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# Growth, Kernel Quality and Yield Assessment of Aerobic Aromatic Rice (*Oryza sativa* L.) Under Different Mulching Types and Spatial Arrangements

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**Abstract:** Low paddy yield of direct seeded rice (*Oryza sativa* L.) continues to remain a problem particularly in conventional flooded rice producing areas. To evaluate the effect of different mulching techniques and planting patterns on growth, kernel quality and yield of direct seeded rice, a field trial was conducted during 2012. The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement. There were nine treatments in total that were replicated thrice. The net plot size was maintained at 3.0 m × 7.0 m. The results revealed that the maximum leaf area indices of 2.78, 4.44 and 5.26 at 30, 50 and 70 DAS, respectively were given by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch). The highest crop growth rates of 8.18 and 10.51 g $m^{-2}$ $d^{-1}$ during 30-45 and 45-60 DAS, respectively were recorded in plots where there were 62.5 cm spaced four rows strips with plastic mulch ($P_3T_1$). The greatest number of normal kernels (58.5%) were given by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) as there were comparatively less number of sterile kernels (6.5%), abortive kernels (3.9%), chalky kernels (22.6%) and opaque kernels (8.5%). Finally the highest paddy yield (4.8 t $ha^{-1}$) was also produced by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch). Thus by using plastic mulch in 62.5 cm spaced four row strips in direct seeded rice has the potential to give 40% higher paddy yield.

**Key words:** Direct seeded rice · Normal kernel · Paddy yield · Water conservation · Wheat straw mulch

## INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major crops which serve as a staple food for more than half of world's populace. This crop requires standing water of 5-10 cm from transplanting till harvesting in traditional transplanted puddled cultivation [1]. However many parts of rice growing regions particularly Asia that provides 75% of world rice supply [2, 3] are facing water scarcity due to more consumption of water in domestic and industrial sectors [4]. In order to cope with emerging water shortages, a variety of techniques to conserve soil moisture has been developed such as saturated soil culture [5], alternate wetting and drying [6], ground-cover systems of rice intensification, raised beds [7], seed priming [8], use of osmo-protectants [9] and silicon nutrition. Direct seedling rice which is the practice of establishing the crop in the field directly from seeds without raising nursery and transplanting [10] is now being considered as an alternative of conventional flooded cultivation of rice [11, 12]. Direct seedling of rice (DSR) omits three practices as puddling (a practice of compacting soil to prevent water percolation), transplanting of seedlings from nursery to field and maintaining the standing water throughout the growing season [13] and thus reduces water requirement up to 30% along with labor requirement [14, 15]. However the provision of soil cover in direct seeded rice is of the utmost importance to minimize the loss of moisture, nutrients [16] and to prevent the weed infestation [17] which is a major problem in direct seeded rice (DSR). In direct seeded rice, of agronomic practices, planting pattern is vital to ensure good seed germination, reduce intra-plant competition for light, moisture, air, nutrients etc. efficient utilization of land as well as to reduce weed population [18-22].

The present study was designed with the dual objectives of assessing the comparative efficacy of different mulches as well as to evaluate the role of different planting patterns in increasing the growth and paddy yield of direct seeded rice.

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## MATERIALS AND METHODS

This field trial to evaluate the comparative efficacy of wheat straw and plastic mulch on growth and yield of direct seeded rice sown at different planting patterns was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (Latitude 31.26 °N, Longitude 73.06 °E) during 2012. Pre-sowing physico-chemical analysis of experimental site was conducted as shown in Table 1. The experiment was laid out in a randomized complete block design (RCBD) with factorial arrangement. The net plot size was 21 $m^2$ (3.0 m × 7.0 m). Wheat straw was used @ 5 t $ha^{-1}$ for mulching along with plastic mulch in black color. Seeds of fine rice (cv. Super Basmati) were sown with hand drill on May 27, 2012 as per treatments. The experimental treatments comprised of no mulch, plastic mulch and wheat straw mulch, while planting patterns were 25cm spaced single rows, 37.5 cm spaced double row strips and 62.5 cm spaced four row strips. Fertilizers were applied @ 140- 90- 70 kg NPK $ha^{-1}$ as urea, di-ammonium phosphate (DAP) and sulphate of potash. Whole quantity of phosphorous and potash were applied as basal dose prior to seeding whereas nitrogen was applied in three splits. Half of the nitrogen was applied at the time sowing and remaining half was applied in two equal splits each at tillering and panicle initiation stages of rice. Observations on growth and paddy yield were recorded by following the standard procedures. Leaf area was measured with the help of digital leaf area meter (Model CI203, CID Bioscience, USA). Leaf area indices (LAI) of rice were recorded at 30, 50 and 70 days after sowing (DAS) by following the formula as suggested by Hunt [23].

