UDC 575.633
https://doi.org/10.2298/GENSR2201027K
*Original scientific article*

# PERFORMANCE OF BASMATI RICE (*Oryza sativa* L.) GENOTYPES UNDER DIFFERENT CROP ESTABLISHMENT METHODS

Hari KESH*[1] and Khushi RAM[2]

[1]Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar-125001 (India)
[2]Rice Research Station, Kaul-136021, CCS Haryana Agricultural University, Hisar-125001 (India)

Kesh H. and K. Ram (2022). *Performance of basmati rice (Oryza sativa L.) genotypes under different crop establishment methods*. - Genetika, Vol 54, No.1, 27 - 42.
The study was conducted to evaluate the performance of thirty-six Basmati rice genotypes for yield and its related traits under direct-seeded rice (DSR), system of rice intensification (SRI), chemical-free cultivation (CFC), and conventional transplanted rice (TPR).The genotypes were evaluated for two years at two locations in randomized block design with three replications. Genotype Pusa Basmati 1121 scored highest ~22% yield increase in system of rice intensification method over transplanted rice followed by Pusa Basmati 1 (~20%) genotypes HKR 11-447 (~18 %). Genotype Pusa Basmati 1, Pusa Basmati 1637-2-8-20-5 and Pusa Basmati1734-8-3-85 produced 8-16 % higher yield in chemical-free cultivation in comparison toTPR. Genotypes HKR 98-476, CSR 30, PAU 6297-1 yielded equally in DSR as well as in TPR. All the genotypes under study showed earlier flowering and maturity in DSR followed by SRI and TPR=CFC. Pusa Basmati 1509recordedthe earliest flowering across the environments. Most of the genotypes showed an increase in panicle weight, number oftillers per plant, number of spikelets per panicle, percent filled spikelets, Biological yield, and grain yield under SRI over other methods of rice crop establishment. Among different methods,SRI was found best thanTPR, CFC, and DSR (wet).
*Key words:* Rice, water, direct-seeded rice, system of rice intensification, chemical-free cultivation, transplanted rice, water.

## INTRODUCTION

In transplanting method (TPR), a huge requirement of water for paddy cultivation, increasing labor rate for puddling operation, nursery uprooting and transplanting, formation of hard-pan and reduction in soil permeability due to puddling, shrinking of water resources, and

*Corresponding author:* Hari Kesh, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar-125001, India, email harikeshkaul55@gmail.com

labor shortage necessitates the development of an alternative method of rice planting that demands less water in comparison to TPR (PANDEY and VELASCO, 1999; BOUMAN *et al.*, 2005; FAROOQ *et al.*, 20011; MONACO *et al.*, 2016; RASUL, 2014).To overcome the water scarcity problem, several methods demanding less water has been proposed such as system of rice intensification (SRI) (LAULANIE, 1993), alternate wetting and drying (BOUMAN and TUONG, 2001), direct dry seeding (TABBAL *et al.*, 2002), aerobic rice culture (BOUMAN *et al*., 2005) and non-flooded mulching cultivation (TAO *et al.*, 2006) as an alternative to TPR.In recent years, two water-saving methods*viz.*, direct-seeded rice (DSR) and system of rice intensification (SRI) are gaining momentum in many South Asian countries (PANDEY and VELASCO, 2002). DSR method offers several advantages over TPR such as earlier flowering (FAROOQ *et al.*, 2006a), early maturity (BALASUBRAMANIAN and HILL, 2002), required 40-50% less labor (PANDEY and VELASCO, 1999; PATHAK *et al*., 2011), demand 35-40% (BHUSHAN *et al.*, 2007)less water for preparation of field, less greenhouse gas emission (PANDEY and VELASCO, 1999; WELLER *et al.*, 2016). However there are some challenges in the adoption of DSR such as high weed infestation, increase soil-borne pathogens, high nitrous oxide emission, weedy rice, diseases and pests, seeds are directly exposed to rats and birds, and immediate rain after seed sowing have an adverse effect on crop establishment (RAO *et al.*, 2007; KUMAR and LADHA, 2011; ISHIBASHI *et al.*, 2007; HOU *et al.*, 2000; KAUR and SINGH, 2017). However, due to water and labor shortages, farmers are again taking interest in adopting DSR method of paddy cultivation. Another water-saving method is system of rice intensification (SRI) which is first used by Laulanı´e in 1983. The major components of this method are planting of 8-12 days young seedling, one seedling is planted per hill with 25 x 25 cm spacing, water is applied 3-6 days interval, the soil is kept moist, manual or mechanical weeding should be applied to control the weeds and for soil aeration and use of organic manures (UPHOFF *et al.*, 2011). High water use efficiency coupled with high grain yield was reported under SRI over traditionally used methods (SATO and UPHOFF, 2007; PANDISELVI *et al.*, 2010). Excessive use of pesticides and chemical fertilizers causes deterioration of soil fertility, deficiency of micronutrients such as zinc and iron, killing off many useful insects, polluted soil, water, and air (HORRIGAN *et al.*, 2002; BHADURI and PURAKAYASTHA, 2011).Therefore it is essential to maintain the soil fertility, productivity, and water quality for sustainable agriculture. Organic farming is believed to sort out many of these problems.The main objective of organic agriculture is to maintain soil health by using FYM and compost, to minimize the use of chemical fertilizers and pesticides, and to control the pest and diseases. An earlier study showed that grain yield and quality wereimproved with the use of FYM and green manuring (BAIG *et al.*, 2004; TRIPATHI and VERMA, 2008; DESPANDEY and DEVASANAPATHY (2010). Therefore the present study was planned to evaluate the performance of basmati rice genotypes for yield and its components under the method of rice crop establishment.

## MATERIAL AND METHODS

*Plant Material*

Thirty-six Basmati rice genotypes namely Basmati 370 (G1), CSR-30 (G2), CSR TPB-1 (G3), Haryana Basmati 1 (G4), Haryana Mahak 1 (G5), HKR -11-509 (G6), HKR 03-408 (G7), HKR 08-417 (G8), HKR 06-434 (G9), HKR 06-443 (G10), HKR 06-487 (G11), HKR 08-425 (G12), HKR 11-447 (G13), HKR 98-476 (G14), HUBR-16 (G15), Improved Pusa Basmati 1

(G16), PAU-6297-1 (G17), Pusa 1475-03-42-45-119-1 (G18), Pusa 1637-2-8-20-5 (G19), Pusa 1656-10-705 (G20), Pusa 1734-8-3-85 (G21), Pusa 1826-12-27-1-4 (G22), Pusa 1884-3-9-175 (G23), Pusa 1884-9-12-14 (G24), PAU 6295-2 (G25), Pusa Basmati 1 (G26), Pusa Basmati 1121 (G27), Pusa Basmati 1509 (G28), Pusa Sugandh 2 (G29), Pusa Sugandh 3 (G30), Pusa Sugandh 5 (G31), Pusa Sugandh 6 (G32), SJR-70-3-2 (G33), Super Basmati (G34), Taraori Basmati (G35) and UPR-386-9-1-1 (G36) were collected from Rice Research Station, Kaul, CCS Haryana Agricultural University (Hisar), Indian Agricultural Research Institute, Regional Research Station (IARI-RRS), Karnal and Central Soil Salinity Research Institute (CSSRI), Karnal were used for conducting the experiment.

*Experimental conditions*

The study was conducted in *Kharif* 2016 and *Kharif* 2017 under four different crop establishment methods (chemical-free cultivation, direct-seeded rice, system of rice intensification, and transplanted rice) at two locations, Rice research station, Kaul (Kaithal), and Regional Research Station, Uchani (Karnal) which falls under the sub-tropical region of North India (Table 1). The soil was clay loam. The genotypes were grown in a Randomized Block Design (RBD) in three replications. Plot size consisted of 5 rows of 1m length. In SRI method, seed rate of 5 kg/ha, 15days oldseedling per hill with25 x 25 $cm^2$ spacing, inorganic fertilization of N(90kg/ha), P(30kg/ha), and K (30kg/ha) and irrigation at 5 days interval upto 90-100 days aftertransplanting (DAT) were practiced. In DSR production system, pre-germinated seeds afterpriming for 24 hours were dibbled at 15 x 20 cm2 spacing in puddled soil surface (wet seeding). Irrigation wasapplied at an interval of 6-7 days when hair cracks developed on the surface. In TPR(conventional) and CFCmethod 27 days old 2-3 seedlings per hill spaced at 15 x20 cm2 were transplanted. The inorganic fertilization of N (90 kg/ha), P (30 kg/ha), and K (30kg/ha) was applied in TPR while in CFC organic fertilization of farmyard manure and vermicomposting at the rate of 5 tone/ha was applied. Irrigation was applied at 3 days intervalup to 90-100 DAT under both TPR and CFC. The seed rate in TPR, DSR, and CFC was 20 kg/ha.

