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Research article

GROWTH ANALYSIS OF BASMATI RICE VARIETIES AND ITS IMPACT ON GRAIN YIELD UNDER SRI

Trinath Panigrahi[1], L. M. Garnayak[2], M. Ghosh[3] and D. C. Ghosh[4]*

[1]Directorate of Agriculture and Food Production, Bhubaneswar, Odisha-751 001, India
[2]Orissa University of Agriculture & Technology, Bhubaneswar, Odisha-751 003, India
[3]Dept. of Agronomy, Bihar Agricultural University, Sabour, Bihar-(813 210, India
[4]Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal-731 236, India
Corresponding author's e mail: dcghosh2011@gmail.com

ABSTRACT: A field experiment was conducted during the *kharif* season of 2007 and 2008 at OUAT, Bhubaneswar to study the response of basmati rice varieties to system of rice intensification (SRI). The results showed that use of organic manure (FYM 15.0 t ha-1) improved growth attributes like plant height, tillering, dry matter accumulation, LAI and CGR of basmati rice varieties and produced high grain (4.42 t ha^{-1}) yield comparable to those of INM (50% RDF+7.5 t FYM ha-1), but significantly greater than those of inorganic fertilization (RDF). Pusa Basmati-1 performed better than Geetanjali. Similarly, crop planted at close spacing (20cm × 20 cm) recorded higher growth attributes and greater grain yield than those of wide spacing (25cm × 25 cm). The growth attributes and grain yield did not vary much between the crops planted with 10 and 15-day old seedlings. Positive and significant correlations between grain yield and dry matter accumulation, LAI and CGR at different growth stages showed their strong and positive impact on grain yield of basmati rice.

Key words: SRI, basmati rice, growth attributes, grain yield, correlation

INTRODUCTION

Rice occupying about 45.54 mha produces 99.1 mt annually with average productivity of 2.18 t ha^{-1} in India [3]. It is the third largest rice exporter, after Thailand and Vietnam amounting to 4.4 mt (1.2 mt Basmati and 3.2 mt non-Basmati) annually. However, the surplus production scenario has no room for complacency keeping in view of increasing food demand and the vagaries of monsoon. About 170 to 180 mt rough rice (115-120 mt milled rice) needs to be produced in India by 2020 with an average productivity of 4.03 t ha^{-1} of rough rice to maintain the present level of self sufficiency. The productivity should almost be double from the current level [9]. This projected rice demand can only be met by maintaining steady increase in production over the years, which is necessarily to come from increased productivity under depleting natural resources, decreasing factor productivity and preservation of environmental quality [8, 18]. A unique package of rice production named '**System of Rice Intensification'** popularly known as '**SRI'**, has come up as a ray of hope that emphasizes on alteration in crop management for quicker, surer and cheaper remedies for the impending hazards. The merits of SRI have now, been demonstrated in all the major rice growing countries of Asia and in many other countries [21]. The key practices in SRI are transplanting very young seedling of 8-12 days old at 2-3 leaf stage, grown in a garden like nursery, singly in a square pattern with wider spacing, avoiding continuous flooding to maintain mostly aerobic soil condition, controlling weeds mechanically and applying compost as much as possible [6, 20]. SRI has claimed substantial increase (3-4 times) in rice yield with consequently increasing the productivity of the land, labour, water and capital [22]. Indian Basmati rice has become a major export item of agricultural products now-a-days, due to increase in its global popularity. Emergence of sizeable middle income groups with perceptible change in their food habit has increased the demand of quality rice like Basmati in India. Production of high quality aromatic rice by the farmers for export as well as domestic purpose is a major thrust of future agriculture strategy. The Basmati rice varieties are expected to respond to the new SRI technique that needs appropriate management of plant, soil, water and nutrients. In the present investigation an attempt has been made to study how SRI technique influences the growth behavior of Basmati rice and its impact on grain productivity.

