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Growth, development and yield response of rice (*Oryza sativa* L.) as influenced by efficient nitrogen management under subtropical climatic condition

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Abstract

Globally, the current important concern is to minimize nitrogen use in rice cultivation under climate change condition. A field experiment in randomized block design (RBD) with three replications was conducted during *kharif* season of 2015 at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut U.P. to determine the effects of ten treatments of different nitrogen splits application on growth physiological traits and yield of rice. Results of growth analysis indicated that, increasing the splits off nitrogen caused the increment of growth indexes (pant height, tillers, DM, LAI, CGR, RGR, NAR, photosynthetic rate), yield and protein content of rice. The growth characters (CGR during 90 DAT) 3.3%, as compared to T_2, (NAR) 22.12 and 7.08 %, (photosynthetic rate)17.5 and 18.2 % as compared to the control during 30-60 and 60- 90 DAT, respectively and grain yield 60 kg over the T_2 (1/2 N as basal, 1/4 at tillering and 1/4 panicle initiation stage) signifi cantly increased with the application of nitrogen as 1/4 N as basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking (T_3). In modern agriculture, efficient N management is a key component to improve growth indexes and sustain crop productivity while maintaining environmental quality.

Keywords: efficient, split application of nitrogen, growth indexes, physiological traits

Introduction

Rice is the most important staple crop and more than half of the world population dependent on rice. The slogan "rice is life" is very much appropriate for India as this crop plays a vital role in ensuring nation's food security. Food security in the world is challenged by increasing food demand to meet the global rice demand, it is estimated that about 114 million tonnes of additional milled rice need to be produced by 2035 which is equivalent to an 2 overall increase of 26 per cent in the next 25 years (Kumar and Ladha, 2011) [9]. India is the second largest consumer and producer of rice in world after China. In india rice area, production and productivity was 43.38 mha, 104.32mt and 24.07q ha^{-1} respectively and Uttar Pradesh is the largest rice growing state after West Bengal but its productivity is low, with an area of 5.98 mha, production and productivity of 14.63 mt and 2.44 t ha^{-1}, respectively (Ministry of Agriculture & Farmers Welfare, 2017) [12].

Nitrogen is the an important nutrient element that determines rice yield, due to its role in the photosynthesis, biomass accumulation and, spikelets formation due to essential constituent of proteins, chlorophyll and metabolites such as nucleotides, phosphatides, alkaloids, enzymes, hormones, vitamins etc. which have great physiological importance in plant metabolism. Apart from promoting vegetative growth, as 75 per cent of leaf nitrogen is associated with chloroplast which physiologically helps in dry matter production through photosynthesis while dry matter contains about 5% N, and influences the sink size thereby increasing the grain yield of rice. (Somasundaram *et al.* 2002 [18] and Yoshida *et al*., 2006) [20].

The excess N may cause significant biochemical changes in plants and may lead to nutritional imbalances due to soil applied nitrogen undergoes several complex physical and chemical transformations which either decrease or increase the availability of nitrogen fertilizer to plant roots. (Salim *et al.* 2002) [17]. Therefore, availability of nitrogen at various appropriate plant growth stages is important to reduce nitrogen loss and increase rice growth and development for higher production. (Saha *et al*., 1998) [15]. However, Nitrogen taken up during early growth stages accumulated in the vegetative parts of the plant and is utilized for grain formation, A large portion of the nitrogen is absorbed during differentiation the leaves and stems contain a large portion of the nitrogen taken up by the plant(Abou-khailfa, 2012) [2].

Split application is still a predominant method to achieve even distribution of fertilizer and reduce the risk of N fertilizer loss associated with levee breakage during the growing season

(Harrell *et al*., 2011) [7]. Another important aspect in terms of N timing is to improve growth and yield due to with mid-season fertilization and increase of protein content in grain improved the resistance to damages from milling machine (Wopereis *et al*., 2002) [19]. The visual symptom associated with N deficiency was the basis of developing leaf color chart (LCC) for monitoring real-time N status in rice. Nonetheless, loss of nitrogen vary depending on the timing, rate, and method of N application. Since N demands are high during the entire plant growth, it is difficult to supply adequate amount of N without burning the leaves. Therefore, foliar N is normally taken only as a supplement. Keeping all these facts in view this study was, therefore, designed to investigate the "effect of split application nitrogen on growth, development, yield and quality of rice (*Oryza sativa* L.)" was carried out at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut (U.P.) during *kharif*, 2015.The objective of the presentst investigation was to study the effect of split application of nitrogen on growth and development of rice.