*Table 1. Crop establishment methods*

| Crop establishment methods | | | | | | | |
|---|---|---|---|---|---|---|---|
| CFC K16 | CFCU16 | DSRK16 | DSRU16 | SRIK16 | SRIU16 | TPRK16 | TPRU16 |
| CFCK17 | CFCU17 | DSRK17 | DSRU17 | SRIK17 | SRIU17 | TPRK17 | TPRU17 |
| CFC - Chemical Free Cultivation | | | | DSR – Direct Seeded Rice | | | |
| SRI – System of rice intensification | | | | TPR – Transplanted Rice | | | |
| K 16- Kaul 2016 | | U 16- Uchani 2016 | | K17- Kaul 2017 | | U17 – Uchani 2017 | |

*Quantitative traits*

Data were recorded on a whole plot basis for days to 50% flowering and five plants were selected randomly in each plot for the other quantitative traits i.e number of tillers per plant, panicle length (cm), number of spikelet per panicle, percent filled spikelets (%), thousand-grain weight (g), biological yield per plant (g), grain yield per plant (g) and harvest index (%).

## RESULTS AND DISCUSSION

*Days to 50% flowering*

All the genotypes showed earlier flowering under DSR and SRImethod as compared to TPR. Genotypes under DSR flowered 2 to 11 days and under SRI 3-7 days earlier. Pusa Basmati 1509 in DSR K16; in DSR U16; in SRI K16; in SRI U16; in CFC K16; in CFC U16; in TPR K16; in TPR U16; in DSR K17; in DSR U17; in SRI K17; in CFC K17; in TPR K17; Pusa 1475-03-42-4 in SRI U17; PAU 6297-1 in CFC U17; Pusa 1475-03-42-4 in TPR U17 took minimum days to 50% flowering (Table S1). Pusa basmati 1509 was found earlier in flowering over the sixteen environments followed by Pusa 1475-03-42-4 andgenotype HKR 11-447 was late in flowering.Water shortage during the vegetative phase affects the crop duration by hastening the senescence. This might be due to the early expression of genes relatedto the remobilization of proteins thatare diverted from leaves to reproductive organs (PIC *et al.*, 2002). This reducedlifespan of a crop is considered an adaptive mechanism, as it permits the crop to complete its life cycle before the onset of the dry spell. This reduced crop cycledecreases the total light intercepted and thus the accumulation of biomass and also affects seed weight (TARDIEU, 2013). Early days to flowering and maturity under DSR were noticed by PANDEY and VELASCO (1999), BALASUBRAMANIAN and HILL (2002), FAROOQ *et al.* (2006a) and KUMAR *et al.* (2018). Under SRI, early flowering in BPT-5204 and Pusa Basmati-1 variety of rice was observed by REDDY (2004) and SINGH *et al.* (2004) respectively.

*Number of tillers per plant*

The number of tillers per plant which contribute to grain and the biological yield were found significantly more in SRI and less in DSR and CFC as compared to TPR. Pusa 1734-8-3-85 (14.16) in DSR K16; in DSR U16 (14.33); in CFC U16 (17.38); in DSR K17 (13.53); and in DSR U17 (14.56); Pusa basmati 1121 (21.68) in SRI K16; in SRI U16 (21.31); in TPR K16 (18.08); in TPR U16 (16.38); in SRI K17 (22.18); in SRI U17 (22.45) and in TPR U17 (17.17); Pusa basmati 1 (19.15) in CFC K17; in CFC U17 (17.40) and in CFC K16 (18.41); Pusa Sugandh 5 (17.36) in TPR K17 recorded maximum number of tillers per plant (Table 2). Under SRI, young10-14 days old seedlings are transplanted which gets more time to adjust tothe field conditions and produce more tillers per plant. GRIHTLAHRE *et al.* (2012) observedthat young age seedlings have more potential for tiller production than old age seedlings. One seedling per hill and wide spacing reduces the competition between the plants for light, nutrient uptake, water, and air and significantly enhances the growth of individual rice plants (GANI *et al.*, 2002; THAKUR *et al.*, 2010). Similarly, moist soil provides good aeration to the plant roots. Competition for space, light, moisture, and nutrients between rice and weedswas observed as a major factor for less tiller production under DSR. Pusa 1734-8-3-85 produced the maximum number of tillers per plant across the environments followed by Pusa basmati 1 and Pusa Basmati 1121. QINGQUAN (2002) observed that hybrids have more yield potential under SRI than TPR due to more tillering capacity, resistance to lodging, and wider adaptability.

*Table 2. Mean performance of Basmati rice genotypes under different crop establishment methods for number of tillers per plant*

| | *Kharif* 2016 | | | | | | | | *Kharif* 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | CFCK16 | CFCU16 | DSRK16 | DSRU16 | SRIK16 | SRIU16 | TPRK16 | TPRU16 | CFCK17 | CFCU17 | DSRK17 | DSRU17 | SRIK17 | SRIU17 | TPRK17 | TPRU17 | Mean |
| G1 | 10.07 | 11.64 | 7.73 | 8.91 | 13.06 | 12.62 | 11.46 | 12.68 | 9.68 | 11.21 | 7.94 | 9.15 | 12.50 | 13.34 | 12.40 | 11.76 | 11.01 |
| G2 | 14.20 | 14.05 | 12.64 | 13.18 | 18.34 | 15.45 | 13.89 | 14.27 | 13.42 | 13.41 | 13.23 | 13.45 | 17.58 | 15.90 | 14.51 | 13.42 | 14.43 |
| G3 | 9.46 | 10.58 | 6.81 | 5.83 | 11.18 | 12.16 | 10.26 | 10.44 | 10.19 | 10.98 | 7.16 | 6.12 | 10.71 | 11.44 | 9.70 | 10.91 | 9.62 |
| G4 | 12.77 | 12.90 | 6.38 | 6.73 | 17.18 | 15.38 | 13.21 | 12.66 | 12.08 | 12.50 | 6.00 | 7.18 | 16.88 | 16.18 | 12.34 | 11.90 | 12.02 |
| G5 | 10.38 | 12.3 | 11.98 | 10.70 | 12.68 | 14.94 | 11.91 | 12.28 | 11.18 | 11.76 | 11.58 | 10.96 | 13.08 | 15.68 | 12.36 | 12.88 | 12.29 |
| G6 | 13.83 | 12.86 | 11.86 | 11.54 | 17.68 | 18.87 | 15.01 | 13.31 | 14.33 | 14.02 | 11.98 | 10.93 | 18.1 | 19.34 | 14.15 | 13.85 | 14.48 |
| G7 | 10.03 | 10.22 | 7.13 | 7.97 | 13.52 | 12.94 | 12.33 | 12.05 | 10.32 | 11.24 | 6.83 | 7.78 | 12.92 | 12.45 | 11.5 | 12.84 | 10.75 |
| G8 | 10.36 | 11.62 | 7.10 | 7.58 | 13.84 | 15.88 | 12.38 | 13.06 | 10.79 | 12.14 | 6.56 | 7.38 | 14.15 | 16.41 | 13.18 | 13.88 | 11.65 |
| G9 | 16.02 | 14.16 | 11.8 | 10.80 | 16.16 | 16.58 | 15.85 | 14.24 | 15.44 | 14.79 | 12.28 | 10.96 | 15.87 | 17.08 | 14.91 | 15.16 | 14.51 |
| G10 | 12.68 | 11.48 | 8.76 | 7.64 | 13.64 | 14.28 | 12.28 | 12.94 | 12.08 | 12.27 | 9.08 | 8.15 | 14.05 | 14.88 | 13.08 | 13.70 | 11.94 |
| G11 | 14.34 | 14.83 | 10.61 | 9.58 | 15.15 | 16.70 | 13.97 | 13.52 | 13.71 | 13.63 | 10.95 | 9.90 | 14.51 | 15.78 | 13.18 | 12.58 | 13.31 |
| G12 | 13.30 | 14.22 | 12.28 | 13.08 | 20.88 | 17.33 | 14.50 | 14.66 | 14.06 | 13.85 | 11.64 | 13.68 | 20.28 | 18.63 | 14.86 | 13.82 | 15.07 |
| G13 | 13.99 | 13.71 | 11.38 | 10.53 | 18.98 | 19.25 | 15.34 | 15.93 | 14.69 | 13.30 | 10.98 | 10.93 | 19.33 | 18.36 | 16.68 | 16.69 | 15.00 |
| G14 | 11.26 | 11.72 | 11.94 | 12.07 | 14.14 | 14.98 | 13.92 | 12.32 | 11.90 | 12.20 | 11.82 | 12.48 | 13.82 | 15.68 | 12.76 | 11.73 | 12.79 |
| G15 | 12.88 | 12.51 | 8.6 | 7.54 | 16.68 | 15.41 | 14.49 | 13.41 | 13.27 | 11.93 | 9.15 | 8.02 | 17.02 | 16.03 | 15.17 | 14.69 | 12.93 |
| G16 | 12.40 | 12.94 | 10.45 | 11.08 | 17.68 | 18.24 | 14.43 | 15.58 | 12.96 | 12.22 | 10.70 | 10.88 | 17.18 | 17.51 | 15.24 | 16.77 | 14.14 |
| G17 | 12.21 | 11.23 | 11.50 | 12.41 | 14.7 | 14.82 | 13.09 | 12.72 | 11.55 | 12.12 | 11.28 | 11.65 | 13.98 | 15.35 | 12.37 | 11.98 | 12.68 |
| G18 | 12.72 | 12.38 | 8.71 | 9.45 | 14.48 | 13.47 | 11.84 | 10.96 | 11.84 | 11.78 | 9.06 | 9.11 | 15.16 | 14.38 | 12.62 | 11.80 | 11.86 |
| G19 | 17.37 | 14.50 | 11.5 | 13.58 | 16.13 | 18.06 | 15.10 | 14.58 | 15.98 | 15.18 | 11.15 | 13.28 | 15.78 | 18.48 | 14.34 | 13.74 | 14.92 |
| G20 | 13.48 | 13.99 | 12.83 | 12.46 | 15.28 | 16.54 | 16.36 | 15.14 | 14.88 | 12.78 | 13.12 | 13.00 | 15.07 | 17.02 | 15.52 | 14.36 | 14.49 |
| G21 | 16.39 | 17.38 | 14.16 | 14.33 | 18.58 | 20.38 | 14.92 | 14.86 | 17.16 | 16.68 | 13.53 | 14.56 | 19.24 | 19.76 | 16.23 | 15.5 | 16.48 |
| G22 | 13.92 | 11.83 | 11.70 | 11.18 | 14.78 | 16.86 | 14.54 | 14.2 | 13.33 | 12.73 | 11.86 | 10.78 | 14.38 | 16.30 | 13.42 | 13.43 | 13.45 |
| G23 | 12.98 | 13.94 | 8.83 | 10.78 | 16.29 | 18.02 | 15.31 | 15.74 | 13.48 | 12.81 | 8.62 | 10.58 | 16.00 | 18.74 | 14.45 | 14.61 | 13.82 |
| G24 | 11.48 | 12.37 | 7.38 | 6.93 | 12.88 | 13.23 | 11.58 | 12.44 | 12.08 | 11.7 | 7.58 | 6.71 | 13.31 | 12.67 | 10.40 | 11.28 | 10.88 |
| G25 | 13.83 | 13.02 | 11.85 | 12.93 | 16.64 | 16.30 | 16.63 | 14.92 | 14.53 | 13.73 | 12.00 | 13.31 | 17.43 | 15.62 | 15.58 | 15.58 | 14.62 |
| G26 | 18.41 | 16.26 | 12.48 | 12.36 | 20.20 | 18.34 | 15.8 | 15.56 | 19.15 | 17.40 | 13.07 | 11.92 | 19.47 | 19.02 | 15.36 | 14.40 | 16.20 |
| G27 | 13.74 | 14.78 | 10.12 | 10.68 | 21.68 | 21.31 | 18.08 | 16.38 | 14.12 | 13.68 | 9.83 | 10.98 | 22.18 | 22.45 | 16.78 | 17.17 | 15.87 |
| G28 | 16.75 | 14.8 | 12.04 | 13.42 | 16.53 | 18.97 | 15.38 | 16.00 | 16.00 | 15.36 | 11.85 | 13.07 | 16.98 | 19.38 | 14.18 | 15.16 | 15.37 |
| G29 | 12.52 | 12.9 | 10.82 | 9.63 | 15.28 | 14.55 | 14.88 | 13.48 | 14.03 | 12.06 | 10.63 | 9.92 | 15.61 | 15.14 | 13.58 | 14.14 | 13.07 |
| G30 | 14.21 | 13.22 | 10.54 | 12.23 | 17.88 | 18.12 | 14.08 | 15.92 | 13.74 | 12.74 | 11.16 | 11.84 | 17.48 | 17.44 | 15.62 | 15.43 | 14.48 |
| G31 | 14.12 | 15.35 | 13.33 | 11.81 | 18.98 | 18.32 | 16.44 | 16.05 | 14.63 | 14.52 | 12.84 | 12.14 | 18.58 | 17.77 | 17.36 | 15.38 | 15.48 |
| G32 | 13.27 | 14.93 | 10.78 | 11.76 | 20.58 | 20.18 | 16.50 | 15.35 | 13.48 | 13.82 | 11.12 | 11.96 | 21.66 | 19.34 | 15.78 | 16.24 | 15.42 |
| G33 | 12.96 | 14.28 | 11.06 | 11.88 | 19.88 | 19.22 | 15.44 | 14.55 | 13.76 | 13.42 | 10.70 | 11.48 | 20.40 | 18.75 | 16.24 | 15.83 | 14.99 |
| G34 | 12.14 | 11.34 | 7.88 | 9.43 | 16.36 | 16.72 | 12.85 | 12.81 | 11.47 | 12.46 | 7.59 | 9.96 | 15.44 | 16.12 | 11.72 | 11.18 | 12.22 |
| G35 | 11.38 | 11.68 | 7.08 | 9.54 | 14.10 | 14.20 | 11.30 | 12.86 | 10.78 | 10.87 | 6.69 | 9.22 | 14.58 | 13.70 | 12.11 | 13.44 | 11.47 |
| G36 | 10.71 | 12.26 | 11.76 | 13.05 | 14.48 | 15.85 | 14.39 | 14.13 | 10.25 | 11.40 | 12.12 | 12.70 | 15.28 | 16.71 | 13.91 | 15.51 | 13.41 |
| Mean | 13.13 | 13.17 | 10.38 | 10.68 | 16.29 | 16.51 | 14.16 | 13.94 | 13.23 | 13.02 | 10.38 | 10.73 | 16.28 | 16.63 | 13.99 | 13.97 | 13.53 |
| CD5% | 2.40 | 2.60 | 2.37 | 1.60 | 2.48 | 2.86 | 2.95 | 1.62 | 2.43 | 2.46 | 2.23 | 2.29 | 2.63 | 2.96 | 2.78 | 2.60 | |

