Madras Agric. J., 2018; doi:10.29321/MAJ 2018.000190

RESEARCH ARTICLE

Screening of Rice Genotypes for Improved Photosynthetic Efficiency

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Received : 30th July, 2018
Revised : 27th August, 2018
Accepted : 27th August, 2018

ABSTRACT

An experiment was conducted to study the photosynthetic efficiency of rice genotypes and mutants at the Glass house, Department of Crop Physiology, TNAU, Coimbatore. The physiological and biochemical parameters *viz.,* chlorophyll index, photosynthetic rate, chlorophyll fluorescence and soluble protein content were measured at different growth stages which depicted the relative ability of the genotypes to the photosynthetic efficiency. Significant variation in the photosynthetic characters among the rice genotypes was noticed in the experimental results. Among the two mutants studied for photosynthetic efficiency the mutant 377-1-1 performed better than the mutant 277-2 due to its superiority in certain morpho-physiological, anatomical and biochemical traits which ultimately contributed for better yield. Hence, the mutant 377-1-1 can be recommended for crop improvement programme for developing elite cultivars with better photosynthetic efficiency and yield.

Keywords: *Rice, Mutants, Photosynthetic efficiency, Yield.*

Rice (*Oryza sativa* L.) belongs to the family Poaceae which is most important staple food crop in the world. It is one of the cereal crops which provides over 21% of the energy of the world's population and even 76% of the energy intake of the population of South East Asia. The crop yield needs to be increased by at least 60% to meet out the adequate food and nutrition to the global population that is expected to reach 9 billion by 2050 (FAO, 2009). It is essential to improve the crop productivity since, increased pressure has been placed on World's food supply due to growing population and global climate change. Despite use of new technologies and improved varieties, the harvest index of two major food crops, rice and wheat is now approaching a plateau and further increases in yield will necessitate an increase in photosynthesis. Developing crop plants with enhanced photosynthesis will improve crop yield and make efficient use of resources in a sustainable manner. Thus through genetic engineering techniques improvement in photosynthetic pathway of rice would sufficiently provide opportunity to enhance the yield potential as well as the grain productivity. From distantly related species the genes of interest can be introduced through genetic engineering which acts as a precise breeding tool (Karki, 2013). Since, photosynthesis is the basis of plant growth, and improving photosynthesis can contribute toward greater food security in the coming decades as world population increases. To increase yield potential, various physical, genetic or gene engineering methods are employed to improve photosynthetic ability per leaf area (Tehrim *et al*., 2012).

On the basis of these findings, certain mutants have been developed for improving photosynthesis which performed better than the parent lines. Mutants with a greater Chl a/b ratio were often accompanied by altered LHC to compensate for changes in photosynthetic efficiency and capacity (Kusaba *et al.,* 2007). A rice mutant with significantly higher level of Chl b and photosynthetic rate, biomass resulted in increased grain yield also compared to the wild-type (Wang *et al.,* 2008). Improvements in rates of photosynthesis of individual leaves within the canopy have become the focus point for current efforts to increase production of rice grains (Hubbart *et al.*, 2007). To improve crop biomass production and yield potential, improving photosynthetic efficiency is regarded as a major target (Zhu *et al.*, 2010). In this light of view, the experiment was conducted to study the photosynthetic efficiency of rice mutants along with few varieties.

Material and Methods

The pot culture experiment was conducted in the Glass house of the Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore during January, 2018. The experiment was carried out with six rice genotypes including two mutants *viz.,* CO 51, ADT 43, IR 64, N22, 377-1-1 and 277-2. Among these genotypes,

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377-1-1 and 277-2 are the mutants of N22. The location is in Western Agro-Climatic Zone of Tamil Nadu at 11.01°N latitude and 76.39°E longitude and at an altitude of 426.7 m above MSL. Large size pots were filled with the pot mixture of clay loam, sand and FYM in the ratio of 3:2:1. The experiment was laid out in Completely Randomized Design (CRD) along with four replication. Crop was applied with recommended dose of fertilizers as per the recommended package of practices of Tamil Nadu Agricultural University, Coimbatore. The physiological and biochemical parameters were recorded at maximum tillering, panicle initiation and flowering stage.

Uprooted plant samples, were first shade dried and then oven dried at 80°C for 48 hours. The dry weight of the whole plant (TDMP) at different phenophases were recorded and expressed as g plant^{-1}. SPAD readings were recorded by using chlorophyll meter (SPAD 502) designed by the Soil Plant Analytical Development (SPAD) section, Minolta, Japan. Soluble protein content of the leaf was estimated by following the procedure described by Lowry *et al.* (1951) and expressed as mg g^{-1} of fresh weight. Gas exchange parameters *viz*., photosynthetic rate, transpiration rate and stomatal conductance were recorded using an advanced Portable Photosynthesis System (PPS) (Model LI-6400 XT, LicorInc, Nebraska, USA).