2. Material and Methods

2.1. Experimental Site

The Field experiment was carried out at Crop Research Center of Sardar Vallabhbhai Patel University of Agriculture and Technology Meerut ($29^0 40'$ North and longitude of $77^0 42'$ East and at an altitude of 237meter above mean sea level) U.P. during *kharif* season of 2015. Meerut lies in the heart of Western Uttar Pradesh and has semi arid sub-tropical climate with extremes of hot weather in summer and cold in winter season. The rains are predominantly caused by south-west monsoon which sets in the last week of June, reaches its peak in July-August and withdraws by the end of September. The area receives 410 mm of rains annually on an average, of which 90% is confined to rainy season (July-September) during the study period and minimum and maximum temperatures recorded during period of plant growth were 38^o and 40^{o}C respectively, whereas mean relative humidity varied between 47.3 to 88.9 per cent. Soil of experimental field was sandy loam with pH of 7.80, electric conductivity (EC) 1.7dSm-1, low in organic C (0.49%), available N (156 kg ha^{-1}), medium in available P (15.02 kg ha^{-1}) and K (238 kg ha^{-1}).

2.2. Experimental design and treatments

The experiment consisted of ten nitrogen application timings treatments viz. (T1 -Control, T2 -1/2 N as basal, 1/4 at tillering and 1/4 panicle initiation stage, T3 -1/4 N as basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking stage, T4-1/2 N as basal, 1% foliar application of nitrogen at tillering and panicle initiation stage, T5-1/2 N as basal, 1% foliar application of nitrogen at tillering, panicle initiation and milking stage, T6-1/2 N as basal, 1% foliar application of nitrogen at tillering, booting, panicle initiation and milking stage, T7- 1/4 N as basal, 1% foliar application of nitrogen at tillering, panicle initiation and milking stage, T8- 1/4 N as basal, 1% foliar application of nitrogen at tillering, booting, panicle initiation and milking stage, T9- 1/2 N as basal, rest through leaf colour chart and T10-1/4 N as basal, rest through leaf colour chart) for comprised of splitting of nitrogen as basal, at tillering, panicle iniation and milking stage in different proportions including foliar spray, use of LCC (< 4) and control. The treatments were arranged in randomized block design replicated three times keeping 20 cm and 15 cm inter and intra row spacing, respectively. All plots received identical cultural treatments in terms of plowing, seed rate, transplanting method, weeding, Irrigation and disease and insect pest control. The crop (PS-5) was fertilized with 60-40-25 kg PKZn ha^{-1} and applied at the time of final land preparation. Nitrogen was applied as per treatments in the form of urea. The leaf colour chart readings were taken at 10 days interval (10, 20, 30, 40, 50, 70, 80 and 90 DAT) starting from 10 DAT till milking stage. Whenever the green colour of more than 5 out of 10 leaves were observed equal to or below a set critical Limit (4) of LCC, nitrogen was applied @ 20 kg ha^{-1}. The 1% nitrogen (17.44 kg urea/800 liter fresh water) solution was sprayed by a knapshek sprayer using flat fan nozzle till all the leaves got moistened at tillering, booting, panical initiation and milking stage of rice. The plots were sprayed during late afternoon hours when wind speed slowed down to less than 10 km hr-1.

2.3. Data Collection

Observation on various growth parameters viz., plant height, number of tillers, leaf area, leaf area index and dry matter accumulation were made at 30, 60, 90 DAT and at harvest stage of the crop. The five hills were selected randomly and tagged from net plot area to recorded such observations. The above ground plant parts were segmented into different components as leaf, stem, leaf sheath and panicle. Leaf area index, area of leaf per unit area of soil surface was measured with the helf of PAR/LAI ceptometer (Accu PAR model LP-80). The instrument calculates the leaf area index based on the above canopy measurement along with other variables. Growth and development parameters were calculated during four growth stages by taken samples from sampling area total dry weight in all treatments.Dry matter accumulation was recorded by selecting five hills randomly from sampling area of each plot. Selected hills were cut carefully closed to the ground surface at 30, 60, 90 DAT and at harvest stage. After sun drying these samples were kept in paper bags by cutting in small pieces and were put in a electric oven at 65$\pm$1 ^{0}C till constant weight. After this the weight was recorded on electronic balance and expressed as dry matter accumulation in g/hill. Based on dry matter accumulated by crop over times, crop growth rate (CGR), relative growth rate (RGR) and net assimilation rate (NAR) were calculated by formulas described by (Hunt, 1978) [8].