CD at 5% Genotypes (across the environments) = 0.55 (CD at 5%) Environments = 0.83

*Panicle length*

Mean panicle length over the environments was found at par under SRI and TPR method, while under CFC and DSR, the length was significantly shorter than TPR. Pusa 1734-8-3-85 in DSR K16 (29.54 cm); in SRI U16 (31.33 cm); in DSR K17 (29.87 cm); in DSR U17 (29.32 cm); Pusa 1637-2-8-20-5 (30.35 cm) in DSR U16; Pusa Basmati 6 (31.91 cm) in SRI K16; Improved Pusa Basmati 1 (30.85 cm) in CFC K16; Pusa 1656- 10-705 (31.28 cm) in CFC U16; Pusa Sugandh 5 (31.60 cm) in TPR U16; Pusa basmati 1 in TPR K16 (31.52 cm); in SRI K17 (31.78 cm); in CFC U17 (30.65 cm) and in TPR U17 (31.49 cm); Pusa basmati 1509 (31.81 cm) in SRI U17; in CFC K17 (30.42 cm); Pusa basmati 1121 (30.90 cm) in TPR K17; and recorded maximum panicle length (Table S2). Across the environments, Pusa basmati 1 recorded maximum panicle length followed by Pusa 1637-2-8-20-5 while the minimum length was recorded for CSR TPB-1. Similar results were also reported by LATIF *et al.* (2005), THAKUR *et al.* (2011), BISWAS *et al.* (2013) and MONDOL *et al.* (2017). Longer panicles under SRI may be due to higher photosynthetic rate, better utilization of the nutrients, and higher dry matter accumulation in the plant. Mechanical weeding and irrigation at short intervals increase the root shoot ratio due to good aeration (UPHOFF and RANDRIAMIHARISOA, 2002).

*Number of spikelets per panicle and Percent filled spikelets*

On the basis of overall mean across the environments, Pusa Sugandh 5 produced a maximum number of spikelets per panicle followed by Pusa Basmati 1 whereas CSR TPB 1 recorded a minimum number of spikelets per panicle. Among the environments,number of spikelets per panicle was lower in direct-seeded rice and chemical-free cultivation and higher in system of rice intensification. Pusa Sugandh 5 produced a maximum of 128 spikelets per panicle in DSR K16; 120 in DSR U16; 156 in SRI K16; 160 in SRI U16; 140 in CFC U16; 146 in TPR K16; 148 in TPR U16; 128 in DSR U17; 152 in SRI K17; 155 in SRI U17; 154 in TPR K17 and 147 in TPR U17 whereas Pusa basmati 1 produced maximum 139 spikelets per panicle in CFC K16; 124 in DSR K17; 145 in CFC K17; 139 in CFC U17 (Table 3). The lower number of filled spikelets per panicle was responsible for reduced grain yield under DSR (MIYAGAWA *et al.*, 1998). Similarly, for percent filled spikelets, Taraori Basmati followed by Pusa 6295-2 recorded maximum filled spikelets while CSR TPB-1 produced a minimum number of filled spikelets per panicle over the environments. DSR produced significantly less percentage of filledspikelets per panicle than TPR. The non-significantdifference was foundfor percent filled spikelets under SRI, CFC,and TPR. Pusa Sugandh 2 (88.15%) produced maximum percent filled spikelets in DSR K16 and in DSR K17 (87.46%); Taraori Basmati (88.30%) in DSR U16; in SRI U16 (92.23%); in CFC U16 (92.38%); in TPR K16 (91.99%); in SRI U17 (91.02%) and in TPR K17 (92.55%); Pusa Basmati 1509 (91.74%) in TPR U16. Pusa 6295-2 (87.62%) produced maximum percent filled spikelets in DSR U17; in CFC K17 (90.71%); in CFC U17 (93.15%) and in TPR U17 (90.47%); CSR-30 (91.87%) in SRI K16; HKR 06-434 (89.87%) in CFC K16; Pusa 1656-10-705 (91.88%) in SRI K17 (Table S3). Under water deficit conditions lower level of starch was produced by anthers which reduces pollen viability. Reduced pollen viability increases the percentage of unfilled spikelets (LALONDE *et al.*, 1997; GARRITY *et al.*, 1986). The high number of opaque and chalky kernels was reportedin DSR compared to TPR (FAROOQ *et al.*, 2006a, b).

