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Research Article

Morphological and grain quality analysis of basmati rice (*Oryza sativa* L.) under different systems in north-west plains of Himalaya

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Abstract
As water scarcity becomes a more pervasive agricultural constraint, any intervention to limit the water requirements in rice cultivation will enhance the overall sustainability and food security in the face of climate change. System of rice intensification (SRI) is a methodology for increasing the rice productivity using reduced inputs, including seeds and chemical fertilizers, and water requirements and has a potential for climate change mitigation through avoiding flooded conditions on rice fields which brings down methane emissions from rice cultivation. It also enhances the resilience of rice cultivation systems against climate risks as it generates healthier and more robust rice plants with deep and more vigorous root systems. Field experiment was conducted during wet season (June-November) 2011 to assess the rice productivity and water usages of a Basmati rice varieties *viz*., Basmati 370, Ranbir Basmati, Basmati 564, Sanwaal Basmati, Toraori Basmati and Nagina 22 (N22) under SRI and conventional transplanted (CTP) methods of rice cultivation. Among the different rice production methods, system of rice cultivation (SRI) produced significantly higher grain yield (3850 to 5200 kg ha-1) than the transplanted rice (3650 to 5000 kg ha-1). Total water productivity of the SRI was 19.3 % higher with saving of 25% irrigation water as compared to conventional method. Among genotypes N 22 had the highest per day productivity (45.02), followed by Basmati 564 (41.60) and Sanwaal Basmati (37.54). This also helps to reduce the water requirement and facilitates to avoid water stress specially rice grown in tail end areas.

Key words
Genetic variability, CTP, Water productivity, SRI, Basmati rice (*Oryza sativa* L.).

Introduction

Rice is the staple food for more than half of the world's population and plays a pivotal role in food security of many countries. More than 90% of the global production and consumption of rice is in Asia. Rice is the primary food source for more than one-third of the world's population, and is grown on 11% of the world's cultivated area. In India, it is the most important crop covering an area of approximately 44 mha (million hectares) with a production level of nearly 103 mt (million tons). Among the rice growing countries in the world, India has the largest area under rice crop (about 45 million ha.) and ranks second in production next to China (IRRI 2002). Demand for rice is growing every year and it is estimated that in 2025 AD the requirement would be 140 million tons. The projected trends indicate that the country has to add 1.7 Mt of additional rice every year under declining rice area, increasing cost of cultivation and shrinking natural resources like water. Among the constraints, water scarcity appears to be a major challenge affecting rice production across the globe. More than 80% of the fresh water resources in Asia are used for agriculture of which about half of the total irrigation water is used for rice production (Dawe *et al.,* 2003). Therefore, future rice production depends on how we improve the water use efficiency of the rice crop. Production of 'more rice crop from every drop of water' will have to be the guiding principle for the future. To sustain present food self-sufficiency and to meet future food requirements, India has to increase its rice productivity by 3 per cent per annum (Thiyagarajan and Selvaraju 2001). Geographical indicator (GI) for Basmati rice increased more area under Basmati rice cultivation in the plains of north-west region of Indian Himalayan. Basmati, the aromatic rice praised for its unique quality, is a connoisseur's delight, a nature's gift to Indian sub- continent. The farmers of this sub-continent have been growing these scented rices for centuries. It is cultivated on the foot hills of the Himalayas in the northwestern parts of Indian sub-continent comprising the states of Haryana, Punjab, Uttaranchal, Western Uttar Pradesh, Jammu & Kashmir, Himachal Pradesh and Delhi. Far as Jammu & Kashmir is considered, it plays an important role in the livelihood of people of this hilly and sub-mountainous state. To assure food security in the rice-consuming countries of the world, those countries will have to produce 50% more rice with improved quality to meet consumers' demand by 2025. This additional rice will have to be produced on less land with less water, less labor and fewer chemicals. The task becomes even more difficult when rice quality preferences gradually receive more attention.