$$LAI = \text{Crop Leaf area } (m^2) / \text{Land area } (m^2)$$

Crop growth rate (CGR) was calculated as suggested by Hunt (1978).

$$CGR = (W_2 - W_1) / (t_2 - t_1)$$

Where $W_2$ and $W_1$ are the dry weights at times $t_2$ and $t_1$, respectively.

Fresh weights were taken from five randomly selected plants and then oven dried to calculate dry weight. Kernel quality was assessed form five randomly selected plants and manually counting different types of kernels.
Harvest index (HI) was calculated as suggested by Hunt [23]

$$HI = \text{Paddy yield/ Biological yield} \times 100$$

Data collected were analyzed statistically using MSTAT-C, a computer package for statistical analysis [24] and difference among treatments means were compared by employing least significant difference (LSD) test at 5% level of probability [25].

Table 1: Pre-sowing physico-chemical analysis of experimental soil from samples taken at 30 cm and 60 cm depth

| Characteristics | Recordings | |
|---|---|---|
| Physical analysis | 30 cm depth | 60 cm depth |
| Sand (%) | 59 | 61 |
| Silt (%) | 19.5 | 20 |
| Clay (%) | 21.5 | 19 |
| Textural class | Sandy clay loam | Sandy clay loam |
| Chemical analysis | | |
| pH | 7.9 | 7.7 |
| EC ($dSm^{-1}$) | 1.41 | 1.50 |
| Organic matter (%) | 0.62 | 0.67 |
| Total Nitrogen (%) | 0.057 | 0.051 |
| Available Nitrogen (ppm) | 6.5 | 6.3 |
| Available potassium (ppm) | 115 | 119 |

ppm= Parts per million

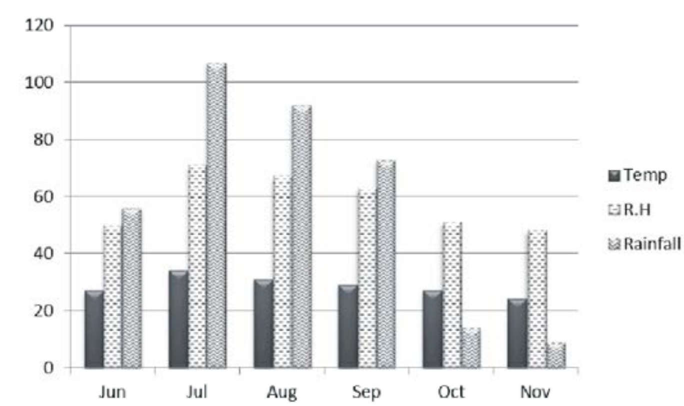


Fig. 1: Mean monthy temperature (ºC), relative humidity (%) and rainfall (mm) during the growing season of direct seeded rice.