*Table 3. Mean performance of Basmati rice genotypes under different crop establishment methods for number of spikelets per panicle*

| | *Kharif* 2016 | | | | | | | | *Kharif* 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | CFCK16 | CFCU16 | DSRK16 | DSRU16 | SRIK16 | SRIU16 | TPRK16 | TPRU16 | CFCK17 | CFCU17 | DSRK17 | DSRU17 | SRIK17 | SRIU17 | TPRK17 | TPRU17 | Mean |
| G1 | 95 | 98 | 81 | 85 | 109 | 110 | 97 | 106 | 87 | 94 | 84 | 87 | 104 | 115 | 105 | 100 | 97 |
| G2 | 85 | 81 | 74 | 74 | 95 | 84 | 82 | 83 | 79 | 76 | 76 | 81 | 91 | 89 | 88 | 77 | 82 |
| G3 | 69 | 72 | 65 | 62 | 79 | 83 | 72 | 71 | 74 | 77 | 69 | 65 | 73 | 77 | 67 | 76 | 72 |
| G4 | 107 | 113 | 87 | 92 | 126 | 121 | 123 | 119 | 102 | 107 | 89 | 95 | 129 | 129 | 117 | 113 | 111 |
| G5 | 91 | 101 | 97 | 98 | 113 | 119 | 106 | 108 | 95 | 94 | 93 | 104 | 117 | 125 | 109 | 116 | 105 |
| G6 | 103 | 96 | 91 | 89 | 110 | 114 | 110 | 99 | 106 | 100 | 94 | 84 | 114 | 117 | 104 | 105 | 102 |
| G7 | 68 | 73 | 68 | 69 | 85 | 94 | 80 | 78 | 74 | 78 | 63 | 67 | 81 | 86 | 75 | 83 | 76 |
| G8 | 72 | 78 | 69 | 72 | 89 | 91 | 84 | 84 | 77 | 82 | 64 | 68 | 92 | 95 | 88 | 92 | 81 |
| G9 | 116 | 108 | 101 | 96 | 122 | 120 | 122 | 112 | 112 | 112 | 107 | 100 | 118 | 125 | 114 | 116 | 113 |
| G10 | 88 | 80 | 75 | 71 | 96 | 100 | 86 | 92 | 82 | 85 | 79 | 74 | 100 | 106 | 93 | 97 | 88 |
| G11 | 92 | 92 | 76 | 72 | 93 | 98 | 86 | 81 | 84 | 86 | 79 | 75 | 90 | 92 | 80 | 77 | 85 |
| G12 | 103 | 115 | 102 | 99 | 120 | 114 | 112 | 112 | 108 | 109 | 95 | 104 | 124 | 121 | 116 | 106 | 110 |
| G13 | 100 | 99 | 91 | 84 | 113 | 116 | 104 | 107 | 104 | 94 | 88 | 88 | 117 | 110 | 108 | 113 | 102 |
| G14 | 76 | 79 | 84 | 85 | 95 | 94 | 94 | 89 | 81 | 85 | 81 | 88 | 92 | 99 | 87 | 83 | 87 |
| G15 | 89 | 88 | 86 | 82 | 103 | 99 | 94 | 87 | 95 | 84 | 88 | 86 | 107 | 104 | 100 | 93 | 93 |
| G16 | 87 | 101 | 77 | 86 | 116 | 113 | 103 | 105 | 94 | 94 | 82 | 82 | 111 | 117 | 108 | 113 | 99 |
| G17 | 94 | 82 | 85 | 89 | 96 | 97 | 89 | 95 | 86 | 87 | 81 | 85 | 93 | 103 | 85 | 91 | 90 |
| G18 | 84 | 79 | 69 | 76 | 95 | 90 | 87 | 81 | 78 | 74 | 73 | 73 | 99 | 98 | 94 | 87 | 84 |
| G19 | 118 | 108 | 92 | 101 | 122 | 119 | 112 | 109 | 114 | 113 | 88 | 95 | 117 | 124 | 106 | 101 | 109 |
| G20 | 110 | 110 | 102 | 100 | 129 | 126 | 126 | 117 | 116 | 106 | 107 | 104 | 124 | 131 | 117 | 113 | 115 |
| G21 | 114 | 124 | 101 | 100 | 125 | 122 | 107 | 106 | 119 | 117 | 94 | 104 | 129 | 127 | 114 | 110 | 113 |
| G22 | 97 | 84 | 86 | 84 | 112 | 107 | 104 | 99 | 91 | 88 | 88 | 81 | 108 | 102 | 98 | 95 | 95 |
| G23 | 93 | 101 | 88 | 91 | 110 | 110 | 107 | 104 | 98 | 96 | 85 | 88 | 107 | 115 | 101 | 100 | 100 |
| G24 | 72 | 82 | 68 | 68 | 82 | 79 | 75 | 79 | 78 | 77 | 72 | 64 | 86 | 85 | 71 | 76 | 76 |
| G25 | 90 | 84 | 78 | 86 | 105 | 105 | 103 | 94 | 97 | 91 | 83 | 89 | 110 | 100 | 97 | 98 | 94 |
| G26 | 139 | 133 | 117 | 114 | 145 | 142 | 137 | 134 | 145 | 139 | 124 | 111 | 142 | 150 | 131 | 127 | 133 |
| G27 | 79 | 88 | 76 | 76 | 102 | 97 | 98 | 87 | 85 | 83 | 72 | 80 | 106 | 103 | 93 | 93 | 89 |
| G28 | 110 | 98 | 95 | 100 | 108 | 114 | 102 | 108 | 106 | 104 | 92 | 95 | 114 | 120 | 97 | 104 | 104 |
| G29 | 95 | 98 | 87 | 89 | 111 | 107 | 108 | 98 | 101 | 92 | 83 | 92 | 115 | 113 | 102 | 104 | 100 |
| G30 | 116 | 109 | 95 | 105 | 126 | 128 | 114 | 122 | 108 | 104 | 100 | 99 | 121 | 122 | 120 | 118 | 113 |
| G31 | 133 | 140 | 128 | 120 | 156 | 160 | 146 | 148 | 138 | 130 | 123 | 128 | 152 | 155 | 154 | 147 | 141 |
| G32 | 104 | 115 | 87 | 94 | 127 | 130 | 124 | 113 | 110 | 110 | 92 | 97 | 132 | 123 | 120 | 119 | 112 |
| G33 | 94 | 104 | 90 | 96 | 122 | 121 | 107 | 104 | 98 | 98 | 85 | 92 | 125 | 114 | 114 | 109 | 105 |
| G34 | 90 | 88 | 78 | 79 | 103 | 108 | 98 | 97 | 85 | 92 | 75 | 84 | 99 | 101 | 92 | 86 | 91 |
| G35 | 76 | 83 | 70 | 76 | 92 | 94 | 78 | 82 | 72 | 78 | 67 | 73 | 95 | 88 | 84 | 89 | 81 |
| G36 | 84 | 90 | 87 | 94 | 98 | 102 | 98 | 95 | 78 | 84 | 90 | 90 | 102 | 108 | 90 | 101 | 93 |
| Mean | 95 | 97 | 86 | 88 | 109 | 109 | 102 | 100 | 96 | 95 | 86 | 88 | 109 | 111 | 101 | 101 | 98 |
| CD5% | 6.77 | 7.54 | 6.95 | 5.86 | 8.28 | 8.23 | 7.11 | 6.48 | 7.07 | 7.13 | 7.58 | 7.13 | 7.10 | 8.15 | 7.62 | 7.80 | |

CD at 5% Genotypes (across the environments) = 2.31 (CD at 5%) Environments = 3.46

Due to better utilization of light, water, space and better dry matter partitioning (WANG *et al.*, 2002; GRIHTLAHRE *et al.*, 2012) increased percentage of filled spikeletswere observed under SRI.

*Thousand grain weight*

SRI was recorded significantly higher while DSR (at Kaul location) significantly lower thousand-grain weights as compared to the transplanted rice. Wider spacing in the SRI method increases the light penetration rate to leaves and maximizes the photosynthetic rates (TERASHIMA and HIKOSAKA, 1995). Underthe SRI method plants showed 48–69% higher photosynthesis rates in comparison to TPR method (THAKUR *et al*., 2011). Higher thousand-grain weight under SRI than TPR and DSR was reported by SHARMA and MASAND (2008); PATRA and HAQUE (2011); (DUBEY *et al.*, 2017). Pusa Sugandh 5 had the highest thousandgrain weight followed by Pusa Basmati 1121 over the environments, while Basmati 370 recorded the lowest thousand grain weight. Pusa Basmati 1121 (28.80 g) recorded highest thousand grain weight in DSR K16 and in DSR K17 (28.90 g); Pusa 6295-2 (29.35 g) in CFC U16; Pusa Sugandh 5 (29.03 g) in DSR U16; in SRI K16 (30.90 g); in SRI U16 (31.55 g); in CFC K16 (30.92 g); in TPR K16 (31.46 g); in TPR U16 (30.70 g); in DSR U17 (29.39 g); in SRI K17 (30.70 g); in SRI U17 (31.47 g); in CFC K17 (31.00 g); in CFC U17 (29.51 g); in TPR K17 (31.54 g); and in TPR U17 (30.64 g) (Table S4). Lower thousand grain weight under direct-seeded rice may be due to poor growth of plants. Similar reportsin DSR werealso reported by NARESH *et al.* (2013) and JNANESHA and KUMAR (2017).