Results and Discussion

Total Dry Matter Production (TDMP) is considered as an indicator for the increased photosynthetic efficiency of plants which has direct relation with photosynthesis and yield, in terms of grain or straw. TDMP is one of the most important growth indicators which have been being applied as a measure of total photosynthesis and respiratory tissues in total dry weight. In the present study, the total dry matter production increased linearly from maximum tillering to flowering stage and a significant difference was observed among the genotypes at all the stages of observation. Among the genotypes, the mutant 377-1-1 recorded the maximum dry matter production in all the stages (Table 1).

Table 1. Total dry matter production (g plant^{-1}), chlorophyll index (SPAD value) and soluble protein content (mg g^{-1})

Genotypes	Total dry matter production (g plant^{-1})			Chlorophyll index (SPAD value)			Soluble protein content (mg g^{-1})		
	Maximum Tillering	Panicle Initiation	Flowering	Maximum Tillering	Panicle Initiation	Flowering	Maximum Tillering	Panicle Initiation	Flowering
CO 51	30.34	39.43	48.25	41.72	46.56	49.83	8.06	9.38	10.81
ADT 43	27.68	34.64	40.27	42.17	46.93	49.42	8.22	10.60	10.84
IR 64	29.43	37.76	45.12	41.45	45.52	49.56	8.43	9.62	10.31
N22	30.68	38.34	46.72	42.35	43.13	45.48	8.72	9.08	9.94
377-1-1	35.39	41.02	49.12	42.63	46.32	51.80	9.22	9.63	10.59
277-2	28.06	36.84	44.28	41.00	43.40	44.67	8.38	8.91	9.98
Mean	30.26	38.01	45.63	41.89	45.31	48.46	8.51	9.54	10.41
SEd	0.40	0.59	0.56	0.47	0.63	0.73	0.12	0.07	0.11
CD (P=0.05)	0.84	1.25	1.17	0.99	1.32	1.53	0.26	0.16	0.23

The mutant 377-1-1 showed 5% increase in TDMP from N22 while 20% difference was observed from the varieties at flowering stage. Among the mutants, the mutant 277-2 registered lower TDMP when compared to N22. Total dry weight was increased over time so that at early growth stages it increases with fewer gradients and in later stages, slope increasing is greater until total dry weight reaches to its maximum (grain filling) and at the end of the growing season, total dry weight is reduced (Yang *et al.*, 2002). The strong capacity of dry matter production before heading was one of the important traits for high yielding rice.

The SPAD (chlorophyll index) value is an indirect measure of assessing the chlorophyll status of plants (Watanabe, 1980). It is a rapid and non-destructive determination of leaf chlorophyll content by measuring leaf transmittance (Knapp and Carter, 1998). Leaf thickness is one of the factors that determine chlorophyll index under different conditions (Yamamoto *et al.*, 2002). An increasing trend in the chlorophyll index was observed from the maximum tillering to flowering stage and declined at post flowering stage. Among the genotypes, the mutant 377-1-1 showed the maximum chlorophyll index at both the maximum tillering (42.63) and flowering stages (51.80). The mutant 277-2 performed relatively the lowest value among the genotypes (Table 1).

Rubisco is the key enzyme in photosynthetic fixation of CO_2 in green plants and is the dominant leaf soluble protein (Ray *et al.*, 1983). This stroma protein is responsible for reduction of CO_2 and it makes up about one third of the protein of the chloroplast. The quantity of soluble protein is one of the important factors for synthesis of other plant materials. In general, there was an increasing trend in soluble protein

Table 2. Gas exchange parameters

Genotypes	Photosynthetic rate (µmol CO_2 m^{-2} s^{-1})			Stomatal conductance (mol H_2O $m^{-2}s^{-1}$)		
	Maximum Tillering	Panicle Initiation	Flowering	Maximum Tillering	Panicle Initiation	Flowering
CO 51	27.54	34.36	36.82	0.52	0.69	1.02
ADT 43	28.31	30.34	35.25	0.48	0.59	0.76
IR 64	27.96	31.61	33.05	0.67	0.74	1.01
N22	25.94	29.05	33.33	0.57	0.77	0.88
377-1-1	29.16	32.13	36.96	0.59	0.88	1.21
277-2	26.12	27.29	29.68	0.42	0.76	0.89
Mean	27.51	30.80	34.18	0.54	0.74	0.96
SEd	0.26	0.42	0.55	0.006	0.008	0.013
CD (P=0.05)	0.54	0.87	1.15	0.013	0.018	0.027

content from maximum tillering to flowering stage in all the genotypes (Table 1). Among the genotypes, the maximum soluble protein content was observed in the mutant 377-1-1 (9.22 mg g^{-1}) which was 14% higher compared to other genotypes at maximum tillering stage. At panicle initiation and flowering stages, the maximum soluble protein was observed in ADT 43 which was significantly higher i.e.10% and 2%, respectively compared to mutant 377-1-1. These findings were in accordance with the findings of Jensen and Bahr (1977) who stated that the soluble protein content, an indirect measure of Rubisco activity, differed among the rice genotypes at different stages of growth that in turn helps in assessing the photosynthetic efficiency of the crop.

