Influence of Seedling Age and Nitrogen Rates on Productivity of Hybrid Rice (Oryza sativa L.)

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Abstract: Hybrid rice technology is one of the most important innovations in order to meet the food requirement of ever growing population of Pakistan. Land and water resources are also declining day by day and it is need of hour to increase production per unit area which is only possible through the cultivation of rice hybrids. Full production technology of it needs to be explored under the climatic conditions of Pakistan. Hybrid rice (Arize H-64) was tested using four seedling ages (10, 20, 30 and 40 days) and five nitrogen levels (0, 100, 135, 170 and 205 kg ha\(^{-1}\)) through field experiment conducted at the Agronomic Research Area, University of Agriculture, Faisalabad during summer 2013. The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement having three replications. The results revealed that seedling age and nitrogen rates had significant effect on total tillers m\(^{-2}\), productive tillers m\(^{-2}\), panicle total grains, filled grains panicle\(^{-1}\), grain and straw yield ha\(^{-1}\). Maximum paddy yield (7487.7 kg ha\(^{-1}\)) was produced when 10-days old seedlings were transplanted while minimum (4735.9 kg ha\(^{-1}\)) was observed in 40-days old seedlings. Yield and yield components were also recorded higher for 10-days old seedlings. Regarding nitrogen levels 205 kg N ha\(^{-1}\) gave maximum (7899.7 kg ha\(^{-1}\)) paddy yield which was statistically at par with the application of 170 kg N ha\(^{-1}\) while minimum (3197.9 kg ha\(^{-1}\)) paddy yield was obtained at control with no nitrogen fertilization.

Keywords: Hybrid Rice, Seedling Age, Nitrogen Rates, Paddy Yield

1. Introduction

Rice (Oryza sativa L.) is one of the most important cereal crop and being the staple food it fulfilling the food requirement of more than 50% world’s population [1]. The world population is estimated to increase 9-11 billion by the year 2025 out of which 4.3 billion people will have to depend on rice for their basic food [2]. Pakistan is the 6th most populous country in the world having population of about 186 million and expected to increase 226 million by the year 2025. So, rice yield will need to be increased manifold to meet the increasing demand of food. In Pakistan, rice is the second major food grain crop after wheat (Triticum aestivum L.) and it is third largest cultivated crop after wheat and cotton (Gossypium hirsutum L.). Three types of rice is grown in Pakistan viz. basmati (aromatic), coarse (IRRI type) and hybrid rice. The yield of basmati and coarse rice is very low and almost remained stagnant for several decades. Pakistan lacks arable land for further extension in area under rice cultivation. Water shortage is also a severe problem for getting higher yield of paddy yield. Hence, there is no chance of escalating more acres under rice cultivation in future and
rice has to produce on less area using limited resources. Cultivation of hybrid rice among the new strategies to increase production per unit area to meet food requirement of population [3] as hybrid rice gives 15-20% more yield than the commercial high yielding varieties. It is reported that rice hybrids yield more due to their vigorous and extensive root system [4]. Proper date of sowing, seedling age for transplantation, optimum spacing for maximum tillering, balanced fertilization, weed control and water management are very crucial for good vegetative growth and for getting higher yield of paddy [5]. Among the improved cultural practices seedling age plays an important role in enhancing the yield of rice. Age of seedling is a key factor which influences the tiller production, grain formation and other yield contributing parameters [6]. Seedling age is the main factor for uniform stand establishment of rice [7] which controls its growth and yield. It was reported that 10-days old seedlings produced more grain yield and yield contributing attributes like plant height, productive tillers, 1000-grain weight and straw yield. Optimum seedling age and transplanting at right time favors the good growth and enhance the tillering capacity of rice [8]. Nitrogen plays a key role in rice production as it is required in huge amount. It is the essential component of cell molecules including chlorophyll, nucleic acids, amino acids and a number of plant hormones. Nitrogen regulates many biochemical processes such as synthesis of protein, carbon metabolism and amino acid metabolism [9]. Application of nitrogen fertilizer either in excess or less than the optimum level both affects yield and quality of rice to the significant extent that’s why optimum use of fertilizer is required not only for getting higher grain yield but also for attaining maximum profit and to protect the environment from hazards of using excessive nitrogen as it pollutes underground water [10]. It is reported that increase in nitrogen level increases panicle length, productive tiller and number of filled grains per panicle leading to increased paddy yield [11, 12]. So, the aim of this study was to optimize the nitrogen rates for hybrid rice transplanted at different seedling ages under the climatic conditions of Pakistan.