*Biological yield per plant*

Most of the genotypes produced higher biological yield per plant under SRI and lower under DSR than TPR. Genotype HKR 06-434 had the highest biological yield per plant followed by Pusa basmati 1 while CSR TPB-1 recorded the lowest biological yield per plant. SJR 70-3-2 (47.10 g) in DSR K16 and in DSR U16 (51.60 g); Pusa basmati 1121 (58.60 g) in SRI K16; in SRI K17 (61.00 g); Pusa basmati 1 (57.34g) in SRI U16; in CFC K16 (51.69 g); in SRI U17 (58.06 g); in CFC K17 (53.50 g); in CFC U17 (50.04 g); Pusa 1734-8-3-85 (52.77 g) in CFC U16; HKR 98-476 (51.00 g) in DSR U17; HKR 06-434 (57.38 g) in TPR K16; in TPR U16 (52.78 g); in DSR K17 (46.44 g); in TPR K17 (54.02 g) and in TPR U17 (53.82 g) produced maximum biological yield per plant (Table S5).The higher biological yield under SRI might be due to a longer vegetative phase than (TPR) which results in higher biomass production (MANNAN *et al.*, 2009). Wider spacing under SRI helps the better utilization ofnutrient by the plants which increase leaf area index and tillers number per plant ultimately leads to higher biomass production (BORKER *et al.*, 2008). DAS (2003) also reported high biological yield in SRI compared to TPR. However, GRIHTLAHRE *et al.* (2012) and DAHIRU (2018) reported more biological yield per plant under conventional transplanting than SRI. Lower biological yield under DSR may be due to high weed intensity (JOHNSON and MORTIMER, 2005; SINGH *et al.*, 2005; RAO *et al.*, 2007).

*Table 4. Mean performance of Basmati rice genotypes under different crop establishment methods for grain yield per plant (g)*

| | *Kharif* 2016 | | | | | | | | *Kharif* 2017 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Code | CFCK16 | CFCU16 | DSRK16 | DSRU16 | SRIK16 | SRIU16 | TPRK16 | TPRU16 | CFCK17 | CFCU17 | DSRK17 | DSRU17 | SRIK17 | SRIU17 | TPRK17 | TPRU17 | Mean |
| G1 | 11.82 | 12.62 | 9.23 | 10.32 | 14.84 | 14.47 | 12.89 | 14.20 | 11.32 | 12.12 | 9.56 | 10.69 | 14.00 | 15.26 | 14.11 | 13.00 | **12.53** |
| G2 | 15.70 | 15.18 | 14.26 | 14.38 | 19.40 | 17.14 | 14.82 | 15.03 | 14.50 | 14.82 | 14.53 | 15.30 | 18.80 | 17.54 | 15.57 | 14.77 | **15.73** |
| G3 | 10.80 | 11.37 | 8.10 | 7.21 | 13.85 | 14.12 | 12.56 | 12.28 | 12.00 | 12.25 | 8.69 | 7.46 | 12.75 | 13.39 | 11.83 | 12.80 | **11.34** |
| G4 | 14.26 | 14.60 | 7.67 | 8.64 | 18.50 | 17.07 | 15.81 | 15.46 | 13.14 | 13.70 | 7.45 | 8.88 | 17.9 | 18.32 | 14.78 | 14.63 | **13.80** |
| G5 | 11.76 | 13.08 | 13.30 | 12.32 | 13.85 | 15.68 | 13.33 | 13.68 | 12.44 | 12.52 | 13.10 | 13.02 | 14.35 | 16.72 | 14.07 | 14.31 | **13.60** |
| G6 | 15.23 | 14.30 | 13.29 | 13.00 | 18.50 | 19.12 | 17.26 | 16.00 | 15.68 | 15.44 | 13.50 | 12.40 | 19.10 | 19.76 | 16.44 | 16.80 | **15.99** |
| G7 | 11.18 | 11.88 | 8.74 | 9.94 | 14.98 | 14.42 | 13.64 | 13.13 | 11.62 | 12.76 | 8.38 | 9.76 | 14.49 | 13.78 | 12.76 | 14.01 | **12.22** |
| G8 | 11.80 | 13.02 | 8.34 | 9.40 | 16.18 | 17.15 | 13.62 | 14.44 | 12.40 | 13.57 | 8.05 | 8.80 | 16.42 | 17.65 | 14.77 | 15.15 | **13.17** |
| G9 | 16.58 | 14.82 | 13.45 | 11.99 | 18.18 | 18.10 | 17.75 | 16.8 | 16.16 | 16.06 | 13.75 | 12.6 | 17.43 | 18.61 | 16.96 | 17.60 | **16.05** |
| G10 | 14.11 | 12.78 | 10.33 | 9.46 | 15.52 | 15.84 | 13.97 | 14.37 | 13.19 | 13.61 | 10.56 | 9.90 | 15.98 | 16.56 | 14.42 | 15.22 | **13.49** |
| G11 | 15.76 | 16.22 | 12.68 | 11.66 | 16.60 | 18.24 | 15.00 | 15.09 | 15.19 | 15.37 | 12.92 | 11.90 | 16.20 | 17.32 | 14.12 | 13.70 | **14.87** |
| G12 | 14.15 | 15.76 | 13.70 | 14.10 | 22.48 | 18.75 | 16.59 | 17.59 | 15.44 | 14.75 | 13.42 | 14.49 | 23.12 | 20.18 | 17.92 | 16.31 | **16.80** |
| G13 | 15.32 | 15.89 | 12.98 | 12.00 | 20.43 | 20.5 | 16.34 | 16.60 | 16.08 | 14.90 | 12.71 | 12.40 | 20.88 | 19.69 | 17.66 | 17.80 | **16.39** |
| G14 | 11.84 | 12.29 | 13.52 | 14.10 | 15.02 | 15.42 | 14.98 | 13.84 | 12.56 | 12.90 | 13.17 | 14.44 | 14.79 | 15.97 | 14.22 | 13.24 | **13.89** |
| G15 | 13.84 | 13.79 | 10.13 | 9.21 | 18.20 | 16.86 | 16.08 | 15.30 | 14.55 | 13.32 | 10.27 | 9.59 | 18.80 | 18.05 | 16.62 | 16.30 | **14.43** |
| G16 | 13.20 | 14.50 | 12.05 | 12.22 | 19.59 | 20.02 | 16.02 | 16.88 | 14.00 | 13.70 | 12.25 | 12.32 | 18.80 | 19.18 | 16.88 | 17.91 | **15.59** |
| G17 | 13.89 | 12.59 | 13.49 | 13.72 | 14.42 | 15.20 | 13.76 | 14.23 | 13.24 | 13.80 | 12.90 | 13.48 | 13.97 | 16.08 | 12.88 | 13.36 | **13.81** |
| G18 | 13.69 | 13.2 | 10.35 | 11.65 | 16.52 | 14.78 | 14.33 | 13.46 | 12.50 | 12.60 | 10.84 | 11.47 | 16.92 | 15.62 | 15.06 | 14.74 | **13.61** |
| G19 | 18.76 | 16.61 | 13.41 | 14.82 | 18.50 | 18.87 | 17.40 | 17.30 | 17.69 | 17.80 | 13.00 | 14.38 | 17.70 | 19.67 | 16.80 | 16.64 | **16.83** |
| G20 | 14.82 | 15.29 | 14.26 | 13.85 | 18.70 | 18.82 | 18.00 | 17.22 | 15.97 | 14.42 | 14.49 | 14.34 | 18.29 | 19.91 | 16.80 | 16.37 | **16.35** |
| G21 | 17.72 | 19.22 | 15.88 | 15.9 | 20.27 | 22.31 | 16.80 | 16.42 | 19.00 | 18.34 | 14.80 | 16.30 | 20.78 | 21.48 | 17.59 | 17.67 | **18.15** |
| G22 | 15.68 | 13.10 | 13.35 | 12.67 | 17.64 | 18.61 | 16.10 | 15.65 | 13.84 | 14.19 | 13.50 | 12.30 | 16.82 | 17.78 | 14.90 | 14.75 | **15.06** |
| G23 | 14.00 | 15.20 | 10.21 | 11.81 | 18.34 | 18.65 | 17.38 | 17.01 | 14.70 | 14.34 | 10.03 | 11.58 | 18.00 | 19.96 | 16.42 | 16.38 | **15.25** |
| G24 | 11.87 | 13.13 | 9.16 | 8.48 | 14.32 | 14.57 | 13.40 | 13.30 | 12.73 | 12.58 | 9.24 | 8.33 | 14.87 | 13.89 | 12.2 | 12.80 | **12.18** |
| G25 | 15.15 | 14.28 | 13.16 | 14.58 | 17.73 | 17.16 | 17.16 | 15.60 | 16.25 | 15.40 | 13.60 | 14.87 | 18.68 | 16.40 | 16.03 | 16.19 | **15.77** |
| G26 | 19.88 | 19.00 | 13.95 | 13.97 | 21.50 | 22.97 | 18.14 | 18.30 | 20.92 | 20.20 | 14.33 | 13.54 | 20.89 | 24.13 | 17.26 | 17.61 | **18.54** |
| G27 | 14.70 | 16.3 | 11.67 | 12.14 | 23.30 | 21.26 | 17.8 | 16.45 | 15.50 | 15.10 | 11.32 | 12.36 | 23.69 | 22.34 | 16.6 | 17.15 | **16.73** |
| G28 | 17.68 | 16.23 | 13.48 | 14.81 | 18.16 | 20.10 | 17.25 | 17.53 | 16.72 | 17.37 | 13.24 | 14.46 | 18.84 | 20.70 | 16.05 | 16.31 | **16.81** |
| G29 | 13.23 | 13.54 | 12.35 | 11.00 | 16.41 | 15.88 | 16.24 | 14.81 | 14.76 | 13.05 | 12.14 | 11.20 | 17.07 | 16.91 | 15.36 | 15.59 | **14.35** |
| G30 | 15.85 | 15.10 | 12.28 | 14.00 | 19.06 | 19.40 | 16.67 | 18.00 | 14.54 | 14.34 | 12.68 | 13.67 | 18.34 | 18.20 | 17.52 | 17.19 | **16.05** |
| G31 | 15.25 | 16.52 | 14.75 | 13.23 | 19.71 | 19.52 | 17.82 | 18.60 | 16.15 | 15.87 | 14.27 | 13.67 | 19.23 | 18.87 | 19.10 | 17.33 | **16.87** |
| G32 | 14.16 | 15.65 | 12.35 | 13.06 | 21.94 | 21.87 | 17.85 | 16.82 | 14.72 | 14.94 | 12.49 | 13.42 | 22.65 | 20.72 | 17.25 | 17.67 | **16.72** |
| G33 | 14.18 | 15.70 | 12.70 | 13.50 | 21.36 | 20.18 | 16.87 | 16.24 | 15.05 | 15.10 | 12.45 | 13.26 | 21.80 | 19.36 | 17.62 | 17.51 | **16.43** |
| G34 | 13.50 | 13.14 | 9.45 | 11.05 | 17.87 | 18.42 | 14.76 | 14.93 | 12.29 | 13.47 | 9.15 | 11.46 | 17.40 | 17.58 | 14.00 | 13.53 | **13.88** |
| G35 | 12.55 | 12.90 | 8.38 | 10.34 | 15.54 | 15.69 | 12.92 | 13.62 | 12.05 | 12.49 | 8.28 | 10.96 | 16.14 | 15.22 | 13.67 | 14.38 | **12.82** |
| G36 | 12.40 | 13.79 | 13.2 | 14.9 | 16.42 | 16.56 | 15.70 | 15.15 | 11.6 | 12.93 | 13.47 | 14.22 | 16.88 | 17.84 | 14.89 | 16.42 | **14.77** |
| Mean | **14.34** | **14.52** | **11.93** | **12.21** | **17.88** | **17.88** | **15.75** | **15.59** | **14.46** | **14.45** | **11.9** | **12.31** | **17.86** | **18.07** | **15.59** | **15.64** | **15.02** |
| CD5% | 1.84 | 2.00 | 2.28 | 1.34 | 2.14 | 2.01 | 1.69 | 2.04 | 1.75 | 1.97 | 1.69 | 1.88 | 1.59 | 1.84 | 1.74 | 2.04 | |