Crop improvement and management played an important role in increasing the production of major food crops in the past. There is no doubt that the task of making gains becomes even more difficult when rice yield has already been at a high level. Rice cultivation requires large quantity of water (1200-1500 mm). About 3000 - 5000 litres of water is required for producing one kg rice, depending on the different rice cultivation methods. Owing to increasing water scarcity, a shifting trend towards less water demanding crops is noticed in most part of India and this warrants alternative methods of rice cultivation that aims at higher water and crop productivity. Transplanting is the dominant crop establishment practice in most of the tropical Asia. In this method, the land is puddled and seedlings are raised in a nursery and transplanted (Islam, 1987). Direct seeding under puddled soil enhanced the crop establishment, vegetative growth and reduced crop duration (Garcia *et al.,* 1994). There are evidences that cultivation of rice through system of rice intensification (SRI) can increase rice yields by two to three folds compared to current yield levels (Abu, 2002). The system of rice intensification (SRI), developed in Madagascar over a 30-year period and synthesized in the early 1980s (Stoop *et al.,* 2002), offers opportunities to researchers and farmers to expand their understanding of potentials already existing in the rice genome. SRI has been promoted for more than a decade as a set of agronomic management practices for rice cultivation that enhances yield (Kabir and Uphoff 2007; Senthilkumar *et al.,* 2008; Zhao *et al.,* 2008), reduces water requirements (Satyanarayana *et al.,* 2007), raises input productivity (Sinha and Talati, 2007), which is accessible to smallholders (Stoop *et al.,* 2002), and is more favorable for the environment than conventional practice with its continuous flooding of paddies and heavy reliance on inorganic fertilization (Uphoff, 2003). Given that water scarcity at field level affects more and more rice growers around the world, SRI has attracted considerable interest, particularly in Asian countries. It is claimed that due to the changes in the cultural practices for growing irrigated rice under SRI can lead to much more productive phenotypes (Uphoff and Randriamiharisoa, 2002). These changes include the use of much younger seedlings than normal transplanting; planting them singly and carefully in a square pattern with wide spacing; in soil that is kept moist but not continuously saturated; and with increased soil amendments of organic matter and active aeration of the soil during weed control operations However, these recommendations have encountered controversy and reports of yield benefits and phenotypical changes with SRI management have been challenged on various grounds (Dobermann 2004; McDonald *et al.,* 2006). SRI is referred to as methodology, not a technology or fixed set of practices (Uphoff, 2003), to be tested and optimized under a range of different agro-ecological environments (Stoop *et al.,* 2002). With such background, the experiment was conducted with six Basmati rice varieties to assess the performance of varieties under two methods of rice cultivation *viz.,* system of rice intensification (SRI) and conventional transplanting (CTP) on the grain yield and quality traits.

Material and Methods

Field experiments were carried out during wet season, 2011 at Dryland Research Sub Station, Dhiansar for system of rice intensification (SRI) and at Research Farm of Division of Plant Breeding and Genetics for conventional transplanted (CTP) of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Chatha (J & K), India. Dryland Research Sub Station, Dhiansar farm of the University situated at 32°38′N latitude and 74°55′E longitude with an elevation of 332m above mean sea level. The experimental field at was clay loam in texture and the organic carbon content was less than 0.50%. Division of Plant Breeding and Genetics of Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, Main Campus, Chatha is situated at altitude of 332m above mean sea level with 32^0 39' N latitude and 74^o 58' E longitude with an annual rainfall of 1000 m and, represents sub-tropical conditions. Temperature at Chatha ranges from 30-41^{o}C during different growth stages of rice beginning from nursery sowing from mid-May to maturity stages in end-October.

Treatments consisted of different Basmati rice varieties *viz.,* Basmati 370, Ranbir Basmati, Sanwaal Basmati, Basmati 564 and Nagina 22 were evaluated in two cultivation methods *viz.,* conventional transplanted (CTP) method and system of rice intensification (SRI). Fourteen days old seedlings were transplanted with a spacing of 22.5 X 22.5 cm in SRI. The conventional transplanted (CTP) method used 21 days old seedlings with a spacing of 20 x 15 cm. The experiment was laid out in randomized block design and the treatments were replicated thrice. Recommended package and practices were followed for rice production under CTP and

SRI methods. Hand weeding twice at 20 and 35 days after transplanting was done in CTP method. Weeding was done thrice using cono weeder at 10 days interval from 10th day after transplanting for SRI plots. Water management varied in different treatments as per the recommended practices. Immediately after disappearance of standing water irrigation at 5 cm depth was applied in conventional transplanting method. Application of 2.5 cm depth of water after the formation of hairline crack was followed in SRI.