Crop growth rate (g/m^2/ day)

CGR was worked out through the standard procedures described as under:

$$CGR = SA \times \frac{Wii - Wi}{Tii - Ti}$$

Where, Wi and Wii are dry weight (g/hill) at time Ti and Tii, respectively.

SA = Ground area occupied by the hill

Relative growth rate (mg/g /day)

RGR was worked out the formula given as:

$$RGR = \frac{\log_e Wii - \log_e Wi}{Tii - Ti}$$

Where, Wi and Wii are dry weight (g/hill) at time Ti and Tii, respectively.

Log_e (Natural log value) = 2.3

Net assimilation rate (g/m^2/day)

NAR was worked out through the standard procedures described as:

$$NAR = CGR \times \frac{\log_e Lii - \log_e Li}{Lii - Li}$$

Where, Li and Lii are leaf area (m^2) at time Ti and Tii, respectively.
CGR = crop growth rate ($g/m^2/day$)

Photosynthetic rate (μmol/m²/sec)

Photosynthesis is the formation of carbohydrates from CO_2 and a source of hydrogen (as water) in the chlorophyll-containing tissues of plants exposed to light. Photosynthetic rate was measured with a portable photosynthesis measuring instrument (Infrared Gas Analyzer) at 30, 60 and 90 DAT in clear sunshine at 11 to 12 hrs. Protein content in grains of rice at maturity was worked out by multiplying the nitrogen percentage of grains with 5.93 (AOAC, 1960) [1]. The crop was harvested from an area of 10.4 m^2 (net plot size) leaving two rows to avoid border effect. After threshing cleaning and drying the grains, the grain yield was recorded in kg $plot^{-1}$. The yield of net plot, then converted to q ha^{-1}.Dry weight of straw collected from net plot was recorded after sun drying for 5-6 days and expressed in q ha^{-1} and after drying weighed the biological yield in $kplot^{-1}$ than converted in q ha^{-1}.

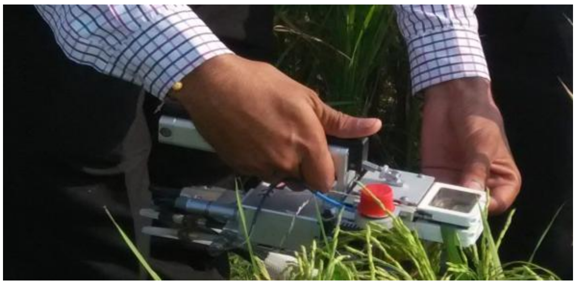

Fig 1: Taken the photosynthetic rate reading at 30 days interval through Infrared Gas Analyzer (IRGA)