MATERIALS AND METHODS

A field experiment was conducted at the Central Farm of OUAT, Bhubaneswar (20^0 15´ N Latitude, 85^0 52´ E Longitude and an altitude of 25.9 m MSL) in split-plot design with three nutrient management practices [F_1 = 60-30-30 kg N-P_2O_5-K_2O ha^{-1} (RDF), F_2 = 50% RDF + 7.5 t FYM ha^{-1} and F_3 = 15 t FYM ha^{-1}] and two spacing (S_1 = 20cm x 20cm and S_2 = 25cm x 25cm) in the main-plots and two basmati rice varieties (V_1 = Geetanjali and V_2 = Pusa Basmati-1) with two seedling age (A_1 = 10 day-old and A_2 = 15 day-old seedlings) in the sub-plots in three replications. The soil was sandy loam with pH 5.7, organic carbon 3.5 g kg^{-1} soil, available N 153 kg ha^{-1}, available P 11.6 kg ha^{-1} and available K 136 kg ha^{-1}. The crop received 1373 and 1521 mm rainfall during 2007 and 2008, respectively. Seedlings were raised in wet garden-like nursery in which seeds of each variety were sown twice at a gap of 5 days to obtain 10 and 15 day-old seedlings to be planted in the main field on the same date. One seedling along with the soil and seed (embryo) attached to the seedling was placed on the grids marked by the marker at the specific spacing as per the treatments. The same layout plan was used for conducting the experiment during both the years. The manures and fertilizers were applied through FYM, urea, single super phosphate and muriate of potash. Full dose of FYM, phosphorus and potassium and one-third of nitrogen were applied as basal. Top dressing of N was done one-third at 10 days after transplanting and remaining one-third after panicle initiation. The nutrient contents of the FYM used were 0.53% N, 0.28% P and 0.56% K. Weeding was done thrice at 10 days interval starting from 10 days after transplanting (DAT) using a cono-weeder. Experimental plots were kept moist up to panicle initiation stage by suitably maintaining the water level in the side channels of each bed. Thereafter a thin film of water was allowed to stand over the bed from panicle initiation stage to 10 days before the harvest of the crop. Excess rain water was drained out as and when required. Gall midge was observed during the *kharif* season of 2007, which was controlled successfully by spraying triazophos @ 2 ml $litre^{-1}$ of water.

Observations on plant height, tillers m^{-2}, LAI and dry mater accumulation were recorded at 14 days interval. Ten (10) hills were randomly tagged in each plot for recording plant height and number of tillers m^{-2}. Five (5) hills from second row of each plot were cut at the base at each stage, their fresh weights were recorded, the green leaf, culm and panicles were separated and dried in a hot air oven at 70^0C for 72 hours till constant weights were obtained. The dry weights of all the plant parts were recorded in each plot to get dry matter accumulation at each stage during both the years. Then LAI and CGR were estimated following standard procedures [24]. The grain yield of the crop was recorded at harvest. Data were analyzed following analysis of variance as suggested by [4] and means of treatments were compared based on the least significant difference (LSD) at the 0.05 probability level. The correlations between grain yield and dry matter accumulation, grain yield and LAI and grain yield and CGR were tested at 5% level of significance.

RESULTS AND DISCUSSION

Growth attributes

The plant supplied with inorganic fertilizer exhibited higher growth parameters at initial stage up to 14 DAT because of readily available plant nutrients from inorganic source. However, the plants under organic manuring were more vigorous at later stages (28 DAT and onwards) than those fed with inorganic source; but were similar to those under integrated nutrient management practices. Application of organic manure (15t FYM ha^{-1}) produced taller plants with more number of tillers $plant^{-1}$ than those obtained with INM and RDF practices (Table 1). Slow release of the nutrients from the organic source and blending effect of FYM on inorganic source under INM treatment helped in reducing nutrient loss, prolonging the availability of nutrients to match with the absorption pattern of rice plant resulting in improvement of growth parameters like plant height and tillering [5, 19]. Close spacing (20 cm × 20 cm) produced taller plants with greater number of tillers per unit area particularly at latter growth stages as compared to those at wide spacing (25 cm × 25 cm). The close planted crop produced taller plants than wider ones particularly in later stages of crop growth which might be due to mutual shading that resulted in low light intensity at the base of the plant that leading to elongation of the lower internodes [15]. Number of tillers per unit area was maximum at close spacing because of more number of hills per unit area (25 hills m^{-2}) than wider spacing (16 hills m^{-2}). Aromatic rice variety Pusa Basmati-1 was relatively shorter in height but produced more number of tillers per unit area throughout the growth period than that of Geetanjali. Transplanting of young seedlings (10-day old) exhibited taller plants at early growth stages and had greater tiller production than that of transplanting old seedlings (15-day old) because young seedlings absorbed the transplanting shock quickly and established themselves well at the early stage that helped early promoting of growth attributes [20].