Data was recorded on randomly selected 10 plants from each plot in each replication. The observations on plant height, days to 50% flowering, days to maturity, root length, grain yield and its attributes, and grain quality attributes were taken. The observations on days to 50 % flowering and days to maturity were done on plot basis in the field at critical stags of crop growth. Plant height was measured from the ground level to the tip of the top most fully opened leaf and expressed in cm. For determining grain yield, all the plants from net plot area were harvested separately, threshed manually and the grain yield for each treatment was expressed in kg/ha at appropriate moisture. The grain yield attributes included number of effective tillers per hill, panicle length, number of spikelets per panicle, and 1000 grain weight. Basmati rice grain quality parameters like grain length (L), grain width (B), L/B ratio, amylose content and protein content were also studied. The other measurements were calculated as given below:

Irrigation water use (mm) = Sum of mean depth of each irrigation in the field Total water use (mm) = Irrigation water use + Rainfall

Water productivity = Grain yield (kg) / Total water consumed (mm)

Observations recorded on different morphological and quality characters were subjected to analysis of variance for estimating magnitude of genetic variability among different rice genotypes with respect to the traits under investigation. The mean data so obtained was subjected to analysis of variance following standard randomised block design (RBD) design. Water productivity was worked out by dividing the grain yield with total water used. The collected data on various parameters was analyzed statistically as per the method suggested by Gomez and Gomez (1984). The treatment combinations were statistically analyzed separately and the results are furnished at five percent critical difference level.

Results and Discussion

Varietal response to SRI, contrary to the perception that SRI method is genotype neutral, significant differences were observed between the varieties under SRI. In general, it was observed that Basmati rice varieties performed better over the varieties under SRI (3.73%) with water saving as against CTP. The varieties Basmati 564, Sanwaal Basmati and Nagina 22 (N22) performed better under both the methods (Table 1 and Table 2). Since number of irrigations and seed requirement are quite low in SRI, this could be the best method for cultivating Basmati rice whose seed cost is relatively higher compared to no Basmati rice. All the Basmati rice varieties generally performed better under both the systems of cultivation but there are reports that some varieties perform much better than others. Results indicated that there was a significant differential response of genotypes to SRI method of cultivation. Based on the mean value for grain yield on plot basis, the performance of medium duration varieties *i.e.* Basmati 564, Sanwaal Basmati and Nagina 22 was found to be better as compared to early duration (Ranbir Basmati) and late duration varieties (Basmati 370 and Toroari Basmati. It is imperative that, under SRI method, due to wider spacing, those varieties which have high tillering ability perform better as compared to the less tillering ones. Significantly higher root length (30.50 to 34.25 cm) at maturity was recorded under system of rice intensification (SRI) compared to conventional transplanted (CTP) method. Basmati rice under SRI produced significantly more number of tillers per hill (11 to 13.50) than CTP method (7.40 to 10.40). Optimum plant population and geometry under SRI led to availability of more resources to the plants that resulted in increased plant height and more number of tillers (Koma and Sinv, 2003). Further, SRI provided optimal growing conditions to individual rice plants so that tillering was maximized and phyllochrons are shortened resulted in accelerated growth rate and reduced tillers mortality (Singh *et al.*, 2013).

System of rice intensification (SRI) registered significantly more number of productive tillers per hill than CTP system of rice cultivation (Table 1 and Table 2). With regard to panicle length, system of rice intensification (SRI) had large panicles compared to conventional transplanting system of rice cultivation. Higher number of spikelets per panicle was observed with system of rice intensification (124.00 to 175.40) compared to conventional transplanting system of rice cultivation (139.50 to 165.40). Grain yield of rice was significantly influenced by different methods of rice cultivation. Among the different rice production methods, system of rice cultivation (SRI) produced significantly higher grain yield (3850 to 5200 kg ha-1) than the transplanted rice (3650 to 5000 kg ha-1). Under SRI, 3.73 % increase in grain yield was noticed compared to transplanted rice. Increased grain yield under SRI is mainly due to the synergistic effects of modification in the cultivation practices such as use of young and single seedlings per hill, limited irrigation, and frequent loosening of the top soil to stimulate aerobic soil conditions (Stoop *et al.*, 2002). Transplanting of very young seedlings usually 8-12 days old, preserves its potential for tillering and rooting which was reduced if transplanted after the occurrence of fourth phyllochron. Further, combination of plant, soil, water and nutrient management practices followed in SRI increased the root growth, along with increase in productive tillers, grain filling and higher grain weight that ultimately resulted in maximum grain yield (Uphoff, 2001). Different genotypes of Basmati rice did not show much variation in grain quality characteristics under SRI and CTP (Table 3 and Table 4). However, SRI method recorded slightly better mean values for grain quality traits compared to CTP except grain length. Sanwaal Basmati had maximum grain length of 7.50 mm followed by Toraori Basmati and Ranbir Basmati. The grain quality as evident by quality parameters was superior in SRI with more grain yield and required less water as compared to that in CTP. The aroma in all the Basmati varieties remained unchanged in both the cases.