2. Materials and Methods

The proposed field study was conducted at the Research Area, University of Agriculture, Faisalabad (Latitude 31.26 °N, Longitude 73.06 °E). The experiment was laid out in Randomized Complete Block Design (RCBD) with factorial arrangement having three replications. The soil texture was clay loam having pH 8.20, EC 2.22 dSm⁻¹, organic matter 1.19%, available nitrogen 0.06%, phosphorus 9.2 ppm and potassium 140 ppm. Hybrid rice (Arize H-64) was tested using four seedling ages (10, 20, 30 and 40-days) and five nitrogen levels (0, 100, 135 and 205 kg ha⁻¹). Nursery was sown using wet method on 20th, 30th May, 10th and 20th June, 2013 respectively. All the varying aged seedlings were transplanted at the same time on 30th June, 2013 in hills with row spacing at 22.5 cm x 22.5 cm keeping plot sizes of 6 m x 2.25 m. The NPK fertilizers in the form of urea, diammonium phosphate (DAP) and sulphate of potash (SOP) were applied. All of P and K fertilizers while 1/3rd of nitrogen fertilizer were applied prior to transplanting as a basal dose. Remaining nitrogen was divided in to two equal splits and applied at two critical stages of growth i.e. first at tillering and other at anthesis (panicle initiation). Phosphorus and potassium were used at the recommended rate of 115 and 60 kg ha⁻¹. The water depth was maintained at about 4-5 cm during transplanting and raised gradually to about 5-7 cm one week after transplantation to avoid seedling mortality and to facilitate early rooting. Dead/uprooted hills were replanted during this period. For weed control Butachlor (Machete 60 EC) was applied @ 800 mL ha⁻¹ 7 days after transplanting in standing water (Reddy, 2004). Carbafuron (Furadan 3G) was broadcasted @ 25 kg ha⁻¹ 55 days after transplanting to protect the crop from stem borers and leaf folders. Irrigation was withheld when the signs of physiological maturity appeared in order to facilitate harvesting. Harvesting was done manually when panicles fully ripened containing about 23-25% moisture. The collected data was analyzed statistically by employing the Fisher analysis of variance technique (Steel et al., 1997) and treatment means were compared by using Least Significance Difference (LSD) test at 5% probability level.

3. Results and Discussion

3.1. Plant Height

Varying levels of seedling age (10, 20, 30 and 40 days) had significant effect on plant height (Table 1). Maximum plant height (86.79 cm) was observed in S. A₁ (10-days old seedlings) followed by S. A₂ (20-days old seedlings) while minimum plant height (78.07 cm) was recorded in S. A₄ (40-days old seedlings). The increase in plant height from younger seedlings might be due to better stand establishment and less transplanting shock because of lesser leaf area which enhanced cell division causing more stem elongation [13]. Our results are in line with findings [14] who reported highest plant height in treatments where younger seedlings were transplanted.

Different levels of nitrogen fertilizer had significant effect on plant height of hybrid rice (Table 1). Maximum plant height (88.62 cm) was obtained in N₄ treatment @ 205 kg N ha⁻¹ whereas minimum plant height (75.26 cm) was observed in control where no nitrogen was applied. The increase in plant height under N₄ treatment was due to various physiological processes including cell division and cell elongation as well as better absorption and utilization of nitrogen fertilizer. Our results are in line with findings of [14] who reported highest plant height in treatments where maximum nitrogen fertilizer rates @ 200 kg ha⁻¹ were applied to rice crop.
better results than rest of treatment [16]. These results are similar to previous studies reported that increasing the nitrogen fertilizer rate [19].

