice BRRI Dhan 28, 30 days old seedlings produced taller plants (98.3 cm) than 15 days old seedlings (90.4 cm).

Table 3. Influence of seedling age and nitrogen rates on plant height (cm) and number of tillers/m² of hybrid rice.

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Plant height (cm)				
0	81.31	78.06	73.82	67.84	75.26 C
100	85.66	85.29	81.09	75.61	81.91B
135	87.43	87.36	86.30	77.92	84.75 AB
170	90.20	90.49	88.98	84.58	88.56 A
205	89.36	90.81	89.92	84.41	88.62 A
Means	86.79 A	86.40 A	84.02 A	78.07 B	
LSD 5%	(S=5.94, N=6.64, S×N= 39.44)				
	Number of tillers/m²				
0	253.80	250.97	223.15	206.76	233.67 D
100	265.30	279.39	246.38	227.22	254.57 C
135	275.72	297.43	259.79	234.05	266.75 BC
170	282.45	311.33	268.45	242.89	276.28 AB
205	296.87	324.92	286.77	254.22	290.70 A
Means	274.83 AB	292.81 A	256.91 B	233.03 C	
LSD 5%	(S=18.69, N=20.89, S×N= 390.43)				

Means sharing the same letters are statistically similar at P ≤ 0.05

Among nitrogen levels, tallest plants (88.62 cm) were observed in 205 kg N and shortest plants (75.26 cm) in control (Table 3). Pramanik and Bera (37) also reported tallest plants in treatments where maximum nitrogen fertilizer (150 kg/ha) was applied to rice crop. Ehsanullah *et al.* (15) reported a gradual PH increase in Basmati rice as nitrogen fertilization increased. Awan *et al*. (9) observed that nitrogen affected plant height and tallest plants (80.00 cm) formed when N was applied at 156 kg against shortest plants (69.43 cm) in 110 kg N. Similarly, Kaushal *et al.* (25) observed greater PH (115.6 cm) when nitrogen was applied at 150 kg and shortest plants (104.1 cm) in 90 kg N per hectare.

Number of tillers (NT/m²)

Rice tillering depends on seedling age at transplanting (34). Maximum NT (292.81/m²) was possible when 20 days old seedlings were transplanted, statistically equivalent to 10 days old seedlings (274.83 tillers/m²) while minimum NT (233.03/m²) was observed in 40 days old seedlings (Table 3). Shrirame *et al*. (42) noted increase in photosynthetic rate stimulates root growth, cell division and cell enlargement, allowing seedlings to be taller and forming more tillers per hill. Salem *et al*. (40) studied three seedling ages (20, 30 and 40 days) and found that transplanting 20 days old seedlings gave higher NT/hill (21) while fewest NT (17/hill) was observed in 40 days old seedlings. Patra and Haque (33) tested seven seedling ages (6, 8, 10, 12, 14 16 and 18 days) and maximum NT (31.33 and 26.73/plant) formed when 10 days old seedlings were transplanted during 2008 and 2009, respectively. Faghani *et al.* (16) observed a significant effect of seedling age on tillering pattern: highest NT (16.3/hill) formed when 25 days old seedlings were transplanted while fewest NT (15.3/hill) formed from 35 days old seedlings. Sarkar *et al.* (41) found that transplanting older (35 days) Aman rice seedlings formed more NT (13.36/hill) than 25 days old seedlings (12.41/hill). Ali *et al.* (5) observed more NT (31.5/hill) when younger (15 days) seedlings were transplanted while 18.0 tillers per hill formed in 30 days old seedlings.