Organic manuring recorded higher LAI and greater dry matter accumulation as compared to those obtained with INM and RDF practices at all the growth stages except at 14 DAT (Table 2). It recorded 18, 14 and 13% higher dry matter production over RDF at 42, 56 and 70 DAT respectively. Superiority of organic manuring and INM practice in SRI was noted because of better mineralization of FYM under prevailing aerobic condition and dissolution of minerals and chelating of micronutrients due to the presence of humic acid in organic source [12]. Close spacing had higher LAI and dry matter accumulation than those at wider spacing. Pusa Basmati-1 produced higher LAI and greater dry matter accumulation throughout the growth period than those of Geetanjali. Higher LAI and greater dry matter accumulation in Pusa Basmati-1 than other basmati rice varieties was also noticed by others [14]. Transplanting of young seedlings recorded greater dry matter accumulation and higher LAI at all the stages than those of transplanting old seedlings. Younger seedlings have faster recovery from transplanting stress and higher potential for LAI development and dry matter production than aged seedlings [17].

Both the crop growth rate (CGR) and net assimilation rate (NAR) of Basmati rice responded in some cases to different cultural practices under SRI. While CGR increased steadily upto 56 DAT, the NAR showed a decreasing trend after 42 DAT as the crop advanced with age. Organic manuring resulted in higher CGR particularly at tillering and panicle formation stages than those of INM and RDF practices; but it had very little effect on NAR of Basmati rice (Table 3). Close spacing had higher CGR than wider spacing; but it had lower NAR than that of wider spacing. The CGR did not vary much between the two Basmati rice varieties; but, Geetanjali showed its superiority over Pusa Basmati-1 on recording higher NAR of this crop. Transplanting of young seedlings had higher CGR during early growth period than that of transplanting old seedlings; but NAR followed the reverse trend in most of the growth periods.

Table 1: Effect of nutrient management practices, spacing and age of seedling on plant height (cm) and tillering of basmati rice varieties under SRI (Avg. data of 2 years)

Treatments	Plant height (cm)					Number of tillers m^{-2}			
Nutrient management	**14 DAT**	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**14 DAT**	**28 DAT**	**42 DAT**	**56 DAT**
RDF*	13.0	20.0	32.0	85.3	94.0	68	184	293	328
INM	12.2	19.8	32.8	88.7	95.4	65	205	311	337
OM	12.4	18.9	34.2	91.2	97.9	57	221	327	349
SEM (±)	0.3	0.3	0.5	1.2	1.1	1.7	7.2	9.1	4.8
CD at 5%	NS	NS	NS	3.7	3.3	5.0	22.5	28.0	15.0
Spacing									
20cm × 20cm	12.2	19.3	32.7	89.8	97.0	78	249	347	385
25cm × 25cm	12.8	19.8	33.3	86.6	94.1	48	158	274	291
SEM (±)	0.2	0.3	0.4	1.0	0.9	1.4	5.9	8.6	4.2
CD at 5%	NS	NS	NS	3.0	2.8	4.5	18.0	27.0	13.0
Variety									
Geetanjali	12.3	19.9	35.7	90.8	97.2	60	190	298	329
Pusa Basmati-1	12.7	19.3	30.3	85.6	93.8	67	217	323	348
SEM (±)	0.2	0.2	0.4	1.0	0.7	1.0	4.5	5.7	3.9
CD at 5%	NS	NS	1.3	2.9	2.2	3.0	13.0	16.5	11.5
Age of seedling									
10 days	13.5	20.2	32.9	86.9	94.9	68	218	323	349
15 days	11.5	18.9	33.1	88.2	96.1	59	190	298	328
SEM (±)	0.2	0.2	0.4	1.0	0.7	1.0	4.5	5.7	3.9
CD at 5%	0.6	0.7	NS	NS	NS	3.0	13.0	16.5	11.5
C V (%)	10.0	7.9	7.6	6.7	5.5	13.6	17.4	14.3	6.8

*RDF (Recommended dose of fertilizer) = 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}; INM (Integrated nutrient management) = ½ RDF + 7.5 t FYM ha^{-1}; OM (Organic manuring) = 15 t FYM ha^{-1}