The productivity of rice plant is greatly dependent on the number of productive tillers (tillers which bears panicle) rather than the total tiller numbers [17]. The interaction effect of seedling age and nitrogen rates on number of productive tillers m⁻² was significant. It was observed from the data given (Table 2) that on overall treatments base S. A₁ (10-days old seedlings) gave more mean productive tillers m⁻² (278.00) at N₂ treatment (205 kg N ha⁻¹) which was statistically at par with the same seedling age at N₁ treatment (170 kg N ha⁻¹) having 276.93 productive tillers m⁻². While minimum productive tillers m⁻² (179.93) were given by S. A₄ (40-days old seedlings) at control N₀ i.e. no nitrogen application. This might be due to less root damage, reduced transplanting shock, better stand establishment and more efficient use of nutrients, light, space etc. which increased plants hill⁻¹ and consequently leading to increased effective tillers m⁻². This interaction between seedling age and nitrogen rates on number of productive tillers was confirmed [18]. In the previous studied reported more effective tillers in younger seedlings [14]. While another studied reported the increased number of productive tillers by increasing the nitrogen fertilizer rate [19].

3.2. Number of Tillers m⁻²

Dynamics of tillering greatly depends on the age of seedling at transplanting [15]. Data in (Table 1) showed the significant effect of varying levels of seedling age (10, 20, 30 and 40-days) on number of tillers m⁻². Results revealed that maximum number of tillers m⁻² (292.81) were produced when S. A₁ (20-days old seedlings) was transplanted and it was statistically at par with S. A₁ (10-days old seedlings) which were 274.83 while minimum number of tillers m⁻² (233.03) were observed when S. A₄ (40-days old seedlings) were transplanted. The young seedlings recorded more plant height and number of tillers hill⁻¹ due to better roots growth, cell division and cell enlargement having increased photosynthetic rate [13]. These results are similar to reported that 20 days old seedlings gave significantly better results than rest of treatment [16].

Varying levels of nitrogen fertilizer had significant effect on number of tillers m⁻² (Table 1) as nitrogen plays an important role in increasing total no. of tillers m⁻² of rice hybrid. Data revealed that maximum number of tillers m⁻² (290.70) were produced in N₂ treatment (205 kg N ha⁻¹) which was statistically at par with the N₂ treatment (170 kg N ha⁻¹) which produced 276.28 tillers m⁻² whereas minimum number of tillers m⁻² (233.67) were observed in control N₀ where no nitrogen was applied. Results showed the significance of nitrogen on tillering of hybrid rice. Our findings are in accordance to the results reported increased number of tillers per plant in hybrid rice by increasing nitrogen fertilizer rate up to 200 kg ha⁻¹ [14].

3.3. Number of Productive Tillers m⁻²

Influence of seedling age and nitrogen rates on Productive tillers and non-bearing tillers m⁻² of Hybrid rice. Our findings are in accordance to the results reported increased number of tillers per plant in hybrid rice by increasing nitrogen fertilizer rate up to 200 kg ha⁻¹ [14].
3.4. Number of Non-bearing Tillers m⁻²

The interaction effect of seedling age and nitrogen rates on number of non-bearing tillers m⁻² was highly significant. It was observed from the data (Table 2) that on overall treatments base S. A₁ (40-days old seedlings) gave more non-bearing tillers m⁻² (48.94) at control N₀ (no nitrogen application) which was statistically at par when S. A₃ (30-days old seedlings) were transplanted at control N₀. While minimum non-bearing tillers m⁻² (17.36) were given by S. A₁ (10-days old seedlings) at the N₄ treatment (205 kg N ha⁻¹). This is might due to higher leaf areas and higher photosynthetic rates in younger seedlings, which resulted in higher yield formation while increased number of non-productive tillers in older seedlings was due to unfavorable effect of seedling age on tiller production. It is reported that younger seedlings gave significantly better results than older seedlings in producing less number of non-bearing tillers per hill [20]. Nitrogen is a vital nutrient for growth, development, production of assimilates and reproductive performance that’s why increased nitrogen rates results in less non bearing tillers m⁻² as compared to control which has more nonbearing tillers.