3. Results and Discussion

3.1. Growth and Development

Growth of rice was discribed by plant height, tiller number, dry matter production, leaf area index, crop growth rate, relative growt rate, net assimilation rate and photosynthesis rate under variable nitrogen splits. The effect of nitrogen splitting treatments on plant height (Table 1) at different stages of crop growth was found to significant, except 30 DAT where plant height, No. of tillers and LAI did not exhibited any significant effect. plant height of rice increased over time by gradual elevation of nitrogen spliting up to 60 days of transplanting afterwards showed a falling trend. Nevertheless, the maximum plant height (96.6 cm) was observed with the application of nitrogen 1/2 as basal, 1/4 at tillering and 1/4 at panicle initiation (T_2) which was statistically *at par* with T_6 and T_9 with 94.7 and 95.4 cm, respectively. Though, the shortest plants were found under control (68.7 cm) at 60 DAT. At 90 DAT and harvest stage T_3 (1/4 nitrogen each basal, at tillering, at panicle initiation and at milking stage) being on par with T_2 and T_{10}, resulted into significantly tallest plants (106 and 109.1 cm) as compared to rest of the treatments. The same result was also reported by Anil *et al*. (2014) [3] where taller plants were recorded in 4 equal splits. Moreover, the significantly highest tillers m^{-2}(370, 357 and 332) were produced with the application of nitrogen as 1/4 basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking stage (T_3) followed by T_2 (1/2 N as basal, 1/4 at tillering and 1/4 at panicle initiation) and T_{10} (1/4 N as basal, rest through leaf colour chart), remained *at par* with each other. Although, the lowest tillers m^{-2} (300, 294 and 286) were recorded under (Table 2) control plot (T_1) in similar trend at 60, 90 DAT and harvest stage of rice, respectively. The rate of increase in leaf area was very fast during 30 to 60 DAT. LAI (Table 3) is the ultimate expression of photosynthetic activities, which may have great bearing on growth and biological yield parameters during the phasic development of plant. The significantly superiour LAI (4.75 and 3.92) was noticed with the application of nitrogen fertilizer as 1/4 basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking stage (T_3) which was *at par* with T_2, T_9 and T_{10} at 60 and 90 DAT, respectively while, lowest in control followed by T_7 and T_8 where only 54 and 62 kg N (1/2 as basal and rest through foliar application) was applied, at both the stages of crop growth. The diminishing trend of LAI after 60 DAT might be due to falling of lower leaves. These trends are in agreement with those obtained by Lampayan *et al.* (2010) [10].

Dry matter accumulation is directly related to the growth pattern of the crop, which influence the grain and straw yield linearly. At 30 DAT stage, the higest (9.00 g) and lowest (7.00 g) dry matter accumulation/hill (Fig. 2) was recorded with the application of nitrogen as 1/4 basal, 1/4 at tillering, 1/4 at panicle initiation and 1/4 milking stage (T_2) and $T_{1,}$ respectively. Though, all the treatments exhibited significant improvement over control but basal application of 1/2 N and then 2/3/4 spray of 1% N accumulated statisticaly similar dry matter/hill. Half or 1/4 N as basal and rest through LCC were also *at par* with each other. However, maximum dry matter accumulation (22.2, 33.9 and 39.80 g/hill at 60, 90 DAT and harvest, respectively) was noticed with the application of nitrogen as 1/4 basal, 1/4 at tillering, 1/4 at panicle initiation and 1/4 at milking stage (T_3) which was *at par* with 1/2 N as basal, 1/4 at tillering and 1/4 panicle initiation (T_2). The minimum (15.5, 23.5 and 27.90 g/hill) dry matter accumulation was noticed in without N application (T_1) at 60, 90 DAT and harvest, respectviely. Moreover, 1/4 N as basal and rest in three equal splits (T_3) and 90 kg N as 1/4 basal and rest through LCC (T_{10}) at harvest accumulated 42.6 and 36.5 per cent more dry matter as compared to control. Elevated nitrogen supply can boost dry matter content through production of photo-assimilates via leaves which is the center of plant growth during vegetative stage and later distribution of assimilates to the reproductive organs. Furthermore, dry matter production in rice is significantly related to intercept photosynthetically active radiation.

Significantly highest relative growth rate (14.52, 12.43 and 9.03 $g/day/m^2$ and 992, 452 and 247 mg/g/day) was recorded with the application of nitrogen as1/4 N basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking stage (T_3), which was statistically *at par* with T_2 during 30-60, 60-90 DAT and 90 DAT- harvest respectively (Fig.3and 4**)**. Though, the lowest CGR and RGR was observed in control, respectively. Higher crop growth rate in T_3, T_2 and T_{10} was mainly due to more dry matter accumulation at all the stages of crop growth. The crop growth rate during 90 DAT to harvest in T_3 was increased to the tune of 3.3% compared to the exhisting recommendation