The data (Table 3) further reveal that maximum NT (290.70/m²) was produced by 205 kg N

which was statistically equivalent to 170 kg N (276.28 tillers/m^2). Minimum NT (233.67/m^2) was observed in control (zero N). Salem *et al.* (40) reported maximum number of tillers (22.5/ hill) in maximum nitrogen rate (164 kg/ha) and minimum number of tillers (16.5/hill) in control (zero nitrogen). Pramanik and Bera (37) also reported an increase in number of tillers per plant in hybrid rice by increasing nitrogen rate to 150 kg per hectare. Yoseftabar (49) studied the response of rice cultivar 'TaromHashemi' to three nitrogen levels (50, 100 and 150 kg/ha) and found that most number of tillers per plant (27.6) formed when nitrogen was applied at 150 kg and fewest number of tillers (22.8) at 50 kg N. Abou-Khalifa (3) found that most NT (679/m^2) formed when nitrogen at 220 kg was applied and fewest NT (574/m^2) in zero level of nitrogen. Similarly, rice variety Sakha 106 gave highest NT (670.5/ m^2) and minimum by GZ 9362 (576.5 tillers/m^2). Awan *et al.* (8) also examined three nitrogen levels (110,133, 156 kg/ha) which affected tillering (cv. KSK-133). Maximum NT (601/m^2) in 156 kg N was noted and fewest NT (527/m^2) in 110 kg N.

Number of productive tiller (NPT/m^2)

NPT determines the productivity of a rice plant, i.e. tillers that bear panicles, rather than on the total number of tillers as mentioned by Hasanuzzaman *et al.* (20). The data (Table 4) indicate that 10 days old seedlings resulted in highest NPT (278.00/m^2) with 205 kg N which was statistically at par with the same seedling in 170 kg N (276.93 NPT/m^2). Fewest NPT (179.93/m^2) resulted from 40 days old seedlings in control.

Table 4. Influence of seedling age and nitrogen rates on productive tillers and non-bearing tillers/m^2 of hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Productive tillers/m^2				
0	211.87fgh	208.65ghi	194.65hij	165.21k	195.10 D
100	248.95 bcd	238.54 bcd	218.19efg	185.55j	222.81C
135	253.25 bc	258.36 ab	230.48 def	190.55ij	233.16B
170	276.93 a	252.90 bc	235.00 cde	235.12cde	249.99A
205	278.00 a	247.83bcd	252.44 bc	229.20 def	251.87A
Means	253.80A	241.26B	226.15C	201.13D	
LSD 5%	(S=9.08, N=10.16, S×N=20.32)				
	Non-panicle bearing tillers/m^2				
0	45.22 abc	37.19 def	48.05 ab	48.94 a	44.85 A
100	30.23 gh	41.20 cde	32.18 fgh	46.80 abc	37.60 B
135	37.05 def	36.96 def	30.21 gh	38.13 def	35.5B
170	21.00 i	29.310 h	42.450 bcd	34.17 fgh	31.73 C
205	17.36 i	36.45 def	35.67 efg	34.02 fgh	30.87 C
Means	30.17 C	36.22 B	37.71 B	40.41 A	
LSD 5%	(S=2.69, N=3.01, S×N=6.02)				

Means sharing the same letters are statistically similar at $P \leq 0.05$

El-Rewainy *et al*. (16) showed an interaction effects of seedling age and nitrogen rate on NPT. Pramanik and Bera (37) found highest NPT (17.98/ hill) in younger seedlings (10 days) and least NPT (10.68) in 30 days old seedlings (cv. hybrid '25-P-25'). Shrirame *et al.* (42) reported that 10 days old seedlings produced better root growth and increased cell division and enlargement due to an increase in photosynthetic rate subsequently increasing plant height and NPT. Faruk *et al*. (18) studied four seedling ages (14, 21, 28, 35 days) of variety BRRI Dhan 33 and observed that 28 days old seedlings produced more NPT (8.26/hill) and least in 14 days old seedlings (6.82 NPT/hill). Prabha *et al.* (36) tested 16 different treatments in rice cultivar 'AS99110' and observed that 14 days old seedlings with three seedlings per hill produced more NPT (501/m^2) while lowest productivity (379 tillers/m^2) was observed when a combination of 21 days old seedlings and one single seedling per hill was used. Ali *et al.* (5) noted that 15 days old seedlings produced more NPT (24.9/hill) than 30 days old seedlings (15.6 effective tillers/hill).