Table 2: Effect of nutrient management practices, spacing and age of seedling on leaf area index (LAI) and dry matter accumulation (gm^{-2}) of basmati rice varieties under SRI (Avg. data of 2 years)

Treatments	Leaf Area Index (LAI)					Dry matter yield (g m^{-2})				
Nutrient management	**14 DAT**	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**	**14 DAT**	**28 DAT**	**42 DAT**	**56 DAT**	**70 DAT**
RDF*	0.14	0.84	2.55	3.29	1.58	15.2	124	390	744	997
INM	0.12	0.91	2.86	3.55	1.76	14.2	125	424	785	1053
OM	0.11	1.08	3.30	4.01	2.19	13.9	128	454	847	1128
SEM (±)	0.00	0.02	0.06	0.07	0.05	0.2	3.0	7.8	10.5	17.6
CD at 5%	0.01	0.08	0.19	0.21	0.16	0.7	NS	24.6	33.2	54.3
Spacing										
20cm × 20cm	0.15	1.16	3.55	4.52	2.30	15.2	133	442	814	1084
25cm × 25cm	0.09	0.72	2.25	2.71	1.39	13.7	118	403	770	1035
SEM (±)	0.00	0.02	0.05	0.06	0.04	0.2	2.5	6.4	7.7	14.6
CD at 5%	0.01	0.06	0.15	0.18	0.13	0.7	7.9	20.1	24.6	NS
Variety										
Geetanjali	0.11	0.86	2.75	3.50	1.61	14.2	125	412	770	1038
Pusa Basmati-1	0.13	1.03	3.06	3.73	2.08	14.7	126	433	814	1081
SEM (±)	0.00	0.02	0.04	0.05	0.02	0.2	1.5	6.5	7.6	10.5
CD at 5%	0.01	0.06	0.12	0.15	0.07	NS	NS	18.6	21.6	30.3
Age of seedling										
10 days	0.13	1.00	3.05	3.94	1.99	15.3	129	435	808	1070
15 days	0.11	0.89	2.76	3.28	1.70	13.6	122	411	776	1048
SEM (±)	0.00	0.02	0.04	0.05	0.02	0.2	1.5	6.5	7.6	10.5
CD at 5%	0.01	0.06	0.12	0.15	0.07	0.5	4.4	18.6	21.6	NS
C V (%)	13.1	13.0	10.3	9.4	12.7	8.6	13.5	9.8	8.3	9.2

*RDF (Recommended dose of fertilizer) = 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}; INM (Integrated nutrient management) = ½ RDF + 7.5 t FYM ha^{-1}; OM (Organic manuring) = 15 t FYM ha^{-1}

Grain yield

The crop under organic manuring (15 t FYM ha^{-1}) produced higher yield (4414 kg ha^{-1}), which were at par with that of INM; but was significantly higher over that of RDF (Fig. 1). Organic manuring and INM practice increased grain yield by 7.5 and 4.5% respectively over application of inorganic fertilizers. Organic manure alone or in combination with inorganic fertilizers might prevent nutrient losses due to its slow release and might supply nutrients in optimal congruence with crop demand responsible for increased grain yield [5]. Beneficial effect of organic manures on grain yield of rice under SRI technique was well documented by [2, 11, 13].