4. Panicle Length

Varying levels of seedling age (10, 20, 30 and 40 days) had no significant effect on panicle length. All the treatments were statistically same and no difference was seen among them with respect to panicle length. Data is presented in (Table 1) which showed maximum panicle length (23.71 cm) was recorded in S. A₁ (10-days old seedlings) followed by S. A₂ (20-days old seedlings) while minimum panicle length (21.81 cm) was recorded in (40-days old seedlings). Better panicle length from younger seedlings is because of their good growth and development ability as compared to older ones. Similar results were reported in the other studied [21].

Panicle length varied significantly due to nitrogen fertilizer application (Table 1). The maximum panicle length (24.31 cm) was obtained by N₄ treatment (205 kg ha⁻¹) that was statistically at par with the N₅ treatment (170 kg ha⁻¹). The minimum panicle length (20.68 cm) was observed in control N₀ with no nitrogen application. Sikdar et al. It was stated that panicle length increased significantly with the increasing rate of nitrogen fertilizer [20]. Optimum supply of essential nutrients can uplift the panicle formation and panicle growth. Minimum panicle length in N₃ treatment was due to less nutrient availability which did not meet the requirements of the rice plant to increase panicle length [17]. Our findings are in accordance with the results of other studied [14].

4.1. Number of Spikelets Panicle⁻¹

Interaction effect between seedling age and nitrogen rates was significant on number of spikelets/grains per panicle was significant among treatments. It was observed from the data (Table 3) that on overall treatments base S. A₁ (10-days old seedlings) gave more mean number of spikelets per panicle (197.17) at N₄ treatment (205 kg N ha⁻¹) followed by S. A₂ (20-days old seedlings) at N₁ treatment (170 kg N ha⁻¹). While minimum number of spikelets per panicle (115.90) was recorded in S. A₄ (40-days old seedlings) at control N₀. It is generally recognized that the number of spikelets/grains per panicle determines rice yield depending upon the cultivar [22]. Our results are supported by findings of already reported studied [21, 23]. They reported that younger seedlings produced maximum numbers of spikelets per panicle when compared with older seedling due to their better nutrition uptake and growth rate. Optimum supply of essential nutrients can uplift the panicle formation and panicle growth which gives maximum number of grains per panicle. Our results are supported by findings of [21] that maximum numbers of spikelets per panicle were obtained when maximum level of nitrogen fertilizer was applied.

4.2. Number of Filled Grains Panicle⁻¹

It is generally recognized that number of panicles per unit area and number of filled grains per panicle determines rice yield depending upon the cultivar [22]. Interaction effect of seedling age and nitrogen rates on number of filled grains panicle⁻¹ was significant. It was observed from the data given in (Table 3) that on overall treatments base S. A₁ (10-days old seedlings) gave more filled grains per panicle (174.26) at N₄ treatment (205 kg N ha⁻¹) followed by same seedling age at N₃ treatment (170 kg N ha⁻¹). While minimum number of kernels per panicle (74.26) was recorded in S. A₄ (40-days old seedlings) at control N₀. Same interaction was reported by [18].
4.3. **1000-Kernel Weight**

Data regarding 1000-kernel weight presented in (Table 3) had exhibited significant effect of seedling age on 1000-kernel weight. On over all means basis S. A1 (10-days old seedlings) produced maximum 1000-kernel weight (23.78 g) which was significantly higher than other treatments and was statistically same with S. A2 (20-days old seedlings). Minimum 1000-kernel weight was recorded from S. A3 (40-days old seedlings) which was 20.08 g. Grain yield in rice depends mainly on number of spikelets per panicle, spikelet filling % and 1000-grain weight [18]. Higher kernel weight in case of S. A1 (10-days old seedlings) might be due to the proper crop growth, development, assimilates synthesis and translocation to the grains.

