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Impact of Drought Adaptive Mechanism on Root and Root Associated Trait of Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Roots play a vital role in plants for a wide variety of processes, including nutrient and water uptake, anchoring and mechanical support. Some phenomenal literature supports several root characters which have relevance for stress adaptation. Root characteristics such as root length density, rooting depth and root distribution have been established as constituting factors of drought resistance. Under drought situation, roots can adapt to continued growth while at the same time, sending signals to shoot that exhibit growth an above ground parts of the plant. Development of plants with deep roots may in fact stimulate photosynthetic yields as these are considered to be more controlled by the carbon sinks of plants. In this context a field experiment was conducted during *Kharif* -2014 in the Department of Crop Physiology, to know the effect and variations in mutants of Rice for root and root associated traits along with growth and productivity besides a few relevant drought adaptive traits. The result revealed that, the root length ranged from 24.46 cm to 38.00 cm with a mean of 32.40 cm, while wild Type recorded 32.33 cm. Similarly, the root volume and root weight recorded 21.67cc to 65cc with a mean 35.51cc and 4 g to as high as 34.30 g with a mean of 17.13g when compared to Wild Type (27.92 cc and 18.49g respectively). The total dry

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matter production ranged from 16.39 g^{-1}plant to 92.12 g^{-1}plant with a mean of 52.73 g^{-1} plant while, the Wild type had a total dry matter production of 55.12 g^{-1}plant. Mutants shows significant variations in root length, root volume, root weight and total dry matter production as compared to wild type and also observe the significant variation among the mutant. These mutants with higher growth character associated with root traits are potential mutant lines for further crop improvement programme.

Keywords: Root trait; total dry matter; drought resistance and variability.

1. INTRODUCTION

Rice is a staple food crop for more than half of the world's population. Being a tropical plant, rice flourishes comfortably in hot and humid climate and mainly grown in rainfed areas that receive heavy annual rainfall and therefore, it is fundamentally a kharif crop in India. Rice is the greatest consumer of water among all crops and consumes about 80% of the total irrigated fresh water resources in Asia [1,2]. Nearly 3000 litres of water is required to produce 1 kg of rice grains and lowland rice fields have relatively high water requirements and their sustainability is threatened by increasing water shortage [1]. Water availability for agriculture in general and rice cultivation in particular is decreasing steadily at an alarming rate of about 5% annually [3]. Therefore, one of the obvious suggestions made in this context has been to save irrigation water from rice ecosystems. In fact, recent years growing scarcity of water have been noticed worldwide and it is projected that by 2050, as much as 2/3rd of global population will live in water scarce areas [4]. Water is a crucial prerequisite for plant's life; both shortage and excess of water may cause severe stress to terrestrial plants and cause significant damage to productivity. It is important in rice for potential reduction in water use because of its large water requirement compared with those of other food crops [4].

Among the various abiotic stresses, drought is the major factor that limits crop productivity worldwide. Drought usually implies a composite stress condition that includes soil water deficits, increased day time temperatures and reduced nutrient availability and occasionally, also increased salinity in the soil. However, the most important factor limiting growth and impairing plant productivity is the drop in water availability to the plant [5]. Many stress adaptive mechanisms found to have relevance under drought conditions of their mechanisms. Many attempts have been made to identify rice genotypes with desirable traits like water mining (associated with root traits), water use efficiency, higher level of tolerance at cellular level, low spikelet sterility and tolerance to moisture stress [6]. The relevant traits need to be pyramided onto agronomically superior background to significantly enhance the levels of drought tolerance in crop plants through a "trait-based" breeding approach [7]. A significant improvement in productivity through enhanced Water use efficiency [8,9] and root traits [10] have been demonstrated. The genetic improvement of root traits by conventional breeding methods has been slow due to difficulty in measuring root dynamics and their interaction with below ground level. However, in areas where there is sufficient water in the deeper profiles, deeper root systems have significantly increased the total biomass as well as yield [11]. People have observed the much awaited result when they incorporated root traits like root length, root biomass and root pulling force in their breeding for improved root systems to achieve better productivity [12]. Rice is characterized by a shallow root system compared with other cereal crops, having limited water extraction below 60 cm [13].