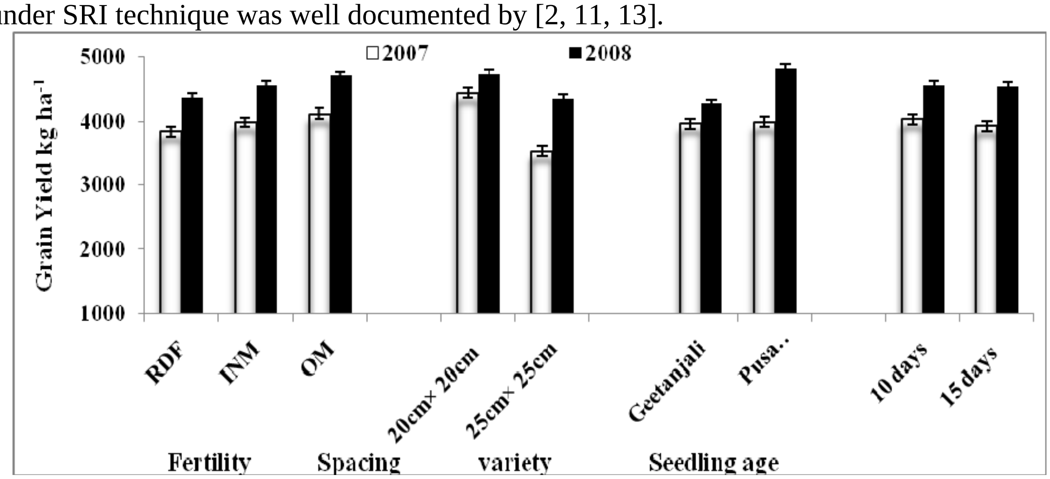


Fig.1: Effect of nutrient management practices, spacing and age of seedling on grain and straw yield of basmati rice varieties under SRI method

SRI system requires reduced plant density so that intra-species competition, being the main cause of pre-mature tiller mortality, is effectively minimized [20]. But better performance of individual plant at wide spacing failed to compensate the reduction in number of hills m^{-2} (by 36%) resulting in declining 14% grain yield than that of close spacing. We observed that crop at close spacing provided improved growth attributes that ultimately resulted in higher grain yield (4587 kg ha^{-1}) than that obtained with wide spacing (Fig. 1). Close spacing with higher plant population has been reported to register more yield than wide spacing with low plant population [1, 16]. Pusa Basmati-1 produced higher grain yield (4460 kg ha^{-1}) which was 9.6% higher than that of Geetanjali (Fig. 1). Greater genetic potential of Pusa Basmati-1 was responsible for its higher grain yield over Geetanjali [14].

Table 3: Effect of nutrient management practices, spacing and age of seedling on crop growth rate (CGR) and net assimilation rate (NAR) of basmati rice varieties under SRI (Avg. data of 2 years)

Treatments	**CGR (g m^{-2} day^{-1})**				**NAR (g m^{-2} day^{-1})**			
Nutrient management	**14 -28 DAT**	**28-42 DAT**	**42 -56 DAT**	**56 -70 DAT**	**14 -28 DAT**	**28-42 DAT**	**42 -56 DAT**	**56 -70 DAT**
RDF*	7.6	17.7	25.3	18.5	7.05	7.69	7.60	7.18
INM	7.9	21.3	26.2	19.2	6.61	8.33	6.87	6.96
OM	8.3	24.0	28.1	19.8	6.99	8.28	6.64	6.70
SEM (±)	0.3	0.7	0.8	1.0	0.28	0.20	0.22	0.34
CD at 5%	NS	2.2	2.6	NS	NS	NS	0.70	NS
Spacing								
20cm × 20cm	8.2	22.7	26.7	18.9	5.25	7.00	5.60	5.43
25cm × 25cm	7.7	19.2	26.4	19.5	8.52	9.22	8.46	8.44
SEM (±)	0.3	0.6	0.7	0.8	0.22	0.16	0.18	0.28
CD at 5%	NS	1.9	NS	NS	0.71	0.51	0.57	0.87
Variety								
Geetanjali	7.9	19.8	26.4	19.1	7.64	8.43	7.40	7.94
Pusa Basmati-1	7.9	22.2	26.7	19.3	6.13	7.79	6.68	5.94
SEM (±)	0.2	0.5	0.6	0.7	0.19	0.30	0.19	0.29
CD at 5%	NS	1.5	NS	NS	0.55	NS	0.55	0.85
Age of seedling								
10 days	8.3	21.3	26.9	19.1	6.57	7.47	6.72	5.93
15 days	7.5	20.7	26.1	19.3	7.20	8.75	7.34	7.96
SEM (±)	0.2	0.5	0.6	0.7	0.19	0.30	0.19	0.29
CD at 5%	0.5	NS	NS	NS	0.55	0.86	0.55	0.85
C V (%)	15.2	12.2	10.5	16.2	13.6	16.3	15.2	19.0

*RDF (Recommended dose of fertilizer) = 60 kg N, 30 kg P_2O_5 and 30 kg K_2O ha^{-1}; INM (Integrated nutrient management) = ½ RDF + 7.5 t FYM ha^{-1}; OM (Organic manuring) = 15 t FYM ha^{-1}

The age of seedling at planting did not exert much effect on grain yield of Basmati rice (Fig. 1). Planting young seedlings (10 day old) marginally increased grain yield by 1.5% over those of planting old seedlings (15 day old). Early establishment of the crop planted with young seedlings due to its faster recovery from transplanting shock was responsible for better growth and higher grain yield when compared with that of planting older seedlings. This is in conformity with the findings of several workers [7, 11, 17].