*Grain yield per plant*

Pusa Basmati 1 (18.54 g) recorded the highest grain yield per plant across the environments followed by Pusa 1734-8-3-85 whereas CSR TPB-1 recorded the lowest grain yield. Grain yield was significantly lower in direct-seeded rice, chemical-free cultivation, and higher in system of rice intensification SRI K16, SRI U16, SRI K17, and SRI U17 as compared to transplanted rice.Pusa 1734-8-3-85 (15.88 g) produced maximum grain yield in DSR K16; in DSR U16 (15.90 g); in CFC U16 (19.22 g); in DSR K17 (14.80 g); in DSR U17 (16.30 g). Pusa Basmati 1121 (23.30 g) in SRI K16 and in SRI K17 (23.69 g); Pusa basmati 1 (22.97 g) in SRI U16; in CFC K16 (19.88 g); in TPR K16 (18.14 g); in SRI U17 (24.13 g); in CFC K17 (20.92 g); in CFC U17 (20.20 g); Pusa Sugandh 5 (18.60 g) in TPR U16; in TPR K17 (19.10 g); and Improved Pusa Basmati 1 (17.91 g) in TPR U17 (Table 4). Better grain yield under SRI was reported by GANESH *et al.*, 2006 (25%), KRISHNA *et al.* (2008, 15.6%), MISHRA *et al.* (2009, 16.6 %), MAHAJAN and SARAO (2009, 11.8%) and 50% (SINGH, 2007). Higher grain yield in SRI may be due to high photosynthetic efficiency of the fully expanded leaves during the tillering stage and better utilization of photosynthates at the grain-filling stage (SINGH *et al.*, 2013).Transplanting of youngage seedlings under SRI produces more effective tillers per hill, a high percentage of filled grains per plant, more panicle weight, and longer panicles which directly contribute to higher grain yield per plant (SHEEHY *et al.*, 2003; GINIGADDARA and RANAMUKHAARACHCHI, 2011). A major reasons for low grain yield in DSR are high weed infestation (SINGH *et al.*, 2005; JOHNSON and MORTIMER, 2005; RAO *et al.*, 2007), high percentage of spikelet sterility (BHUSHAN *et al.*, 2007), crop lodging, particularly under wet seeding and broadcasting (RICKMAN *et al.*, 2001; HO and ROMLI, 2002; FUKAI, 2002; YOSHINAGA, 2005) and lack of proper knowledge of nutrient and water management especially of micronutrient deficiencies (SHARMA *et al.*, 2002; SINGH *et al.*, 2008; HUMPHREYS *et al.*, 2010; YADAV *et al.*, 2011a,b).

*Harvest index*

Harvest index is the ratio of grain yield over biological yield. The high harvest index reveals the better translocation of assimilates to the panicle. Pusa Basmati-1 recorded the highest harvest index across the environments followed by Pusa 1509 while Basmati 370 recorded the lowest harvest index. Harvest index was found significantly lower under direct-seeded rice and higher under system of rice intensification (SRI U16 and SRI U17) as compared to transplanted rice. Pusa basmati 1 (38.46%) had maximum harvest index in DSR K16; in DSR K17 (36.86%); in SRI U17 (41.55%); in CFC U17 (40.37%) and TPR U17 (43.12%); Pusa basmati 1509 (35.86%) in DSR U16; in SRI U16 (41.40%); in TPR K16 (42.25%); in DSR U17 (36.53%); SJR 70-3-2 (41.15%) in SRI K16; Pusa Sugandh 5 (41.07%) in CFC K16 and in CFC K17 (40.42%); Pusa Sugandh 3 (40.63%) in CFC U16; Pusa 1656-10-705 (42.65%) in TPR U16; Haryana Basmati -1 (40.74%) in TPR K17; Pusa 1637-2-8-20-5 (42.31%) in TPR K17 (Table S6). Under different methods of rice crop establishment, a non-significant difference was observed for harvest index by JNANESHA and KUMAR (2017) and DAHIRU (2018).

Received, September 27th, 2020
Accepted June 18th, 2021

REFERENCES


BAIG, M.B., M.S. ZIAELDIN, R. MAHLER (2004): Rehabilitation of problem soils through environmental friendly technologies - I: Effect of sesbania (*Sesbania Aculeata*) and farmyard manure. Arab Gulf J. Sci. Res., *22*: 51-59.

BALASUBRAMANIAN, V., J.E. HILL (2002): Direct seeding of rice in Asia: emerging issues and strategic research needs for the 21st century. In: Pandey, S., M., Mortimer, L., Wade, T.P., Tuong, K., Lopez, B., Hardy (Eds.) Direct Seeding: Research Strategies and Opportunities. International Rice Research Institute, Los Ban˜os, Philippines: 15–42.

BHADURI, D., T.J. PURAKAYASTHA (2011): Soil available Zn: a potent soil quality indicator in a rice–wheat system. The 3rd International Zinc Symposium, October 10–14, 2011, Hyderabad, India, pp. 10–14.

BHUSHAN, L., J.K. LADHA, R.K. GUPTA, S. SINGH, A. TIROL-PADRE, Y.S. SAHARAWAT, M. GATHALA, H. PATHAK (2007): Saving of water and labor in a rice–wheat system with no tillage and direct seeding technologies. Agron. J., *99*: 1288–1296.

BISWAS, P.K, TOHIDUZZAMAN, T.S. ROY (2013): Screening of rice varieties responsive to system of rice intensification (SRI) in boro season. Bangladesh Agron. J., *16*: 51-60.

BORKAR, L.S. V.S. KHAWALE, B. RAUT, T.S. PATIL, S.K. HARSHA (2008): Studies on spacing and nitrogen management under System of Rice Intensification (SRI). J. Soil Crops, *18*: 438-441.

BOUMAN, B.A.M., S. PENG, A.R. CASTANEDA, R.M. VISPERAS (2005): Yield and water use of irrigated tropical aerobic rice systems. Agric. Water Manage., *74*: 87–105.

BOUMAN, B.A.M., T.P. TUONG (2001): Field water management to save water and increase its productivity in irrigated lowland rice. Agric. Water Manage., *49*: 11–30.