(T_2). Crop growth rate and relative growth rate exhibited an uprising trend with crop age up to 90 DAT and thereafter it declined till maturity. Significantly higher net assimilation rate and photosynthetic rate (4.14 and 2.87 g/m^2 leaf area/day and 23.5 and 20.7 µmol/m^2/sec) was noticed with the application of nitrogen as 1/4 panicle initiation and 1/4 milking stage (T_3) than other treatments during 30-60 and 60-90 DAT respectively. The net assimilation rate increased by (Fig.5 and 6) 22.12 and 7.08 % as compared to the control in T_3 during 30-60 and 60- 90 DAT, respectively (Esfahani *et al.* 2006) [6]. The photosynthesis rate was increased by 17.5 and 18.2 % as compared to control during 30-60 and 60- 90 DAT, respectively while the lowest photosynthetic rate (20 and 17.5 µmol/m^2/sec) was recorded in control followed by T_7, and T_8. The phenomena of CGR,RGR, NAR and PR tend to be low again during later stage and negative towards maturity considerably due to several reasons like leaves shading owing to early closure of canopy which hinder solar radiation absorbed by the leaves therefore less photosynthetic assimilates produced which causes lowering the net assimilation rate, excessive leaf senescence after reproductive stage diminishing photosynthesis rate upkeep of respiration burden increases over time which hinge on biomass and particularly its N content and ineptitude of the plants to maintain post floral N uptake or cannot store significant N reserves in other organs excepting leaves. These results are in agreement with those obtained by Azarpour *et al*. (2014) [4], Paul *et al*. (2016) [13] and Salem *et al.* (2011) [16].

3.2. Grain and Straw Yield (q ha^{-1})
The split application of nitrogen as 1/4 basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking stage (T_3) produces significantly higher grain (Table 4) yield (52.40 q ha^{-1}), which was statistically *at par* with (T_2) and (T_{10}) than rest of the treatments. These treatments also out-yielded control by 25.4, 24.80 and 23.2 and q ha^{-1}, respectively. Moreover, T_3 treatment gave 60 kg more grains/ha than the existing recommendation (T_2). However, the 1% foliar application of nitrogen as 1/4 basal, 1% foliar application of nitrogen at tillering, booting, panicle initiation and milking stage (T_8) gave the 70 kg more yield compared to T_7 (1/4 N as basal, 1% foliar application of nitrogen at tillering, panicle initiation and milking stage).Each successive increase of 8 kg N/ha through foliar mean over 60 kh N/ha (1/2) as basal improved the grain yield by 80 and 70 kg ha^{-1} in T_5 to T_6, respectively. The lowest grain yield (27.00 q ha^{-1}) was recorded under control plot (T_1). The split application of nitrogen as 1/4 basal, 1/4 at tillering, 1/4 panicle initiation and 1/4 milking stage (T_3), being *at par* with T_2, T_{10} and T_9.These treatments also gave the 29.60, 29.32, 28.07 and 27.85 q ha^{-1} more yield to control, respectively. However, the lowest straw yield (43.72 q ha^{-1}) was recorded under control plot (T_1). Moreover, the control plot gave the lowest straw yield (43.72 q ha^{-1}). Significantly higher protein (8.6%) content in grains was noticed in T_3 and statistically *on par* between the treatments, T4, T5, T_6, T_7 and T_8, which brought significantly variation than control. Higher protein content in grains was mainly due to more nitrogen content in grains which in turn improved the protein. The result of Perez *et al*. (1996) [14] The increment of grain yield in this study at higher nitrogen levels might be due efficient absorption of nitrogen which raise the production due to highly relying on the number of spike-bearing tillers produced by each plant and translocation of the dry matter from source to sink and efficient partitioning of biomass into reproductive parts and also due to significantly higher values of yield attributes *viz.* panicle m^{-2}, length of panicle, filled grains panicle^{-1} and test weight (g) etc. which ultimately led to more biomass and grain yield production. These findings were in agreement with the findings of Ebaid *et al.* (2000) [5], Mannan *et al*. (2012) [11] and Youseftabar, *et al*. (2012) [21].

4. Conclusions
From the overall appraisal of the study, it can be concluded that there are wide variations in physiological as well as growth dynamics, biomass partitioning and as well as yield of rice under different nitrogen treatment. The important point is to conclude here that increased splits of nitrogen could be able to enhance growth dynamics, biomass partitioning and yield of rice plant due to efficient utilization of nitrogen. Nitrogen application in three equal splits (1/4 basal, 1/4 at tillering, 1/4 at panicle initiation and 1/4 milking stage) at tillering, panicle emergence and milking stage is essential, as nitrogen applied in splits is utilized in a better way towards increasing grain yield. It is, therefore, recommended that nitrogen spilt application at three growth stages (tillering, panicle emergence and milking stage) should be followed to obtain higher yield under the agroecological condition of Western Utter Pradesh.