System of rice intensification (SRI) method received only 14400 m^3 of water which is 14.43% less of that for ST (16101 m^3/ha). Total water productivity of the SRI was 19.3 % higher as compared to conventional method (Table 5). SRI saved nearly 25% irrigation water without any penalty on yield compared to conventional transplanting. Using intermittent irrigation, Thiyagarajan *et al.* (2002) reported water saving of 50% in SRI over the traditional flooding without any adverse effect on grain yield.

Water saving, variation in water usage and water productivity of Basmati rice under SRI and CTP methods of cultivation are presented in Table 5. The conventional transplanting system required more number of irrigations (35) compared to SRI (27). Under SRI, there is a saving of 8 irrigations compared to transplanted rice. Conventional transplanting system of rice cultivation used higher amount of water (16101m^3) compared to SRI (14400 m^3). Water saving under SRI was 14.43 % over conventional transplanting method of rice cultivation. Impounding of 2.5 cm of irrigation water, irrigation after formation of hairline cracks showed considerable water saving besides better root environment in SRI. Similar findings were reported by Thiagarajan *et al.* (2002). With respect to water productivity, SRI method of rice cultivation registered the higher water productivity (0.31 kg m-^{3}) compared to conventional transplanted method (0.31 kg m-$^{3)}$. Thus, cultivation rice through system of rice intensification increased the grain yield by 3.73 % besides saving of water by 14.43 % over conventional method of rice cultivation.

Field experiments conducted for assessing the potential benefit of SRI especially in terms of reducing the duration of the crop. Six promising high yielding Basmati rice varieties were evaluated on two methods of crop establishment (CTP and SRI) and significantly reduction of days to 50% flowering and days to maturity was observed under SRI method compared to CTP. Further SRI method recorded higher grain yield with reduced duration of crop and helped to cultivate succeeding crop timely. Due to reduction in duration and increase in yields SRI recorded a higher per day productivity to an extent of 34.25 kg/ha/day compared to CTP which was 31.56 kg/ha/day (Table 5). Among genotypes N 22 had the highest per day productivity (45.02), followed by Basmati 564 (41.60) and Sanwaal Basmati (37.54) whereas, Taroari Basmati recorded the lowest per day productivity of 24.63 kg/ha/day under SRI (Fig. 1 and Fig. 2). Similar trend of reduction in growth duration and increase in per day productivity under SRI have also been reported earlier (Babu, 2007). This also helps to reduce the water requirement and facilitates to avoid water stress specially rice grown in tail end areas.

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Table 1. Mean value of different morphological, yield and grain quality characteristics of rice under conventional transplanted (CTP) method

Particulars	Plant height (cm)	Root length (cm)	Days to 50 % flowering	Days to maturity	Effective tillers m^{-2}	Panicle length (cm)	Spikelets/ panicle (Nos.)	Per day productiviy (kg/ha/day)
Basmati 370	142.90	29.50	119.00	141.00	10.40	25.50	165.40	26.24
Ranbir Basmati	131.30	32.00	107.40	137.40	9.00	25.60	152.50	29.70
Sanwaal Basmati	132.00	29.75	108.40	138.40	7.40	24.40	145.50	35.23
Basmati 564	129.40	29.00	107.00	127.00	8.20	25.50	145.25	38.64
Taraori Basmati	165.50	30.75	135.40	160.25	7.40	25.50	156.25	22.05
N 22	105.00	32.75	105.25	130.50	8.50	23.20	139.50	43.33
SE(d) ±	0.065	0.073	0.041	0.065	0.049	0.065	0.057	0.055
SE(m) ±	0.046	0.052	0.029	0.046	0.035	0.046	0.040	0.045
CV (P = 0.05)	0.060	0.294	0.044	0.058	0.707	0.321	0.046	0.266