DAHIRU, T.M. (2018): Comparative analysis on the cropping system of rice intensification and traditional method of rice production in Mubi North, Adamawa State, Nigeria. Int. J. Innov. Agric. Biol. Res., *6*:7-26.

DAS, L. (2003): Varification and refinement of the System of Rice Intensification in selected areas of Bangladesh. Trial Monitoring Report. SAEF Development Group.

DESHPANDE, H.H., P. DEVASENAPATHY (2010): Effect of green manuring and organic manure on yield, quality and economics of rice (*Oryza sativa* L.) under lowland condition. Karnataka J. Agric. Sci., *23*: 235-238.

DUBEY, R., D. SINGH, A. MISHRA (2017): Effect of Weed Management Practices and Establishment Methods on Growth, Productivity and Economics of Rice. Int. J. Curr. Microbiol. Appl. Sci., *6*: 65-72.

FAROOQ, M., K. H.M. SIDDIQUE, H. REHMAN, T, AZIZ, D.J. LEE D, A. WAHID (2011): Rice direct seeding: Experiences, challenges and opportunities. Soil Tillage Res., *111*: 87–98.

FAROOQ, M., S.M.A. BASRA, A. WAHID (2006a): Primimg of field sown rice seed enhances germination, seedling establishment, allometry and yield. Plant Growth Regul., *49*: 2985-294.

FAROOQ, M., S.M.A. BASRA, R. TABASSUM, I. AFZAL (2006b): Enhancing the performance of direct seeded fine rice by seed priming. Plant Prod. Sci., *9*: 446–456.

FUKAI, S. (2002): Rice cultivar requirements for direct seeding in rainfed lowlands. In: Direct Seeding: Research strategies and opportunities, International Rice Research Institute, Los Ban˜os, Philippines, pp. 257–269.

GANESH, M.N., M. REDDY, B.G. REDDY, R. ANKAIAH (2006): Andhra Pradesh-A seed hub of India. In: Souvenir of XII National Seed Seminar on Prosperity through quality seed pp: 21-23.

GANI, A., A. RAHMAN, R, DAHONO, H. HENGSDIJK (2002): Synopsis of water management experiments in Indonesia. In: Water Wise Rice Production, IRRI, pp. 29-37.

GARRITY, D.P., L.R. OLDEMAN, R.A. MORRIS (1986): Rainfed lowland rice ecosystems: characterization and distribution. In: Progress in Rainfed Lowland Rice, International Rice Research Institute, Manila, Philippines, pp. 3–23.

GHRITLAHRE, S.K., A.K. SARIAL, M. RAM, D.R. ANEJA, R. SINGH (2012): Genetic yield potential of rice (*Oryza sativa* L.) through water saving and high yielding SRI technology. Indian J. Agric. Sci., *82*: 260–263.

GINIGADDARA, G.A.S., S.L. RANAMUKHAARACHCHI (2011): Study of age of seedlings at transplanting on growth dynamics and yield of rice under alternating flooding and suspension of irrigation of water management. Recent Res. Sci.Technol., *3*: 76-88.

HO NAI-KIN, Z.,ROMLI (2002): Impact of direct seeding on rice cultivation: lessons from the Muda area of Malaysia. In: Pandey, S., M. Motimar, L. Wade, T.P. Toung, K. Lopez and B. Hardy (ed.). Direct seeding: research issues and opportunities. Proceedings of the International Workshop on Direct Seeding in Asian Rice Systems: Strategic Issues and Opportunities, 25-28 January 2000, Bangkok, Thailand. Los Baños, (Philippines): International Rice Research Institute, 383.

HORRIGAN, L., R.S. LAWRENCE, P. WALKER (2002): How sustainable agriculture can address the environmental and human health harms of industrial agriculture. Environmental Health Perspectives, *110*: 445–456.

HOU, A.X., G.X. CHEN, Z.P. WANG, O. VANCLEEMPUT, W.H. PATRICK (2000): Methane and nitrous oxide emissions from a rice field in relation to soil redox and microbiological process. Soil Sci. Soc. Am. J., *64*: 2180–2186.

HUMPHREYS, E., S.S. KUKAL, E.W. CHRISTEN, B. SINGH, S, YADAV, R.K. SHARMA (2010): Halting the ground water decline in north west India-which crop technologies will be winners? Adv. Agron., 155-217.

ISHIBASHI, E. S., YAMAMOTO, N. AKAI, H. TSURUTA (2007): The influence of no-tilled direct seeding cultivation on greenhouse gas emissions from rice paddy fields in Okayama, Western Japan. 4. Major factors controlling nitrous oxide emission from rice paddy fields under no-till direct seeding cultivation. Japanese J. Soil Sci. Plant Nut., *78*: 453–463.

JNANESHA, A.C., A. KUMAR (2017): Effect of crop establishment methods on growth yield and water productivity of rice. Int. J. Agric. Sci., *8*: 40- 45.

JOHNSON, D.E., A.M. MORTIMER (2005): Issues for weed management in direct-seeded rice and the development of decision-support framework. In: Singh, Y., G., Singh, V.P., Singh, P., Singh, B., Hardy, D.E., Johnson, M. Mortimer (Eds.) Direct-Seeding of Rice and Weed Management in the Irrigated Rice-Wheat Cropping System of the Indo Gangetic Plains pp.20.Directorate of Experiment Station, G.B. Pant University of Agriculture and Technology, Pantnagar, India.

KAUR, J., A. SINGH (2017): Direct Seeded Rice: Prospects, Problems/ Constraints and Researchable Issues in India. Curr. Agric. Res. J., *5*: 13-32.

KRISHNA, A., N.K. BIRADARPATIL, K. MANJAPPA, B.B. CHANNAPPAGOUDAR (2008): Evaluation of system of rice intensification cultivation, seedling age and spacing on seed yield and quality in samba masuhri (BPT-5204) rice. Karnataka J. Agric. Sci., *21*: 20-25.

KUMAR, V., J.K. LADHA (2011): Direct seeded rice: Recent development & future research needs. Adv. Agron., *111*: 297-413.

KUMAR, V., S. SINGH, V. SAGAR, M.L. MAURYA (2018): Evaluation of different crop establishment method of rice on growth, yield and economics of rice cultivation in agro-climatic condition of eastern Uttar Pradesh. J. Pharmacogn. Phytochem., *7*: 2295-2298.

LALONDE, S., D. BEEBE, H.S. SAINI (1997): Early signs of disruption of wheat anther development associated with the induction of male sterility by meiotic-stage water deficit. Sex. Plant Reprod., *10*: 40–48.

LATIF, M.A., M.R. ISLAMA, M.Y. ALIA, M.A, SALEQUEB (2005). Validation of the system of rice intensification (SRI) in Bangladesh. Field Crops Res., *93*: 281-292.

LAULANIE, H. (1993) Le syste`me de riziculture intensive malgache. Tropicultura, *11*: 110–114.

MAHAJAN, G., P.S. SARAO (2009). Evaluation of system of rice (*Oryza sativa* L.) intensification (SRI) in irrigated agro-ecosystem of Punjab. The J. Res. ANGRAU, *37*: 1-6.

MANNAN, M.A., M.S.U. BHUIYA, S.M.A, HOSSAIN, M.I.M. AKHAND (2009): Study on phenology and yielding ability of basmati fine rice genotypes as influenced by planting date in aman season. Bangladesh J. Agric. Res., *34*: 373- 384.

MISHRA, B, R.K. SINGH, D. SENADHIRA (2009): Strategies for developing rice-wheat genotypes for conservation agriculture. Lead papers 4th world Congress on Conservation Agriculture. pp: 234-241.

MIYAGAWA, S., S. KONCHAN, Y. KONO (1998). Yielding ability in direct seeding rice culture in northeast Thailand. Japan J. Trop. Agric., *42*: 248-256.

MONACO, F., G. SALI, M. BEN HASSEN, A. FACCHI, M. ROMANI, G. VALÈ (2016): Water management options for rice cultivation in a temperate area: a multi-objective model to explore economic and water saving results. Water, *8*: 336–355.

MONDOL, A.P., P.K. BISWAS, M.S. ISLAM (2017): Performance of system of rice intensification with conventional method of rice cultivation. Bangladesh Agron. J., *20*: 75-80.

NARESH, R.K., A.K. MISRA, S.P. SINGH (2013): Assessment of direct seeded and transplanting methods of rice cultivars in the western part of Uttar Pradesh. Int. J. Pharm. Sci. Bus. Manag., *1*: 1-8.

PANDEY, S., L. VELASCO (1999). Economics of direct seeding in Asia: patterns of adoption and research priorities. Mini Rev., Int. Rice Res. Notes, *22*: 6–11.

PANDEY, S., L. VELASCO (2002). Economics of direct seeding in Asia: patterns of adoption and research priorities. In: Pandey, S., M., Mortimer, L., Wade, T.P., Tuong, K., Lopes B., Hardy (eds.) Direct Seeding: Research Strategies and Opportunities. International Rice Research Institute, Los Baños Philippines.

PANDISELVI, T., R. VEERAPUTHIRAN, V. GANESARAJA, J. PONNI PRIYA, B.J, PANDIAN (2010): Productivity, water use efficiency and economics of system of rice intensification in Sivagangai district of Tamil Nadu. Int. J. Agric. Sci., *6*: 138-140.