Non-panicle bearing tillers (NPBT/m²)

The data (Table 4) further indicate that 40 days old seedlings produced more NPBT (48.94/m²) in control (zero N). Fewest NPBT (17.36/m²) formed in 10 days old seedlings when N was applied at 205 kg. Sarkar *et al.* (41) reported that 25 days old younger seedlings gave significantly more NPBT (3.17/hill) than older seedlings (35 days old) (4.28/hill).

Panicle length (PL)

Maximum PL (23.71cm) was recorded in 10 days old seedlings followed by 20 days old seedlings (23.04 cm) while minimum PL (21.81 cm) was recorded in 40 days old seedlings (Table 5). Patra and Haque (35) also found longer panicles (22.55 cm) by transplanting 10 days old seedlings in rice variety Ranjit and shortest panicles (18.09 cm) in 6 days old seedlings. Sarkar *et al.* (41) studied Aman rice BR23 (Dishari) and found a significant effect of seedling age on PL: longest panicles (27.98 cm) in 25 days old seedlings and shortest panicles (27.36 cm) in older (35 days) seedlings. Similarly, Rahimpour *et al.* (38) studied four rice cultivars (Tarem Deylamani, Danesh, Noksiah and Fajr) and found longer panicles (22.95 cm) in Danesh (27 days old seedlings) than 35 days old seedlings in Noksiah (21.04 cm).

In case of N fertilization, maximum PL (24.31 cm) was obtained in 205 kg N which was statistically equal to 170 kg N. Longest panicles (20.68 cm) were observed in control (zero nitrogen). Yoseftabar (49) applied 300 kg N and maximum PL was observed (28.64 cm) in hybrid rice while 100 kg N resulted in minimum PL (27.71 cm). Abou-Khalifa (3) found longest panicles (20.90 cm) at the highest nitrogen rate (220 Kg/ha) than control (no nitrogen) (18.29 cm). Metwally *et al*. (30), using an Egyptian hybrid 'H1', recorded maximum

Table 5. Influence of seedling age and nitrogen rates on Panicle length (cm) and number of spikelets/panicle of Hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Panicle length (cm)				
0	21.44	20.69	20.80	19.81	20.68 C
100	22.80	23.11	22.29	21.78	22.49 B
135	22.99	22.31	22.72	21.97	22.49 B
170	25.40	24.37	23.46	22.99	24.05 AB
205	25.93	24.73	24.09	22.51	24.31 A
Means	23.71	23.04	22.67	21.81	
LSD 5%	(S=, N=1.80, S×N=)				
	Number of spikelets/panicle				
0	178.73bcd	167.97def	135.00 hi	115.90j	149.40D
100	174.44cde	176.56cde	148.61 gh	132.28i	157.97C
135	178.10bcde	186.28abc	162.39efg	137.01hi	165.94B
170	186.26abc	193.92ab	166.30def	154.05fg	175.13A
205	197.17a	182.00 abcd	177.30cde	169.57def	181.51A
Means	182.94A	181.34A	157.92B	141.76C	
LSD 5%	LSD 5%(S=7.12, N=7.96, S×N=15.93)				

Means sharing the same letters are statistically similar at P ≤ 0.05

Number of spikelets/panicle (NS/P)

Ten days old seedlings produced more NS (197.17/P) in response to 205 kg N and fewest NS (115.90) in 40 days old seedlings from control (zero nitrogen) (Table 5). Rahimpour *et al*. (38) found a significant effect of seedling age on NS:

maximum (114.6) in 27 days old seedlings and minimum (106.4) in 30 days old seedlings while rice cultivar 'Danesh b2' produced 119.66 spikelets per panicle and fewest (94.68) in 'Fajr b4'.

Among N rates, 205 kg N produced maximum NS (176.14/P) and was statistically equal to 170 kg N, while lowest NS (135.27/P) was observed in control (Table 5).