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Table 1: Effect of various treatments on plant height (cm) at different growth stages of rice

Treatment	Plant height (cm)			
	Growth stages			
	30 Dat	60 Dat	90 Dat	At harvest
T_1	45.3	68.7	78.0	80.0
T_2	50.2	96.6	104.4	107.4
T_3	48.9	93.6	106.0	109.1
T_4	49.1	94.0	98.3	101.2
T_5	49.2	94.3	99.1	102.1
T_6	49.4	94.7	100.2	102.7
T_7	47.8	91.4	96.4	99.3
T_8	48.1	92.0	97.0	100.0
T_9	49.8	95.4	101.4	104.7
T_{10}	48.5	93.0	102.6	105.5
S Em ±	1.6	0.7	1.2	1.4
CD (P=0.05)	NS	2	3.7	4.3

Table 2: Effect of various treatments on number of tillers/m^2 at different growth stages in rice

Treatment	Tillars/m^2 Growth stages			
	30 Dat	60 Dat	90 Dat	At harvest
T_1	250	300	294	286
T_2	302	367	355	329
T_3	303	370	357	332
T_4	291	352	341	316
T_5	293	355	343	317
T_6	295	357	345	319
T_7	286	348	335	310
T_8	288	350	337	313
T_9	297	360	348	323
T_{10}	299	363	350	326
S Em ±	0.54	2	3	3
CD (P=0.05)	NS	7	8	9

Table 3: Effect of various treatments on leaf area index at different growth stage in rice

Treatment	Leaf area index Growth stage		
	30 Dat	60 Dat	90 Dat
T_1	2.16	3.45	3.12
T_2	2.50	4.71	3.83
T_3	2.50	4.75	3.92
T_4	2.33	4.50	3.56
T_5	2.35	4.51	3.61
T_6	2.36	4.53	3.64
T_7	2.26	4.42	3.42
T_8	2.27	4.44	3.45
T_9	2.40	4.60	3.70
T_{10}	2.42	4.64	3.73
S Em ±	0.04	0.05	0.08
CD (P=0.05)	NS	0.17	0.25

Table 4: Effect of various treatments on yield (grain and straw) and protein content (%) of rice

Treatments	Yields (q ha^{-1})			Protein content (%)
	Grain	Straw	Biological	
T_1	27.00	43.72	71.33	5.81
T_2	51.80	73.04	125.00	8.48
T_3	52.40	73.36	125.67	8.60
T_4	46.50	69.75	116.33	7.95
T_5	47.30	70.00	117.33	8.01
T_6	48.00	70.56	118.67	8.12
T_7	44.00	67.32	111.33	7.71
T_8	44.70	67.94	112.67	7.77
T_9	49.70	71.57	121.33	8.30
T_{10}	50.20	71.79	122.33	8.36
S Em ±	0.86	0.73	1.27	0.11
CD (P=0.05)	2.60	2.19	3.82	0.34

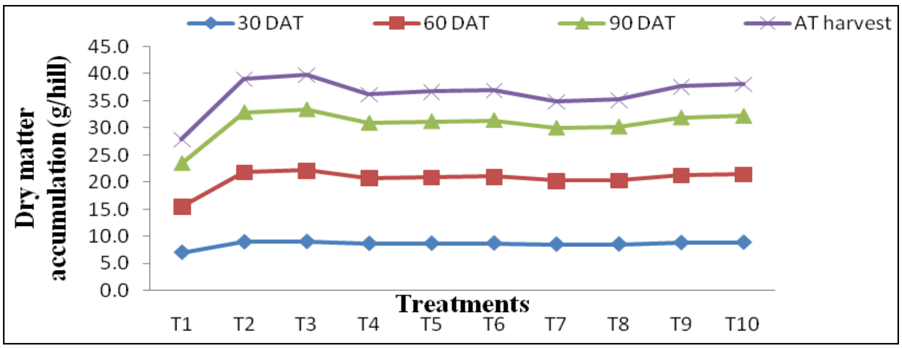

Fig 2: Effect of various treatments on dry matter accumulation (g/hill) at different growth stages of rice