Relationship between grain yield and growth attributes

The dry matter production during the growth period of rice is important for determination of its grain yield [25]. Dry matter accumulation at maximum tillering (Fig. 2b), panicle formation (Fig. 2c) and grain development stages (Fig. 2d) showed very strong and positive relationship with grain yield of Basmati rice. High determination coefficient (R^2 > 0.8) at these stages showed a linear increase in the grain yield with the corresponding increase in dry matter accumulation. LAI at different stages [tillering (Fig. 3a), panicle initiation (Fig. 3b), panicle emergence (Fig. 3c) and flowering (Fig. 3d)] showed positive and significant relationships with grain yield of this crop.

The results indicated that high LAI functioning over all the above growth stages was largely responsible for improving panicle production and grain development that ultimately helped in increasing grain yield of rice [14]. CGR during the periods of panicle initiation (Fig. 4b), panicle development (Fig. 4c) and grain formation (Fig. 4d) recorded positive and significant correlations with grain yield of Basmati rice and the regression accounted for 73%, 33.4% and 27.8% variability for the respective stages. However, CGR during the period of tillering (Fig. 4a) did not show significant correlation with grain yield. The yield potential of rice might, thus, be explained by the production of CGR values during the vital periods of panicle initiation, panicle development and grain formation [10, 23]. The results clearly showed that dry matter accumulation, LAI and CGR during the vital crop growth periods could explain well the yield potential of Basmati rice.