Root traits associated with drought tolerance are important for drought resistant mechanisms of plants. Root characteristics such as root length density, rooting depth and root distribution have been established as constituting factors of drought resistance [14]. Under drought, roots can adopt to continued growth while at the same time, sending signals to shoot that exhibit growth above ground [15]. A significant genetic variability in root biomass and other traits in rice recombinant inbred lines (Ayyappa, 2004) and Mulberry germplasm accessions [16])] is revealed by Department of crop physiology, Bangalore. Water mining through deeper root system [17], water conservation through accumulation of epicuticular waxes (Prathibha 2012), superior Water use efficiency is often consider as the most relevant traits need to be pyramided (Sheshsshayee et al., 2003). With this background, the activation tagged mutants of rice generated earlier in the Department of Crop

Physiology, University of Agricultural Sciences, Bangalore was used to characterize them for root and root associated traits along with growth and productivity besides a few relevant drought adaptive traits.

2. MATERIALS AND METHODS

In order to determine whether or not, the mutants indeed showed any improvement in root traits over the wild type, 60 mutants includes those with high biomass, low biomass, photo sensitive and insensitive, high and low water use efficiency mutants were examined for root traits. During *Kharif* -2014 the selected mutants were sown in the nursery. After 22 days, the seedlings were transplanted to root structure with the dimension of 60ft long, 10ft wide and 4 ft tall, built above ground using solid cement blocks. Before transplanting the root structures was filled with soil and allowed for complete compaction after regular watering. The plants were transplanted in a Randomized Complete Block Design (RCBD) at a spacing of 20 x 25 cm and all the agronomic practices were followed to ensure good growth of plants.

At the time of flowering, the walls of the root structures were dismantled. Before going to dismantle plant height was recorded. Plants were extracted along with the root system (Plate1). Once the plants were extracted, the root was separated and measured the shoot length, root length, root volume and also record the root dry weight after complete drying of roots. To get a total dry matter production, leaves and stem were separated and were oven dried separately. Using analysis of variance (ANOVA), traits were analyzed. The extent of variation of mutants was shown by plotting frequency distribution for root traits and total dry matter production. Based on the extent of variations in root traits, high and low root mutants were identified.

The same set of mutants used for root traits studies were also used for assessing the growth and productivity under the field condition. The experiment was laid out in randomized block design with replicated thrice. Follow the package of practices of University of Agricultural Sciences, Bangalore throughout the cropping season. When the plants were physiologically matured and were in the process of drying, they were harvested and the panicles were separated from rest of the plant biomass. The panicles were later threshed and cleaned and seed yield per plant was measured. Similarly, the rest of the plant biomass (excluding stubble and root) was oven dried and weight of this was taken. The data was analyzed using analysis of variance (ANOVA). The extent of variation of mutants was shown by plotting frequency distribution for total dry matter production and seed yield.

3. RESULTS AND DISCUSSION

The results of the study indicated that, there is considerable amount of variation in root traits besides growth parameters. Accordingly, the plant height ranged from 69.50 cm to 109.50 cm with a mean of 95.20 cm and 98.25cm was recorded by Wild type. When the root traits was checked, it was found that, the root length ranged from 24.46 cm to 38.00 cm with a mean of 32.40 cm (Wild type 32.33 cm). Further, root volume was recorded and it ranged from 21.67cc to 65.00cc with a mean 35.51cc (Wild type 27.92 cc). As compared to wild type (18.49 g) other mutants recorded the root weight ranged from 4 g to as high as 34.30 g with a mean of 17.13g. Besides these, the mutants also exhibited a wide variation in total dry matter and observed the total dry matter production was ranged from 16.39 g^{-1}plant to 92.12 g^{-1}plant with a mean of 52.73 g^{-1} plant while, the wild type had a total dry matter production of 55.12 g^{-1}plant (Table 1a). All the traits found the highly significant difference among the mutants (Table 1b). The variation in root trait was found to be highly significant across the mutants (Plate 2). Such variation in root traits also reported by Sumanth kumar [18] and he shown significant variations in N22 rice mutant population. Variation in root traits in rice germplasm also reported by Mohan kumar [19], Raju [6]. Such variation in root traits also shown in many crops *viz.*, Sunflower [20,21], Groundnut [12], Mulberry [22], Pigeon pea [23] etc. These studies unequivocally proved that variability in root traits exist not only in genotypic pools but also in the mutants. However, depending on the requirement, one can exploit this variation and use them either for molecular analysis or for crop improvement programmes.