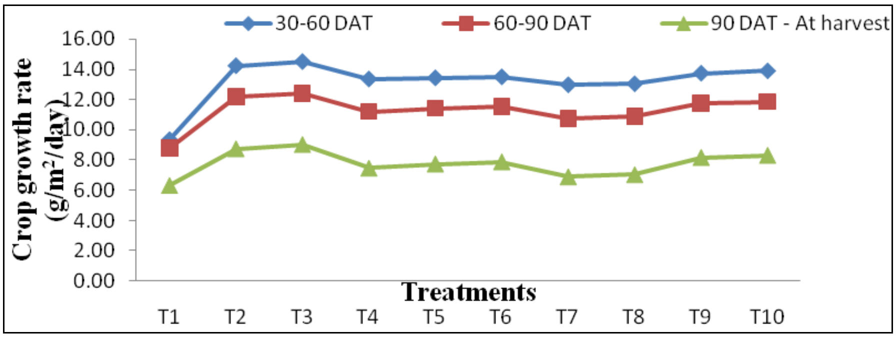

Fig 3: Effect of various treatments on crop growth rate (g/m^2/day) at different intervals

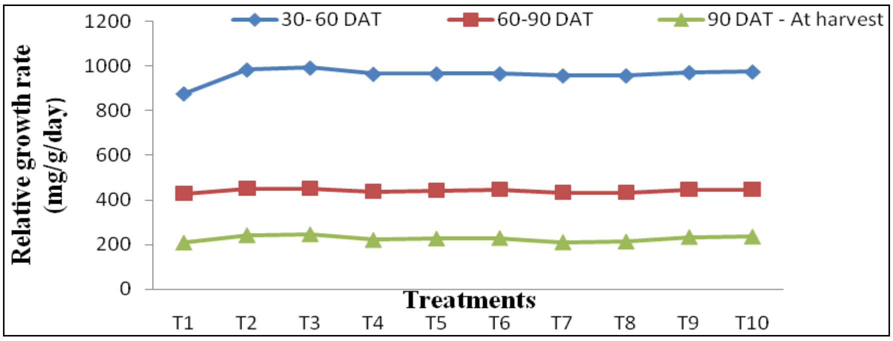

Fig 4: Effect of various treatments on relative growth rate (mg/g/day) at different intervals in rice

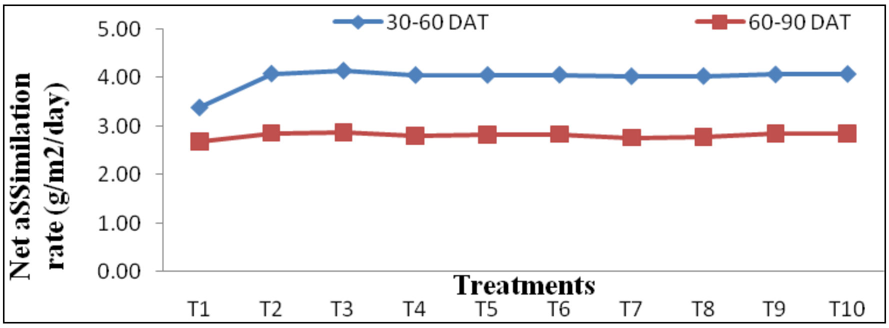

Fig 5: Effect of various treatments on net assimilation rate (g/m^2/day) at different intervals in rice

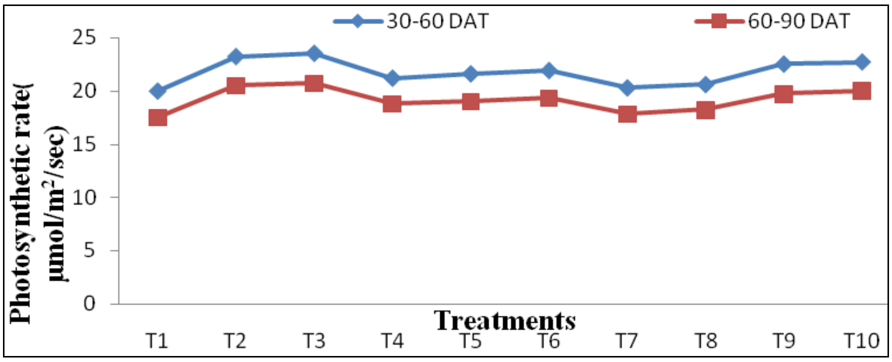

Fig 6: Effect of various treatments on photosynthesis rate (µmol/m^2/sec) at different intervals in rice

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