## RESULTS AND DISCUSSION

**Crop Growth and Development:** As Table 2 indicates that the maximum leaf area indices (LAI) of 2.78, 4.44 and 5.26 at 30, 50 and 70 DAS, respectively were given by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) and it was followed by $P_3T_2$ (62.5 cm spaced four rows strips with wheat straw mulch) and this pattern was observed throughout the duration of study at 30, 50 and 70 days after sowing (DAS). The higher leaf area indices increment occurred during 30-50 days after sowing as compared to other 0-30 and 50-70 days after sowing as evident from Table 2, while the minimum leaf area indices were given by $P_1T_0$ (25 cm spaced single rows strips with no mulch). Similarly higher crop growth rate was recorded during 30-45 and 45-60 days after sowing (DAS) and as Figure 2 reveals the fact that comparatively high crop growth rates of 8.18 and 10.51 g $m^{-2}$ $d^{-1}$ during 30-45 and 45-60 DAS, respectively were recorded in plots where there were 62.5 cm spaced four rows strips with plastic mulch ($P_3T_1$). It was followed by $P_3T_2$ (62.5 cm spaced four rows strips with wheat straw mulch) which gave 7.65 and 9.77 g $m^{-2}$ $d^{-1}$ during 30-45 and 45-60 DAS, respectively, while the minimum crop growth rate were given by $P_1T_0$ (25 cm spaced single rows strips with no mulch). Leaf area index is an important physiological growth parameter as more leaf area results in better photosynthesis rate. The higher leaf area shows more leaf growth and higher leaf growth results in better economic yield because the leaves are the vital photosynthesizing plant organs. 62.5 cm spaced four row strips with plastic mulch gave significantly higher leaf area indices of rice with passage of time due to more leaves formation as well as leaf expansion as better moisture and nutrient retention was made by plastic mulch as compared to wheat straw mulch. More water availability increased photosynthesis rate because

Table 2: Leaf area indices (LAI) of direct seeded rice as influenced by different mulching types and planting patterns

| | Leaf area indices | | |
|---|---|---|---|
| Treatments | 30 DAS | 50 DAS | 70 DAS |
| $P_1T_0$ (25 cm spaced single rows strips with no mulch) | 1.69 f | 3.13 f | 3.80 e |
| $P_1T_1$ (25 cm spaced single rows strips with plastic mulch) | 1.92 e | 3.90 c | 4.89 c |
| $P_1T_2$ (25 cm spaced single rows strips with wheat straw mulch) | 2.48 d | 4.01 b | 4.71 d |
| $P_2T_0$ (37.5 cm spaced double rows strips with no mulch) | 2.52 c | 3.15 d | 4.91 c |
| $P_2T_1$ (37.5 cm spaced double rows strips with plastic mulch) | 2.24 g | 3.87 c | 5.17 b |
| $P_2T_2$ (37.5 cm spaced double rows strips with wheat straw mulch) | 2.42 d | 3.73 d | 4.47 e |
| $P_3T_0$ (62.5 cm spaced four rows strips with no mulch) | 2.45 d | 4.00d | 4.92 c |
| $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) | 2.78 a | 4.44 a | 5.26 a |
| $P_3T_2$ (62.5 cm spaced four rows strips with wheat straw mulch) | 2.66 b | 3.76d | 5.18 b |
| LSD 0.05 | 0.12 | 0.68 | 0.08 |

DAS= Days after sowing

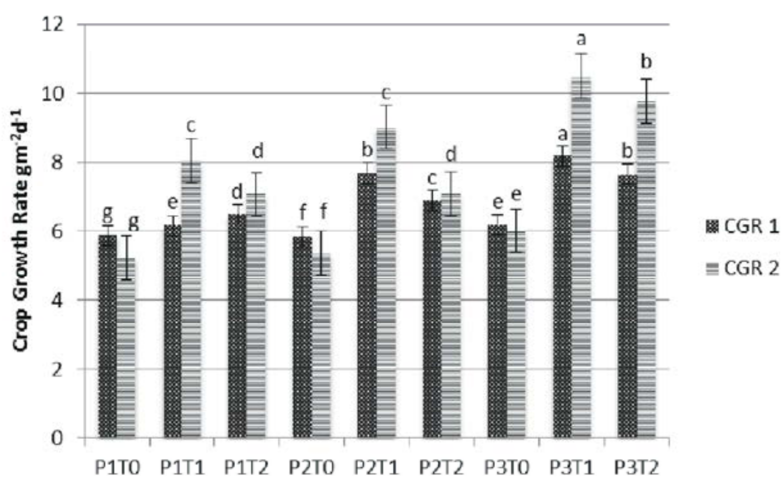


Fig. 2: Crop growth rates (CGR) ($gm^{-2}d^{-1}$) of direct seeded rice as influenced by different mulching types and planting patterns