Number of filled grains/panicle (NFG/P)

Ten days old seedlings formed higher NFG (174.26/P) in 205 kg N and fewest NFG (74.26) in 40 days old seedlings (Table 6). Better adaptation by younger seedlings to climatic conditions improved panicle formation and panicle growth resulting in maximum NFG and fewest sterile spikelets (Table 6).

Table 6. Influence of seedling age and nitrogen rates on Number of filled grains/panicle and 1000-kernel weight (g) of Hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Number of filled grains/panicle				
0	144.21cdef	137.12ef	93.82j	74.26k	112.35 E
100	152.52bcd	149.17cde	111.23 hi	92.41 j	126.33 D
135	165.28ab	153.43bc	129.27 fg	98.17 ij	136.54 C
170	171.75a	165.81ab	140.25cdef	117.55 gh	148.84B
205	174.26a	165.96ab	155.08bc	137.92 def	158.30A
Means	161.60A	154.30B	125.93C	104.06D	
LSD 5%	(S=6.69, N=7.48, S×N=14.96)				
	1000-kernel weight (g)				
0	19.88	19.72	19.11	18.10	19.20 C
100	22.90	22.86	20.73	19.78	21.56 B
135	23.10	22.95	22.39	21.78	22.55 AB
170	23.41	23.35	23.25	22.35	23.09 AB
205	23.82	23.72	23.61	22.68	23.45 A
Means	22.62	22.52	21.81	20.93	
LSD 5% (S=, N=1.76, S×N=)					

LSD: least significant difference, Means sharing the same letters are statistically similar at $P \leq 0.05$

Manjunatha *et al*. (28) observed that older seedlings (18 days) resulted in fewest (146.87) NFG while younger seedlings i.e. 9 and 12 days produced significantly more NFG (159.33 and 158.13/P). Ali *et al.* (5) observed maximum NFG (188/P) when younger seedlings of 'BRRI dhan28' (15 days) were transplanted but fewest NFG (170/P) was noted when older seedlings (30 days) were used. Sarkar *et al.* (41) studied six rice cultivars (Binadhan-7, BRRI dhan56, BRRI dhan57, IR83377-B-B-93-3, IRRI123, and IR83381-B-B-6-1) and reported maximum NFG (84/P) by transplanting younger seedlings (14 days) and lowest NFG (77/P) when older seedlings (35 days) were transplanted. Maximum NFG (87/P) was noted in two rice cultivars (BRRI dhan56 and IR83377-B-B-93-3) and minimum NFG (72.5/P) in BRRI Dhan 57. Prabha *et al.* (36) found highest NFG (211/P) when 14 days old seedlings of rice cultivar AD-99110 were transplanted and fewest NFG (141/P) when 21 days olds seedlings were used. Patra and Haque (35) studied rice variety. Ranjit and found that 10 days old seedlings produced more NFG (123.30/P) than 6 days old seedlings (86.20 NFG/P).

Kaushal *et al*. (25) reported that an increase in nitrogen level increased panicle length, number of productive tillers and number of filled grains per panicle. Hasanuzzaman *et al*. (20) found a significant response of nitrogen rate on NFG and observed a maximum value (154.67) when nitrogen was applied as urea granules at 75 kg per hectare which was statistically at par with 80, 120 and 160 kg N. Minimum NFG value (126.16) was observed in control (zero nitrogen). The authors concluded that fewer kernels in control was due to less nutrient availability; consequently,

the plant could not produce fertile grains. Yoseftabar (49) reported a significant increase in NFG in rice 'TaromHashemi' as nitrogen level increased: maximum NFG (209.85) was recorded when nitrogen was applied at 300 kg, fewestNFG (190.31/P) were noted in 100 kg N. Abou-Khalifa (3) observed highest NFG (117/P) when N was applied at maximum rate (220 kg) and minimum NFG (105/P) in control. Awan *et al.* (9) also observed maximum NFG (132.97/P) when applied high N rate 9156 kg/ha) in rice variety KSK-133 (156 kg/ha) and more NFG (132.97/P) formed than 110 kg N.