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Table 2. Mean value of different morphological, yield and grain quality characteristics of rice under system of rice intensification (SRI) system

Particulars	Plant height (cm)	Root length (cm)	Days to 50 % flowering	Days to maturity	Effective tillers	Panicle length (cm)	Spikelets/ panicle	Per day productivity (kg/ha/day)
Basmati 370	140.25	30.50	115.00	145.20	13.50	26.10	175.40	27.45
Ranbir Basmati	128.10	32.50	99.40	125.50	12.40	26.70	124.00	32.01
Sanwaal Basmati	129.20	30.50	103.40	133.40	11.00	26.80	147.00	37.54
Basmati 564	125.00	31.25	102.00	132.50	12.50	25.70	151.00	41.60
Taraori Basmati	150.25	31.50	130.25	155.30	11.50	27.00	169.50	24.63
N 22	105.50	34.25	100.40	125.50	11.25	24.30	142.40	45.02
SE(d) ±	0.049	0.057	0.041	0.049	0.041	0.057	0.065	0.060
SE(m) ±	0.035	0.040	0.029	0.035	0.029	0.040	0.046	0.038
CV (P = 0.05)	0.046	0.220	0.046	0.044	0.416	0.268	0.053	0.265

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Table 3. Mean value of different morphological, yield and grain quality characteristics of rice under conventional transplanted (CTP) method

Particulars	Yield/ Plot (kg)	Grain yield (kg/ha)	Water productivity (kg/ m^3)	1000-grain weight (g)	Grain length (mm)	Grain breadth (mm)	Length/ breadth ratio	Amylose content (%)	Protein content (%)
Basmati 370	3.75	3750	0.23	21.50	6.70	2.35	2.85	24.10	6.50
Ranbir Basmati	3.90	3900	0.24	21.50	7.30	2.40	3.04	22.90	6.00
Sanwaal Basmati	4.65	4650	0.29	22.50	7.50	2.33	3.21	23.30	5.85
Basmati 564	5.00	5000	0.31	22.50	7.10	2.55	2.78	22.00	6.50
Taraori Basmati	3.65	3650	0.23	23.50	7.30	2.40	3.04	25.50	7.00
N 22	4.55	4550	0.28	21.50	7.20	2.88	2.50	21.80	6.00
SE(d) ±	0.065	0.033	0.065	0.056	0.057	0.057	0.049	0.073	0.065
SE(m) ±	0.046	0.023	0.046	0.035	0.040	0.040	0.035	0.052	0.046
CV (P = 0.05)	1.815	0.001	30.380	0.227	0.974	2.817	2.067	0.387	1.268

Table 4. Mean value of different morphological, yield and grain quality characteristics of rice under system of rice intensification (SRI) system

Particulars	Yield/ plant (kg)	Grain yield/ha (kg)	Water productivity (kg/ m^3)	1000-grain weight (g)	Grain length (mm)	Grain breadth (mm)	Length/ breadth ratio	Amylose content (%)	Protein content (%)
Basmati 370	3.85	3850	0.27	22.00	6.69	2.20	3.04	24.00	6.50
Ranbir Basmati	4.10	4100	0.28	21.50	7.20	2.30	3.13	21.75	6.60
Sanwaal Basmati	4.85	4850	0.34	22.75	7.15	2.35	3.04	22.00	6.00
Basmati 564	5.20	5200	0.36	23.50	7.10	2.30	3.08	22.50	6.75
Taraori Basmati	3.70	3700	0.26	24.00	7.35	2.26	3.25	24.50	6.90
N 22	4.75	4750	0.33	22.50	6.58	2.75	2.39	22.50	6.10
SE(d) ±	0.065	0.049	0.073	0.057	0.049	0.065	0.057	0.073	0.065
SE(m) ±	0.046	0.035	0.052	0.040	0.035	0.046	0.040	0.052	0.046
CV (P = 0.05)	1.815	0.001	29.348	0.308	0.856	3.390	2.342	0.393	1.236

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Table 5. Water usage and water productivity of Basmati rice under CTP and SRI systems of rice cultivation

Systems of Basmati rice cultivation	No. of irrigations	Total water used (m^3/ha)	% water saving over transplanted rice	Overall increase in yield over transplanted rice (%)	Overall per day productivity (kg/ha/day)	Overall water productivity (kg/ m^3)
CTP	35	16101	-	-	31.56	0.26
SRI	27	14400	14.43	3.73	34.25	0.31