The significant variation among the activation tagged mutants was also confirmed through frequency distribution chart where, spreading of mutants was seen for the root weight and total dry matter production (Fig 1). Based on the root weight and total dry matter production, the mutants were classified as low root mutants and high root mutants. The selected high root mutants had an average root weight of 29.80 g with total dry matter production of 79.34 g while, the low root mutants had 8.81 g of root weight along with 34.02 g of total dry matter production. However, the wild type had the root weight of 18.49 g and 55.12 g of total dry matter production (Fig 2, Table 2). The high root mutants are good material and they can use for further advancement.

3.1 Assessing the Growth and Productivity of Selected Mutants

The same sets of 60 mutants were also used for characterizing the growth and productivity under the field condition. The result of the experiment reveals that, the mutants exhibited significant variation in total dry matter production and seed yield. The range 19.95 g to 62.54 g of total dry matter production was recorded with a mean of 34.81 g, while wild type recorded 27.10 g of total dry matter production. The seed yield of mutants ranged from 10.59g to 38.97g with a mean of 20.62g. However, the wild type showed a seed yield of 12.46 g (Table 3a). Highly significant difference for seed yield and total dry matter production among the mutants were observed (Table 3b). The significant variation among the activation tagged mutants was also confirmed through frequency distribution chart where spreading of mutants was seen for the total dry matter production and seed yield (Fig 3). Such increased total dry matter production and seed yield was also reported by Anitha [24] and Sumanth kumar [18]. In fact, majority of the mutants showed higher seed yield and total dry matter production compared to wild type. Therefore, a few promising high productivity mutants can be forwarded further for crop improvement programmes.

Plate 1. Extraction of rice plants along with the root system from the root structures

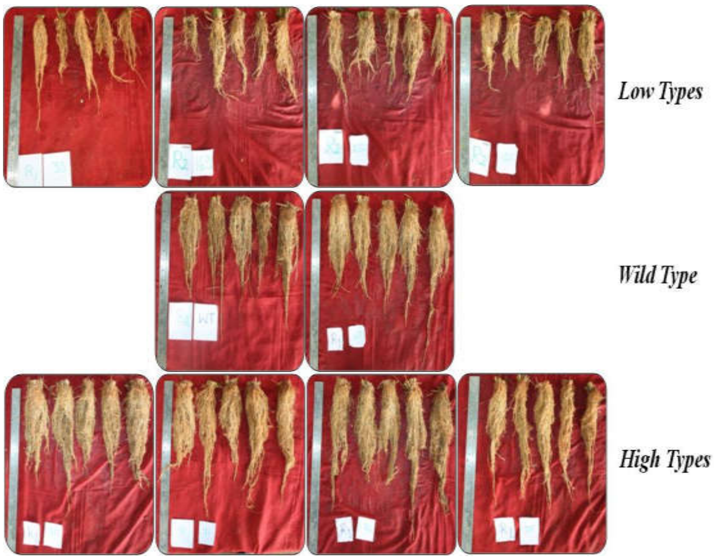

Plate 2. Variation in root traits among the selected mutants in root structure experiment

Table 1a. Variation in root traits besides growth traits in selected mutants of rice