1000-kernel weight (1000-KW)

The data (Table 6) showed that 10 days old seedlings produced maximum 1000-KW (22.62g) which was higher than other treatments but statistically equivalent to 20 days old seedlings (22.52). Minimum 1000-KW (20.93g) was recorded in 40 days old seedlings. Brar *et al.* (11) reported 30, 45 and 60 days old seedling had no significant effect on 1000-KW. Rahimpour *et al.* (36) observed maximum 1000-KW (22.08 g) with 27 days old seedlings while 30 days old seedlings produced least kernel weight (20.33 g). Ali *et al.* (5) observed maximum 1000-KW (22.61 g) of rice variety BRRI Dhan28 when younger seedlings (15 days) were transplanted while lowest 1000-KW (21.00 g) was found when 30 days old seedlings were used.

Among N rates 205 kg N produced highest 1000-KW (23.45 g) which is significantly higher than other treatments but statistically equal to 170 kg N (Table 6). Minimum 1000-KW (19.20 g) was recorded in control.

Hossain *et al*. (21) noted that application of balanced fertilizer is necessary for rice grain formation and development. Yoseftabar (49) reported minimum 1000-KW (23.3 g) in lowest nitrogen rate (50 kg) and maximum 1000-KW (25.6 g) in maximum nitrogen level (150 kg/ha) in rice 'TaromHashemi'. Pramanik and Bera (37) evaluated the productivity of hybrid rice '25-P-25' at three seedling age levels and five nitrogen application levels. They observed that 1000-KW was affected significantly by both factors. Abou-Khalifa (3) studied five rice varieties (Sakha 106, Sakha 105, GZ 7565, GZ 9075 and GZ 9362) and found maximum 1000-KW (25.59) in Sakha 106 and minimum 1000-KW (21.59) in GZ 9362. Further, when nitrogen was applied at 220 kg, 1000-KW was 24.7g against control, (21.97g). Hasanuzzaman *et al.* (20) reported significantly higher 1000-KW (29.35 g) when nitrogen was applied at 75 kg in the form of super urea granules and the lowest value (27.86 g) in control (zero N). Abou-Khalifa (3) found an increase in 1000-KW at higher nitrogen rates due to an increase in chlorophyll content of leaves, leading to higher photosynthetic rates and availability of photosynthates during grain development.

Paddy yield (PY)

Paddy yield is a function of productive tillers, 1000-KW and the balanced application of NPK nutrients according to Hasanuzzaman *et al*. (20). Based on overall treatments, 10 days old seedlings gave higher mean PY (9482.0 kg/ha) in 205 kg N, which was statistically equal (9135.7 kg/ha) at the same seedling age in 170 kg N (Table 7). Minimum PY (2434.6 kg/ha) was recorded in 40 days old seedlings in control treatment.

Several scientists reported young seedlings had a significant effect on PY. Rahimpour *et al.* (38) noted that younger rice seedlings (27 days) produced higher grain yield (5.82 t/ha) than 35 days old seedlings, which resulted in lowest PY (5.38 t/ha). Ali *et al.* (5) studied different seedling ages of Boro rice BRRI Dhan-28 and observed maximum grain yield (8.77 t/ha) when 15 days old seedlings were transplanted but lowest PY (6.90 t/ha) in 30 days old seedlings. Brar *et al.* (11) noted that younger seedlings (30 days) produced higher grain yield (6.82 t/ha) than 60 days old seedlings, which produced minimum grain yield (6.47 t/ha). Sarkar *et al.* (41) noted higher grain yield (4.13 t/ha) in younger seedlings (25 days) than 35 days old seedlings (3.68 t/ha). El-Rewainy (16) hypothesized that higher PY in younger seedlings due to healthy growth and greater vigour, as well as more leaves and productive tillers, ensured more resource consumption than older seedlings.