Different nitrogen rates also shown significant effect on 1000-kernel weight. Data regarding 1000-kernel weight presented in (Table 3) had been due to the increase in chlorophyll content of leaves which led to higher photosynthetic activities of the plants leading to increased photosynthetic rates [25].

Grain yield was significantly affected by the combined effect of seedling age and nitrogen rates. It was observed from the data given in (Table 5) that on overall treatments base S. A1 (10-days old seedlings) gave more mean grain yield (9482.0 kg ha⁻¹) at N₄ treatment (205 kg N ha⁻¹) which was statistically at par (9135.7 kg ha⁻¹) at same seedling age using N₁ treatment (170 kg ha⁻¹). While minimum grain yield (2434.6 kg ha⁻¹) was recorded in S. A₃ (40-days old seedlings) at control N₀. Same interaction was reported by [18]. Higher paddy yield by younger seedlings is might be due to the vigorous and healthy growth, more productive tillers and leaves ensuring larger resource utilization as compared to the old age seedlings. Similar results reported by [14]. Grain yield is a function of productive tillers, 1000-kernel weight and balanced application of NPK nutrients [17]. Increased grain yield in N₄ may be due to the favorable growth with higher nutrient uptake, more translocation of carbohydrates towards the sink which increased yield attributes and resulted in producing higher grain yield [26]. Similar results reported by [25].

5. **Paddy Yield**

Grain yield was significantly affected by the combined effect of seedling age and nitrogen rates. It was observed from the data given in (Table 5) that on overall treatments base maximum straw yield (11879 kg ha⁻¹) was recorded in S. A₁ (10-days old seedlings) at N₄ treatment (205 kg N ha⁻¹) followed by S. A₃ (30-days old seedlings) at the same nitrogen level. While minimum straw yield (4609 kg ha⁻¹) was recorded in S. A₄ (40-days old seedlings) at control N₀ (without N application). Increased straw yield may be due to increased plant height, leaf area, tiller production and dry matter accumulation [27]. It was reported similar results of higher straw yield with younger seedlings (10-days old) [14]. Higher straw yield by the application of increased nitrogen rates is due to the fact that N encourages biomass development in almost all the plants by enhancing cell elongation, building new meristematic cells and increasing photosynthetic activities of the plants leading to increased straw yield [25].

6. **Straw Yield**

Straw yield was significantly affected by the combined effect of seedling age and nitrogen rates. It was observed from the data given in (Table 5) that on overall treatments base maximum straw yield (11879 kg ha⁻¹) was recorded in S. A₁ (10-days old seedlings) at N₄ treatment (205 kg N ha⁻¹) followed by S. A₃ (30-days old seedlings) at the same nitrogen level. While minimum straw yield (4609 kg ha⁻¹) was recorded in S. A₄ (40-days old seedlings) at control N₀ (without N application). Increased straw yield may be due to increased plant height, leaf area, tiller production and dry matter accumulation [27]. It was reported similar results of higher straw yield with younger seedlings (10-days old) [14]. Higher straw yield by the application of increased nitrogen rates is due to the fact that N encourages biomass development in almost all the plants by enhancing cell elongation, building new meristematic cells and increasing photosynthetic activities of the plants leading to increased straw yield [25].