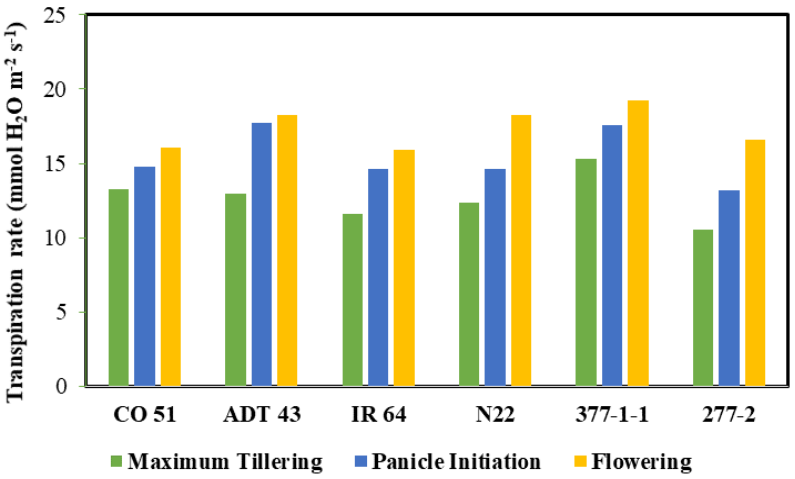

Fig. 1. Transpiration rate (mmol H_2O $m^{-2}s^{-1}$)

Photosynthesis is the foundation of dry matter production in plants (Liu *et al.*, 2001). In rice, 90% of grain yield originates from the photosynthetic production of leaves after flowering, especially from flag leaf. The amount of dry matter accumulation mainly depends on the capacity of photosynthetic production, which was determined by photosynthesis and duration of photosynthetic function. In this study, the mutant 377-1-1 recorded maximum photosynthetic rate at maximum tillering (29.16 µmol CO_2 m^{-2} s^{-1}) and flowering stage (36.96 µmol CO_2 m^{-2} s^{-1}) (Table 2). The mutant 377-1-1 showed 10% and 11% difference in photosynthetic rate over N22 at maximum tillering and flowering stages, respectively. The mutant 277-2 found to have the minimum photosynthetic value compared to other genotypes. Ding *et al.* (2014) reported that the rate of photosynthesis in leaf depends on many physiological and biochemical processes such as stomatal conductance, internal carbon dioxide (CO_2) and activities of carbon fixation enzymes. Transpiration rate is an important characteristic that influences the plant water relations (Farooq *et al.*, 2009). Plants open and close the stomata for the movement of gases and water vapour which helps in maintaining the leaf temperature. Thus any changes in transpiration rate will affect many physiological and biochemical processes of plant system. In this study, all the genotypes showed significant increase in transpiration rate from maximum tillering stage to flowering stage (Fig. 1). The mutant, 377-1-1 showed 23%, 20% and 5% higher transpiration rate compared to its parent N22 at maximum tillering, panicle initiation and flowering stages, respectively. The mutant, 277-2 showed the minimum value which was 14%, 10% and 9% lesser in transpiration rate than N22 at maximum tillering, panicle initiation and flowering stages, respectively. In the present study, regardless of the genotypes, the stomatal conductance was found to increase from maximum tillering stage to flowering stage (Table 2). The maximum stomatal conductance

was recorded in IR 64 (0.67 mol H_2O m^{-2} s^{-1}) at maximum tillering stage whereas the maximum value was recorded in the mutant 377-1-1 at panicle initiation and flowering stages with a value of 0.88 mol H_2O m^{-2} s^{-1} and 1.21 mol H_2O m^2 s^{-1} respectively. The effect of stomatal conductance on photosynthetic potential have been recently reported by (Adachi *et al.*, 2013). Kusumi *et al.* (2012) reported that an artificial increase in stomatal conductance via genetic engineering may, therefore, improve the productivity and yield of rice plants.

Conclusion

Rice yield being reaching the plateau, the only way for yield improvement is improving the photosynthetic efficiency. There is a significant variation in the photosynthetic characters among the rice genotypes was evident in this study. Among the two mutants used, the mutant 377-1-1 performed better than the mutant 277-2. The better performance of the mutant 377-1-1 may be due to superior performance in certain physiological and biochemical traits which ultimately can contribute for better yield compared to the mutant 277-2. Hence, the mutant 377-1-1 having the enhanced photosynthetic characters as evidenced from this study, might be recommended for the use of breeding purpose for developing elite cultivars with better photosynthetic efficiency and yield.

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