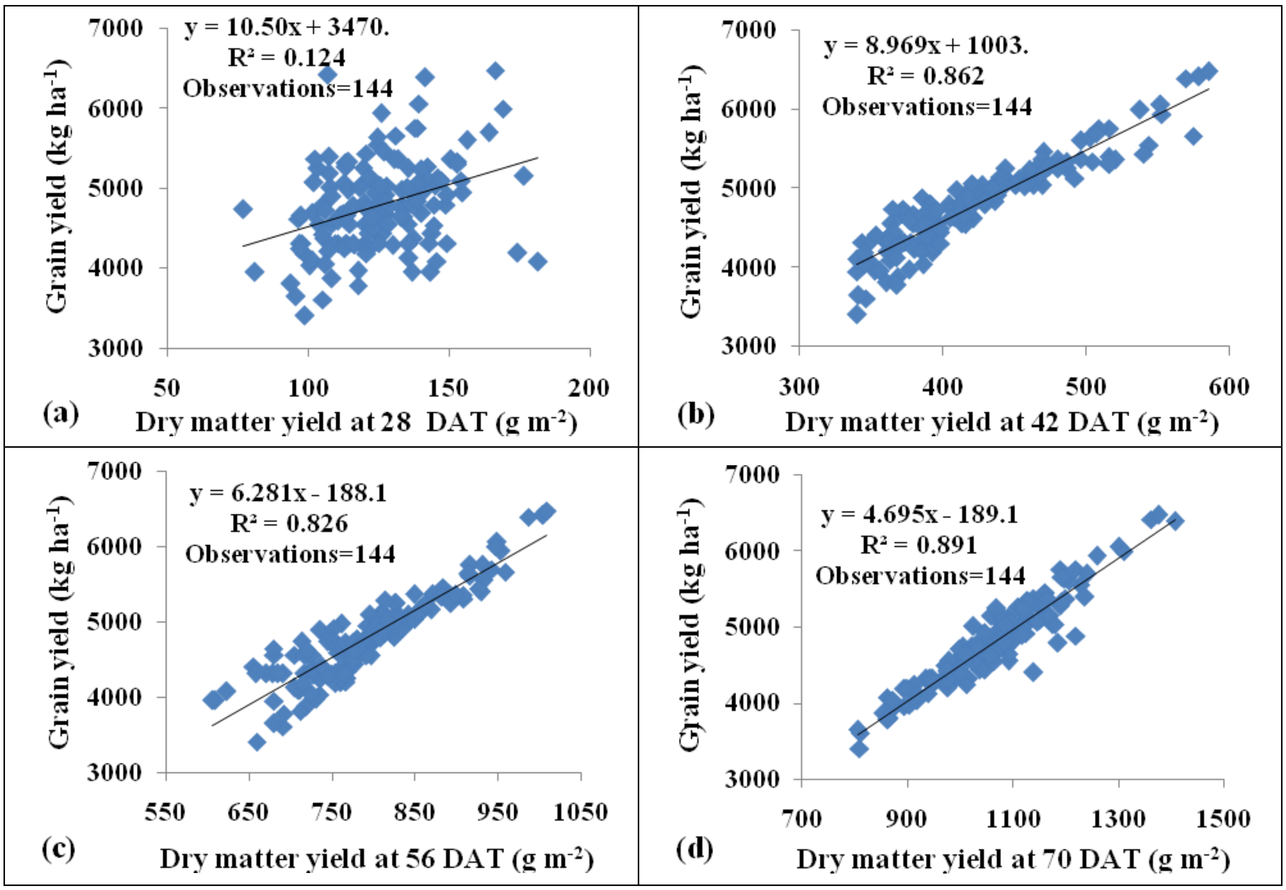
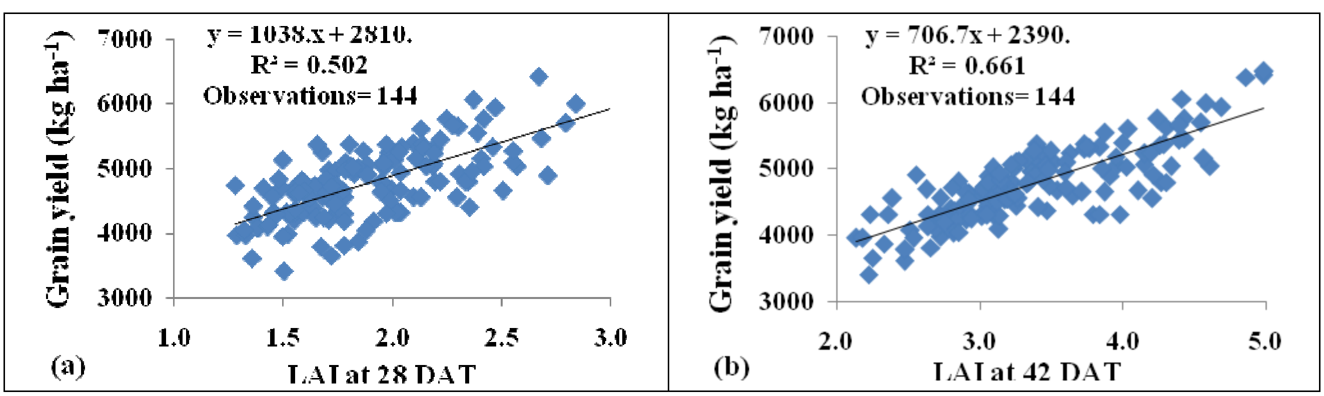


Fig.2: Relationship between grain yield and dry matter accumulation at (a) 28 DAT, (b) 42 DAT, (c) 56 DAT and (d) 70 DAT



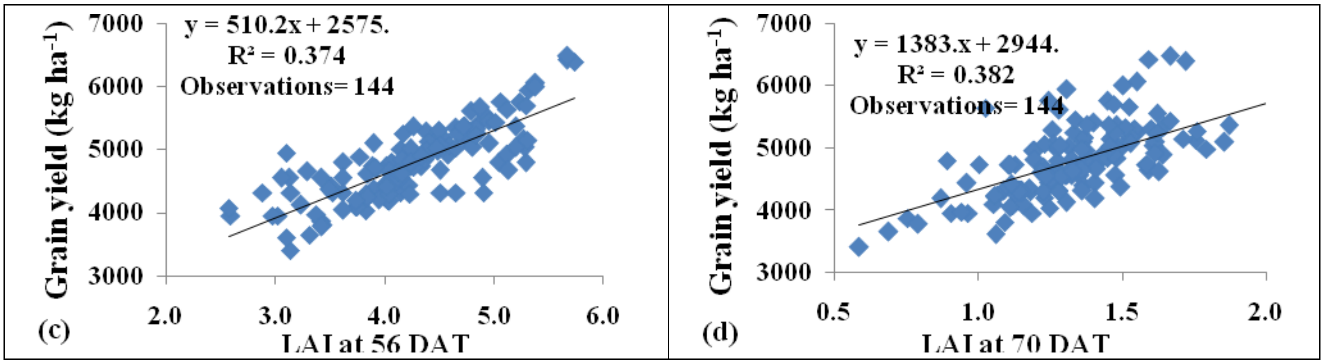


Fig.3: Relationship between grain yield and LAI at (a) 28 DAT, (b) 42 DAT, (c) 56 DAT and (d) 70 DAT