### Table 4. Influence of seedling age and nitrogen rates on 1000-kernel weight and Harvest Index of Hybrid rice.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>1000-kernel weight (g)</th>
<th>Harvest index (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seedling age (days)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 days</td>
<td>23.78 a</td>
<td>43.40 a</td>
</tr>
<tr>
<td>20 days</td>
<td>23.21 a</td>
<td>44.22 a</td>
</tr>
<tr>
<td>30 days</td>
<td>21.61 b</td>
<td>39.92 b</td>
</tr>
<tr>
<td>40 days</td>
<td>20.08 c</td>
<td>38.00 c</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>1.49</td>
<td>1.57</td>
</tr>
<tr>
<td>Nitrogen levels (kg/ha)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>19.64 d</td>
<td>36.76 c</td>
</tr>
<tr>
<td>100</td>
<td>21.32 c</td>
<td>39.46 d</td>
</tr>
<tr>
<td>135</td>
<td>22.28 bc</td>
<td>41.27 c</td>
</tr>
<tr>
<td>170</td>
<td>23.22 ab</td>
<td>43.52 b</td>
</tr>
<tr>
<td>205</td>
<td>24.39 a</td>
<td>46.15 a</td>
</tr>
<tr>
<td>LSD 5%</td>
<td>1.67</td>
<td>1.76</td>
</tr>
<tr>
<td>Interaction</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

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

### Table 5. Influence of seedling age and nitrogen rates on paddy yield and straw yield of Hybrid rice.

<table>
<thead>
<tr>
<th>Nitrogen (kg ha⁻¹)</th>
<th>Paddy Yield kg ha⁻¹</th>
<th>Straw Yield kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seeding Age (days)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>3453.9 j</td>
<td>3379.6 j</td>
</tr>
<tr>
<td>135</td>
<td>7103.5 efg</td>
<td>6954.4 fg</td>
</tr>
<tr>
<td>170</td>
<td>8263.2 BCD</td>
<td>8005.3 CDE</td>
</tr>
<tr>
<td>205</td>
<td>9135.7 AB</td>
<td>8172.0 CD</td>
</tr>
<tr>
<td>Means</td>
<td>7487.7 A</td>
<td>7064.7 B</td>
</tr>
</tbody>
</table>

LSD 5% (S=421.70, N=471.48, S×N=942.95) (S=618.78, N=691.82, S×N=1383.6)

Means sharing the same letters are statistically similar at P ≤ 0.05
7. Harvest Index

Harvest index reflects the partitioning of photosynthates between the grain and the vegetative part of the plant. Different levels of seedling age had significant effect on harvest index (Table 4). S. A2 (20-days old seedlings) gave maximum harvest index (44.42%) which was statistically same with S. A1 (10-days seedlings) whereas S. A4 (40-days old seedlings) gave minimum harvest index (38.00%). Higher HI in younger seedlings might be due to the better crop growth, development and assimilates translocation to the grains. Similar findings were reported by [14].

It is clear from the table 4 that the effect of different nitrogen rates on harvest index is remarkably significant. The harvest index was the highest (46.15%) in N4 treatment where nitrogen was applied @ 205 kg ha-1 and the lowest harvest index (36.76%) was observed in control N0 where no nitrogen was applied. Our findings are in accordance with [27] who reported highest harvest index when maximum level of nitrogen was applied @ 156 kg ha-1.

Maximum paddy yield (7487.7 kg ha-1) was produced when 10-days old seedlings were transplanted while minimum (4735.9 kg)

8. Conclusion

It is concluded that seedling age and nitrogen rates had significant effect on total tillers m-2, productive tillers m-2, panicle total grains, filled grains panicle-1, grain and straw yield ha-1) was observed in 40-days old seedlings. Yield and yield components were also recorded higher for 10-days old seedlings. Regarding nitrogen levels 205 kg N ha-1 gave maximum (7899.7 kg ha-1) paddy yield which was statistically at par with the application of 170 kg N ha-1 while minimum (3197.9 kg ha-1) paddy yield was obtained at control with no nitrogen fertilization. So, the optimal suggested nitrogen rate is 170 kg N ha-1 along with 10-days old seedling for hybrid rice under the climatic conditions of Pakistan. It is also economically feasible for small farmers

References