Table 3: Sterile (%), abortive (%) and chalky (%) kernels of direct seeded rice as influenced by different mulching types and planting patterns

| Treatments | Sterile kernel (%) | Abortive kernel (%) | Chalky kernel (%) |
|---|---|---|---|
| $P_1T_0$ (25 cm spaced single rows strips with no mulch) | 12.38 b | 6.10 b | 20.25 |
| $P_1T_2$ (25 cm spaced single rows strips with plastic mulch) | 7.36 f | 6.15 e | 20.38 |
| $P_1T_3$ (25 cm spaced single rows strips with wheat straw mulch) | 9.58 d | 4.35 d | 20.30 |
| $P_2T_0$ (37.5 cm spaced double rows strips with no mulch) | 13.23 a | 6.71 a | 20.35 |
| $P_2T_1$ (37.5 cm spaced double rows strips with plastic mulch) | 8.71 e | 4.33 d | 20.29 |
| $P_2T_2$(37.5 cm spaced double rows strips with wheat straw mulch) | 10.77 c | 4.32 d | 20.33 |
| $P_3T_0$ (62.5 cm spaced four rows strips with no mulch) | 10.79 c | 5.86 c | 20.25 |
| $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) | 6.53 g | 3.78 g | 22.60 |
| $P_3T_2$ (62.5 cm spaced four rows strips with wheat straw mulch) | 8.58 d | 4.15 e | 20.41 |
| LSD 0.05 | 0.85 | 0.61 | N.S |

N.S= Non-significant

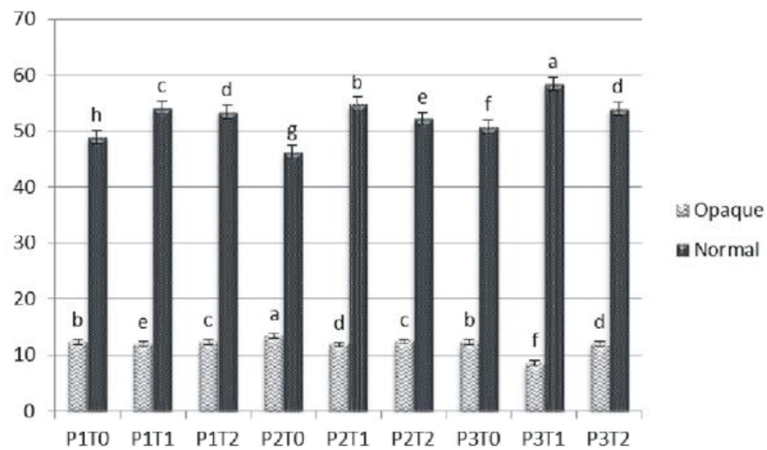


Fig. 3: Normal kernels (%) of direct seeded rice as influenced by different mulching types and planting patterns

plastic mulch prevented percolation which sometimes account for 70-80% of water loss in light textured soils [26]. This finding is in agreement with those obtained by Bhagirath *et al.* [27] and Cabuslay *et al.* [28], who stated that when mulches are applied, more vigorous growth of plants takes place due to water conservation and weed control, while wheat straw mulch was less efficient in preventing weeds infestation as well conserving soil moisture. More crop growth rate occurred where 62.5 cm spaced four rows strips with plastic mulch was used because plastic mulch not only controlled weeds infestation but also conserved moisture, because for water to evaporate water needs to change form liquid to vapor and then diffuse through plastic mulch [29]. Moisture was also conserved because there was less direct solar radiation striking the soil due to plastic mulch hence less evaporation. Leaf area indices (LAI) are also closely correlated with crop growth rate (CGR) as larger leaf area intercepts more photo-synthetically active radiation (PAR) and hence more crop growth rate takes place. These results are in confirmation with the findings of Mahajan *et al.* [22] and Iqbal and Ali [30], who reported more crop growth rate in rice due to mulches and narrow lines of rice crop.