Ahmad *et al.* (4) studied two rice cultivars (Super Basmati and Basmati-2000) and noted that when rice was transplanted in first week of July, PY was significantly enhanced at three sites compared to transplanting in the third week of July. Abou-Khalifa (3) observed higher grain yield (10.64 t/ha) at maximum nitrogen level (220 kg/ha) but grain yield (7.11 t/ha) was lowest when no nitrogen was applied. Awan *et al.* (9) found that rice KSK-133 gave maximum grain yield (5461.03 kg/ha) when nitrogen was applied at a maximum rate (156 kg/ha) against minimum PY (4354.60 kg/ha) in 110 kg N.

Table 7. Influence of seedling age and nitrogen rates on paddy yield and straw yield of Hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Paddy yield (kg/ha)				
0	3453.9 j	3379.6 j	3523.3 j	2434.6 k	3197.9 D
100	7103.5 efg	6954.4 fg	5301.6 i	3968.3 j	5832.0 C
135	8263.2 BCD	8005.3CDE	6328.1 GH	6002.2 HI	7149.7 B
170	9135.7 AB	8172.0 CD	8415.6 BCD	5731.8 HI	7863.8 A
205	9482.0 A	8812.2ABC	7762.1 DEF	5542.4 HI	7899.7 A
Means	7487.7A	7064.7 B	6266.2 C	4735.9 D	
LSD 5%	(S=421.70, N=471.48, S×N=942.95)				
	Straw yield (kg/ha)				
0	8420 def	7304 efg	6849 G	4609 h	6796 D
100	8715 cd	8972 cd	8592 cdef	6589 g	8217 C
135	9072 bcd	8991 cd	8685 cde	7219 fg	8492 BC
170	9132 bcd	9724 bcd	9159 bcd	8490 cdef	9126 B
205	11879 a	9478 bcd	10442 b	9846 bc	10411 A
Means	9443.6 A	8893.7 AB	8745.7B	7350.4C	
LSD 5%	(S=618.78, N=691.82, S×N=1383.6)				

Means sharing the same letters are statistically similar at P ≤ 0.05

Straw yield (SY)

Based on overall treatments, maximum SY (11879 kg/ha) was recorded in 10 days old seedlings in 205 kg N followed by 30 days old seedlings at the same nitrogen level (10442 kg) (Table 7). Minimum SY (4609 kg/ha) was recorded in 40 days old seedlings in control (zero nitrogen).

Vasantha *et al.* (46) observed that high SY is due to taller plants and greater leaf area, tiller production and dry matter accumulation. Abou-Khalifa (1), studying the application of increased nitrogen rates on the growth of five rice varieties, found that nitrogen encourages an increase in biomass by enhancing cell elongation, building new meristematic cells and increasing the photosynthetic activities of the plants, thus leading to increased SY. Manjunatha *et al.* (28) found that 9 days old seedlings produced maximum SY (7019 kg/ha) but least SY in 21 days old seedlings (6716 kg/ha). Hasanuzzaman *et al.* (20) found that nitrogen @ kg produced maximum SY (15 t/ha) against minimum SY (5.5 t/ha) in control N. Awan *et al.* (8) found SY significantly increased when nitrogen level increased, obtaining maximum SY (9662.03 kg/ha) when nitrogen was applied at 156 kg and lowest SY (7867.27 kg/ha) when N was applied at 110 kg per hectare. Pramanik and Bera (37) observed maximum SY (7734 kg/ha) when a higher N level (200 kg/ha) was applied but lowest values (5213 kg/ha) when no nitrogen was applied.

Biological yield (BY)

Ten days old seedlings produced maximum BY (16689 kg/ha) followed by 20 days old seedlings (15844 kg) while minimum BY (13080 kg) was observed in 40 days old seedlings (Table 8). Pramanik and Bera (35) reported higher BY in younger (10 days) seedlings. Highest BY (18543 kg/ha) was produced after applying nitrogen fertilizer at 205 kg and lowest BY (10628 kg/ha) in control (Table 8).