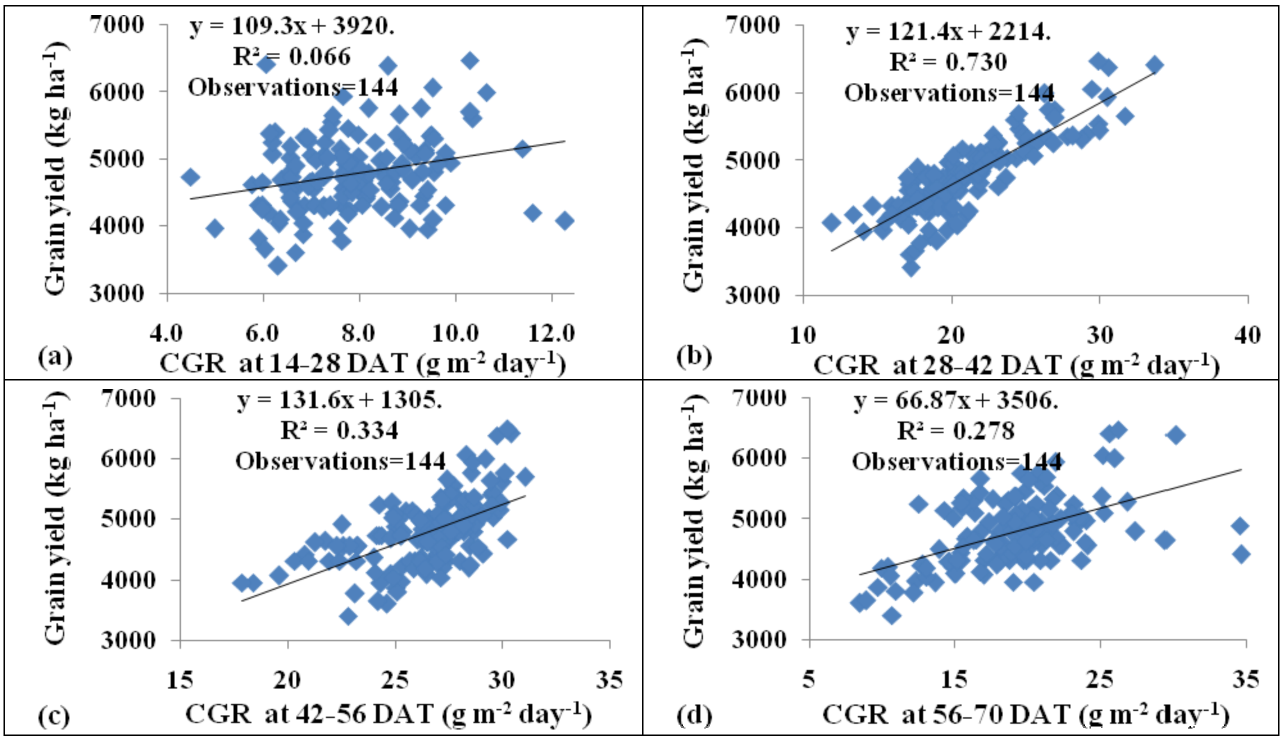


Fig.4: Relationship between grain yield and crop growth rate at (a) 14-28 DAT, (b) 28-42 DAT, (c) 42-56 DAT and (d) 56-70 DAT

CONCLUSION

Organic manuring (15t FYM ha^{-1}) or integrated nutrient management (50% RDF+7.5t FYM ha^{-1}) may be practice under system of rice intensification (SRI) for the production of high grain yield of basmati rice. The results further indicate that Pusa Basmati-1 may be planted at close spacing (20 cm × 20 cm) with single seedling per hill for better growth and higher productivity.

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