PATHAK, M., R.C. SHAKYWAR, D. SAH, S. SINGH (2011): Prevalence of insect pests, natural enemies and diseases in SRI (System of Rice Intensification) of Rice cultivation in North East Region. Ann. Plant Prot. Sci., *20*: 375-379.

PATRA, P. S, S. HAQUE (2011): Effect of seedling age on tillering pattern and yield of rice (*Oryza sativa* L.) under system of rice intensification. J. Agric. Biol. Sci., *6*: 33-35.

PIC, E., B.T. DE LASERVE, F. TARDIEU, O. TURC (2002): Leaf senescence induced by mild water deficit follows the same sequence of macroscopic, biochemical, and molecular events as monocarpic senescence in pea. Plant Physiol., *128*: 236–246.

QINGQUAN, Y. (2002): The system of Rice Intensification and its use with hybrid rice varieties in China. P. 109-111. (In:) Proceeding of International Conference. Assessments of the system of Rice Intensification.Sanya, China, April, 1-4, 2002.

RAO, A.N., D.E. JOHNSON, B. SIVAPRASAD, J.K. LADHA, A.M. MORTIMER (2007): Weed management in direct-seeded rice. Adv. Agron., *93*: 153–255.

RASUL, G. (2014): Food, water and energy security in South Asia: a nexus perspective from the Hindu Kush Himalayan region. Environ. Sci. Policy, *39*: 35–48.

REDDY, K.G. (2004): Varietal performance and spatial requirement of rice under System of Rice Intensification during Kharif season.M.Sc. (Agri) Thesis, Acharya N.G. Ranga Agricultural University, Hyderabad.

RICKMAN, J.F., M. PYSETH, S. BUNNA, P, SINATH (2001): Direct Seeding of Rice in Cambodia. In: Proceedings of an International Workshop. 30 October–2 November. ACIAR Proceedings No. 101, Vientiane, Laos.

SATO, S., N. UPHOFF (2007): A review of on-farm evaluations of system of rice intensification (SRI) method in eastern Indonesia. In: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. Commonwealth Agricultural Bureau International, Wallingford, UK.

SHARMA, P.K., L. BHUSHAN, J.K. LADHA, R.K. NARESH, R.K. GUPTA, B.V. BALASUBRAMANIAN, B.A.M. BOUMAN (2002): Crop–water relations in rice–wheat cropping under different tillage systems and water management practices in a marginally sodic medium textured soil. In: Bouman, B.A.M., H., Hengsdijk, B., Hardy, B., Bihdraban, T.P., Toung, J.K. Ladha (Eds.), Proceedings of the International Workshop on Water-wise Rice Production. International Rice Research Institute, Los Baños, Philippines, pp. 223–235.

SHARMA, P.K., S.S. MASAND (2008). Evaluation of SRI in a high rainfall area of NW Himalayas. Oryza, *45*: 206–11.

SHEEHY, J.E., A, PENG, P.L. DOBENNANN, A.F. MITCHELL, Y. JIANCHANG, Z. YINGBIN, Z. XUHUA, H. JIANLIANG (2003): Fantastic yields in the system of rice intensification: Fact or fallacy. Field Crops Res., *88*: 1- 8.

SINGH, A. (2007): Performance of system of rice intensification and conventional rice cultivation methods under Punjab conditions: Agriculture Development Officer, Department of Agriculture, Punjab.

SINGH, K., V. KUMAR, Y.S. SAHARAWAT, M. GATHALA, J.K. LADHA (2013): Weedy Rice: an emerging threat to direct-seeded rice production systems in India. J. Rice Res., *1*: 106.

SINGH, K.K., S.K. YADAV, B.S, TOMAR, J.N. SINGH, P.K, SINGH (2004): Effect of seedling age on seed yield and seed quality attributes in rice cv. Pusa Basmati-1. Seed Res., *32*: 5-8.

SINGH, S., G.,SINGH, V.P. SINGH, A.P. SINGH (2005): Effect of establishment methods and weed management practices on weeds and rice in rice-wheat cropping system. Indian J. Weed Sci., *37*: 51-57.

SINGH, S., J.K. LADHA, R.K. GUPTA, L. BHUSHAN, A.N. RAO (2008): Weed management in Aerobic rice systems under varying establishment methods. Crop Prot., *27*: 660– 671.

TABBAL, D.F., B.A.M. BOUMAN, S.I. BHUYIAN, E.B. SIBAYAN, S.I. SATTAR (2002): On-farm strategies for reducing water input in irrigated rice; case studies in the Philippines. Agric. Water Manage., *56*: 93–112.

TARDIEU, F. (2013): Plant response to environmental conditions: assessing potential production, water demand, and negative effects of water deficit. Front. Physiol., *4*: 1-11.

TERASHIMA, I., K. HIKOSAKA (1995): Comparative ecophysiology of leaf and canopy photosynthesis. Plant Cell Environ., *18*: 1111-1128.

THAKUR, A.K., S. RATH, D.U. PATIL, A. KUMAR (2011): Effects on rice plant morphology and physiology of water and associated management practices of the system of rice intensification and their implications for crop performance. Paddy Water Environ., *9*: 13-24.

THAKUR, A.K., S, RATH, S. ROYCHOWDHURY, N. UPHOFF (2010): Comparative performance of rice with system of rice intensification (SRI) and conventional management using different plant spacings. J. Agron. Crop Sci., *196*: 146–159

TRIPATHI, N., R.S. VERMA (2008). Assessment of grain quality attributes of basmati rice produced by organic system. Pantnagar J. Res., *6*: 192-195.

UPHOFF, N., A. KASSAM, R. HARWOOD (2011): SRI as a methodology for raising crop and water productivity: productive adaptations in rice agronomy and irrigation water management. Paddy Water Environ., *9*: 3-11.

UPHOFF, N., R. RANDRIAMIHARISOA (2002): Reducing water use in irrigated rice production with the Madagascar System of Rice Intensification (SRI). In: Water Wise Rice Production, IRRI, pp.71-87.

WANG, H., B.A.M. BOUMAN, D. ZHAO, C. WANG, P.F. MOYA (2002): Aerobic rice in northern china-opportunities and challenges. In: Bouman, B.A.M., H., Hengsdijk, B., Hardy, P.S., Bihdraban, T.P., Toung, J.K., Ladha (Eds.) Water-wise Rice Production,pp: 143-54, International Rice Research Institute, Los Baños, Philippines.

WELLER, S., B. JANZ, L. JÖRG, D. KRAUS, H. S. RACELA, R., WASSMANN, *et al*. (2016): Greenhouse gas emissions and global warming potential of traditional and diversified tropical rice rotation systems. Glob. Change Biol., *22*: 432–448.

YADAV, S., G. GILL, E. HUMPHREYS, S.S. KUKAL, U.S. WALIA (2011a): Effect of water management on dry seeded and puddled transplanted rice: part 1: crop performances. Field Crops Res., *120*: 112–122.

YADAV, S., E. HUMPHREYS, S.S. KUKAL, G. GILL, R, RANGARAJAN (2011b): Effect of water management on dry seeded and puddled transplanted rice: part 2: waterbalance and water productivity. Field Crops Res., *120*: 123–132.

YOSHINAGA, S. (2005): Improved lodging resistance in Rice (*Oryza sativa* L) cultivated by submerged direct seeding using a newly developed hill seeder. JARQ, *39*: 147-152.

## PERFORMANSE GENOTIPA BASMATI PIRINČA (*Oriza sativa* L.) KOD RAZLIČITIH METODA ZASNIVANJA USEVA

Hari KESH*[1] i Khushi RAM[2]

[1]Department za genetiku i oplemenjivanje, CCS Haryana Poljoprivredni Univerzitet, Hisar-125001, Indija
[2]Istraživačka stanica za pirinač, Kaul-136021, CCS Haryana Poljoprivredni Univerzitet, Hisar-125001, Indija

Izvod

Studija je sprovedena da bi se procenile performance trideset šest genotipova basmati pirinča u pogledu prinosa i srodnih osobina kod: direktno zasejanog pirinča (DSR), sistema intenziviranja pirinča (SRI), gajenja bez hemikalija (CFC) i konvencionalno presađenog pirinča (TPR). Genotipovi su ocenjeni dve godine na dve lokacije u randomizovanom blok dizajnu sa tri ponavljanja. Genotip Pusa Basmati 1121 postigao je najveće povećanje prinosa od ~22% u sistemu metode intenziviranja pirinča u odnosu na presađeni pirinač, a zatim Pusa Basmati 1 (~20%) genotipovi HKR 11-447 (~18%). Genotip Pusa Basmati 1, Pusa Basmati 1637-2-8-20-5 i Pusa Basmati1734-8-3-85 dali su 8-16% veći prinos u gajenju bez hemikalija u poređenju sa TPR. Genotipovi HKR 98-476, CSR 30, PAU 6297-1 dali su podjednako u DSR kao I u TPR. Svi ispitivani genotipovi su pokazali ranije cvetanje i zrelost u DSR, zatim pri i TPR=CFC. Pusa Basmati 1509 zabeležila je najranije cvetanje širom okruženja. Većina genotipova je pokazala povećanje mase metlice, broja klasića po metlici, procenta popunjenih klasića, biološkog prinosa i prinosa zrna pod SRI u odnosu na druge metode gajenja pirinča. Među različitim metodama, SRI je bio najbolji u odnosu na TPR, CFC i DSR.

Primljeno 27.IX.2020.
Odobreno 18.V.2021