Vasantha *et al.* (46) noted increase in BY may be due to high plant height, dry matter accumulation, leaf area and tiller production. Abou-Khalifa (2) noted increased BY as nitrogen application encourages biomass accumulation in plants as it is one of the most essential elements that plays a prominent role in enhancing cell elongation, building new meristematic cells and thus increasing photosynthetic activity. Thus, increased BY caused indirectly by the increased nitrogen levels was due to improved yield-contributing components such as number of productive tillers, non-panicle bearing tillers, 1000-kernel weight and panicle length. Hossain *et al.* (22) also noted maximum BY when a maximum level of nitrogen fertilizer was applied.

Table 8. Influence of seedling age and nitrogen rates on biological yield (kg/ha) and harvest index (%) of Hybrid rice

Nitrogen (kg/ha)	Seedling age (days)				
	10	20	30	40	Means
	Biological yield (kg/ha)				
0	12608	11460	10373	8069	10628 E
100	15818	15704	13894	11042	14115 D
135	16833	16474	14714	12947	15242 C
170	17625	17792	16899	15838	17038 B
205	20561	17792	18314	17503	18543 A
Means	16689 A	15844 B	14839 C	13080 D	
LSD 5%	(S=751.89, N= 840.64, S×N=632068.81)				
	Harvest index (%)				
0	33.27 i	36.22 hi	33.94 i	42.93 cdef	36.59 D
100	45.04 abcd	42.96 cdef	38.22 gh	40.49 fg	41.68 C
135	46.14 abc	45.45 abcd	41.09 efg	44.28 bcde	44.24 B
170	48.25 a	45.40 abcd	45.92 abc	46.39 abc	46.49 A
205	42.22 def	46.73 ab	43.06 cdef	43.97 bcdef	43.99 B
Means	42.98 A	43.35 A	40.44 B	43.61 A	
LSD	(S=1.62, N=1081, S×N=3.62)				

Means sharing the same letters are statistically similar at P ≤ 0.05

Harvest index (HI)

Harvest index is an important trait associated with the dramatic increase in crop yield that occurred in the 20th century (43). Forty days old seedlings gave maximum HI (43.61%), which was statistically equal to 10 and 20 days old seedlings. However, 30 days old seedlings gave minimum HI (40.44%) (Table 8). Pramanik and Bera (37) observed higher HI in younger seedlings might be due to better crop growth and development. Sarkar *et al*. (41) reported maximum HI (0.46%) when younger seedlings (25 days) were transplanted but minimum (0.40%) when 35 day old seedlings were used. Ginigaddara and Ranamukhaarachchi (19) observed maximum HI (0.51%) in 9 days old seedlings. Ali *et al*. (5) recorded maximum HI by transplanting younger (15 days) seedlings than 30 days old seedlings. More *et al.* (32) found higher grain yield to straw yield ratio when 15 days old seedlings were used than 20 and 28 days old seedlings.

HI was highest (46.15%) in treatment when nitrogen was applied at 205 kg and lowest (36.76%) in control. Pramanik and Bera (37) observed a significant effect of nitrogen on HI: highest HI (47.07%) was observed when nitrogen was applied at 150 kg but minimum (42.60%) in the control (zero nitrogen). Ehsanullah *et al*. (15) found highest HI (38.32%) when nitrogen was applied at 100 kg ha^{-1} to basmati rice.

CONCLUSION

The study concludes that 10 days old seedlings in 205 kg N significantly improved leaf area index, leaf area duration, crop growth rate, plant height, non-panicle bearing tillers/m^2, number of productive tillers/m^2, number of filled grains/panicle, number of spikelets/panicle, paddy yield, straw yield, biological yield and harvest index. These two conditions (205 kg N/ha and 10 days old seedlings) are thus recommended for hybrid rice grown under the climatic conditions of Pakistan.

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CONTRIBUTION OF AUTHROS

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