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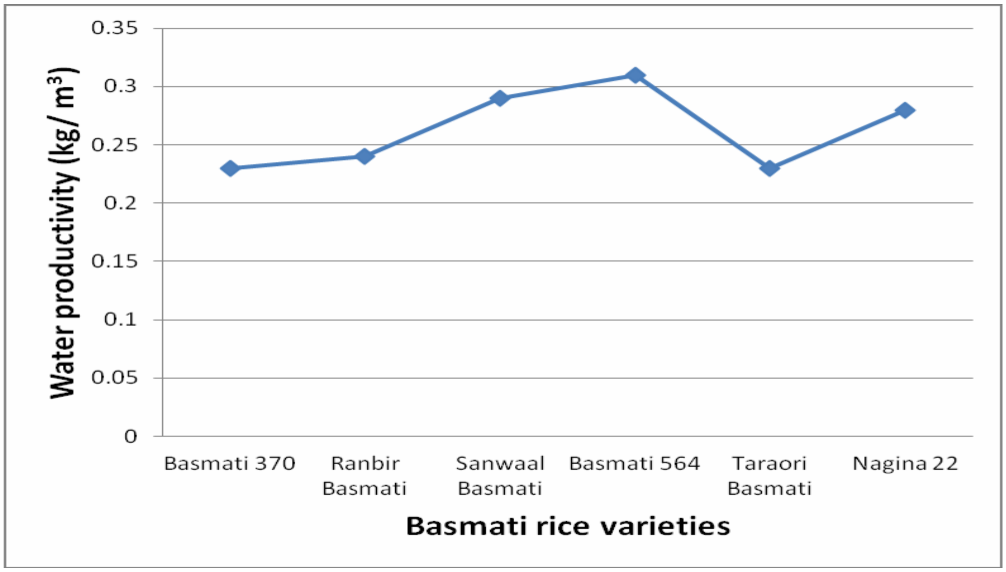

Fig. 1 Water productivity (kg/ m^3) of different Basmati rice varieties under CTP method of rice production

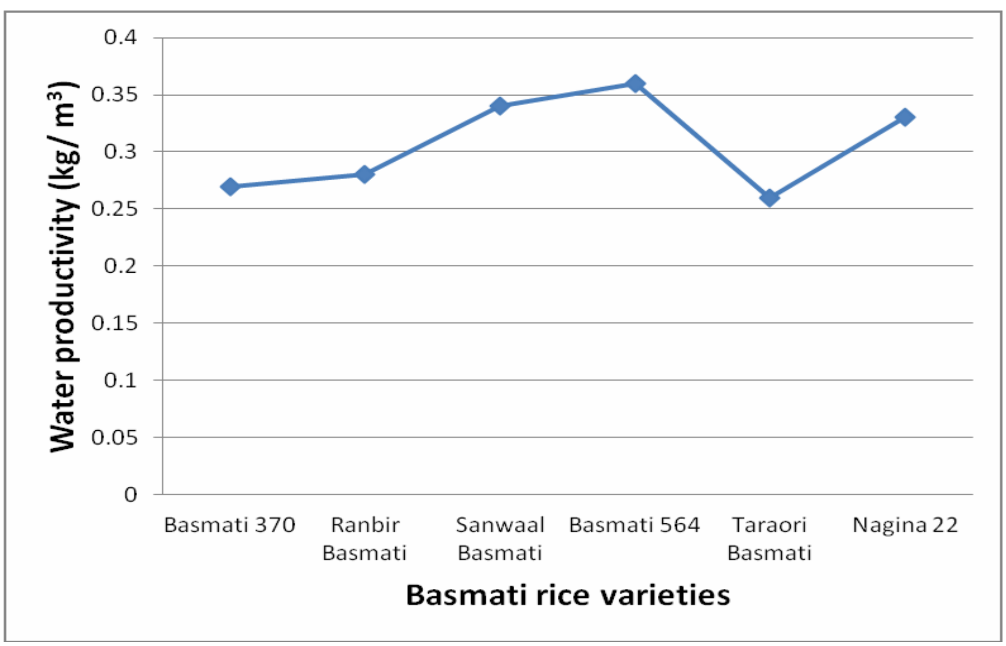

Fig. 2 Water productivity (kg/ m^3) of different Basmati rice varieties under SRI