**Kernel Quality:** As Figure 3 shows that the maximum number of normal kernels (58.5%) were given by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) as in these plots there less were number of sterile kernels (6.5%), abortive kernels (3.9%), chalky kernels (22.6%) (Table 3) and opaque kernels (8.5%) and it was followed by $P_1T_2$ (25 cm spaced single rows strips with plastic mulch), but it was much less significant than $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) as there were comparatively more sterile, abortive and opaque kernels. The minimum number of normal kernels were given by $P_1T_0$ (25 cm spaced single rows strips with no mulch) (Fig. 3). Treatment with plastic mulch performed comparatively better than no mulch and wheat straw mulch. The number of normal kernels is an important morphological and physiological indicator of grain yield in rice [31]. The number of normal kernels always serves as grain yield

Table 4: Paddy yield (t $ha^{-1}$), biological yield (t $ha^{-1}$) and harvest index (%) of direct seeded rice as influenced by different mulching types and planting patterns

| Treatments | Paddy yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | HI (%) |
|---|---|---|---|
| $P_1T_1$ (25 cm spaced single rows strips with no mulch) | 3.29 g | 9.62 de | 29.27 de |
| $P_1T_2$ (25 cm spaced single rows strips with plastic mulch) | 4.04 b | 11.87 bc | 34.29 bc |
| $P_1T_3$ (25 cm spaced single rows strips with wheat straw mulch) | 3.45 d | 10.72 cd | 30.80 cd |
| $P_2T_0$(37.5 cm spaced double rows strips with no mulch) | 3.29 g | 9.21 de | 29.17 de |
| $P_2T_1$ (37.5 cm spaced double rows strips with plastic mulch) | 4.07 b | 11.17 bc | 32.89 bc |
| $P_2T_2$(37.5 cm spaced double rows strips with wheat straw mulch) | 3.39 e | 9.80 de | 30.64 cd |
| $P_3T_0$ (62.5 cm spaced four rows strips with no mulch) | 3.33 f | 10. 0 de | 30.60 cd |
| $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) | 4.86 a | 13.30 a | 35.53 a |
| $P_3T_2$ (62.5 cm spaced four rows strips with wheat straw mulch) | 3.61 c | 10.70 cd | 32.42 bc |
| LSD 0.05 | 0.79 | 0.26 | 2.47 |

t $ha^{-1}$= ton per hectare

limiting factor in rice and is strongly influenced by plant nutrition, particularly nitrogen [32]. Though rice can utilize both forms of nitrogen but which form favors the most in direct seeded rice needs further investigation. Higher crop growth rate was closely related to normal kernel production as abortive and sterile kernels are produced due to less availability of nitrogen. These finding are in line with those reported by Fan *et al.* [7], who stated better quality kernels under the influence of mulching and planting pattern in direct seeded rice.

**Paddy Yield, Biological Yield and Harvest Index:** Finally the highest grain yield (4.8 t $ha^{-1}$) was recorded by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) and it was followed by $P_2T_1$ (37.5 cm spaced double rows strips with plastic mulch) that was statically at par with $P_1T_2$ (25 cm spaced single rows strips with plastic mulch) as shown in Table 4, while the minimum paddy yield was given by $P_1T_1$ (25 cm spaced single rows strips with no mulch). The highest biological yield (13.3 t $ha^{-1}$) and harvest index (35.53) were recorded by $P_3T_1$ (62.5 cm spaced four rows strips with plastic mulch) and it was followed by $P_2T_1$ (37.5 cm spaced double rows strips with plastic mulch). Comparatively higher paddy yield was due to cumulative effect of more leaf area indices (LAI), crop growth rate (CGR) as well as the number of normal kernels. Higher leaf area resulted in accelerated crop growth rate and ultimately more number of normal kernels was produced. More vegetative growth resulted in higher biological yield and harvest index as a result of better utilization of soil and environmental resources by employing plastic mulch and close planting pattern. These finding are in agreement with those obtained by Alam *et al.* [33], who reported more chlorophyll contents due to nitrogen application and more normal kernels and yield was achieved due to moisture and nutrients conservation by using plastic mulch along with better weeds control due to planting pattern.

## CONCLUSIONS

Surface covering by plastic sheet mulch along with 62.5 cm spaced four row strips of direct seeded rice has the potential to give significantly higher paddy yield (47%) by increasing leaf area indices, crop growth rate and number of normal kernels. This appears to be due to moisture conservation by plastic mulch, preventing direct striking of solar radiation to soil, better nutrient retention in root zone and weed control. However, there is a dire need to conduct in-depth research to explore the production potential of different organic and inorganic mulches in relation to planting geometries while keeping in view the economics of different mulches.

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