Parameters	Wild type	Mutants					
		Min	Max	Mean	SD	Skewness	Kurtosis
Plant height (cm)	98.25	69.50	109.50	95.20	10.48	-0.80	-0.33
Root length (cm)	32.33	24.46	38.00	32.40	3.10	-0.40	-0.34
Root volume (cc)	27.92	21.67	65.00	35.51	8.92	0.80	0.62
Shoot weight (g)	17.25	5.50	25.58	15.35	4.88	0.06	-0.87
Root weight (g)	18.49	4.00	34.30	17.13	6.27	0.75	0.47
Total dry matter production (g)	55.12	16.39	92.12	52.73	16.50	0.21	-0.48

Table 1b. Analysis of variance in root traits besides growth traits in selected mutants

	Plant height (cm)	Root length (cm)	Root volume (cc)	Shoot weight (g)	Root weight (g)	Total dry matter production (g)
SEM±	132.59	39.49	204.07	18.58	28.13	70.53
CD@5%	1308	7.14	16.23	4.89	6.02	9.54
CV%	12.08	19.39	24.80	18.56	23.92	15.9

Table 2. List of high and low Root type mutants selected

High Root type			Low Root type		
Mutant no	Root weight (g)	Total dry matter production (g)	Mutant no	Root weight (g)	Total dry matter production (g)
30	26.62	80.93	28	4.00	16.39
216	27.40	78.35	169	7.50	30.16
132	28.58	71.64	66	11.33	42.61
35	28.93	78.77	122	9.50	27.22
110	31.00	83.54	80	11.33	44.62
127	31.80	70.03	59	11.00	43.98
133	34.30	92.12	183	10.83	33.15
Mean	29.80	79.34	Mean	8.81	34.02
Wild type	18.49	55.12			

Table 3a. Variation in growth and productivity of selected mutants of Rice

Parameters	Wild type	Mutants				
		Min	Max	Mean	Skewness	Kurtosis
Stem weight (g)	14.64	6.50	28.50	14.19	0.87	0.71
Seed Yield (g)	12.46	10.59	38.97	20.62	0.72	-0.06
Total dry matter production (g)	27.10	19.95	62.54	34.81	0.78	0.07

Table 3b. Analysis of variance in growth and productivity of selected mutants

	Stem weight (g)	Seed weight (g)	Total dry matter production(g)
SEM±	28.57	15.89	43.84
CD@5%	5.24	3.91	6.50
CV%	24.89	19.60	19.16

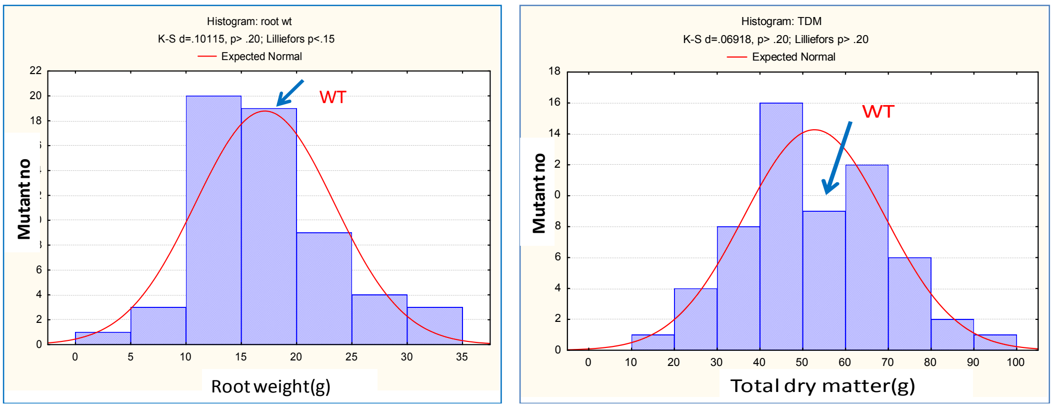

Fig 1. Frequency distribution of mutants for Root weight and Total dry matter production (TDM)

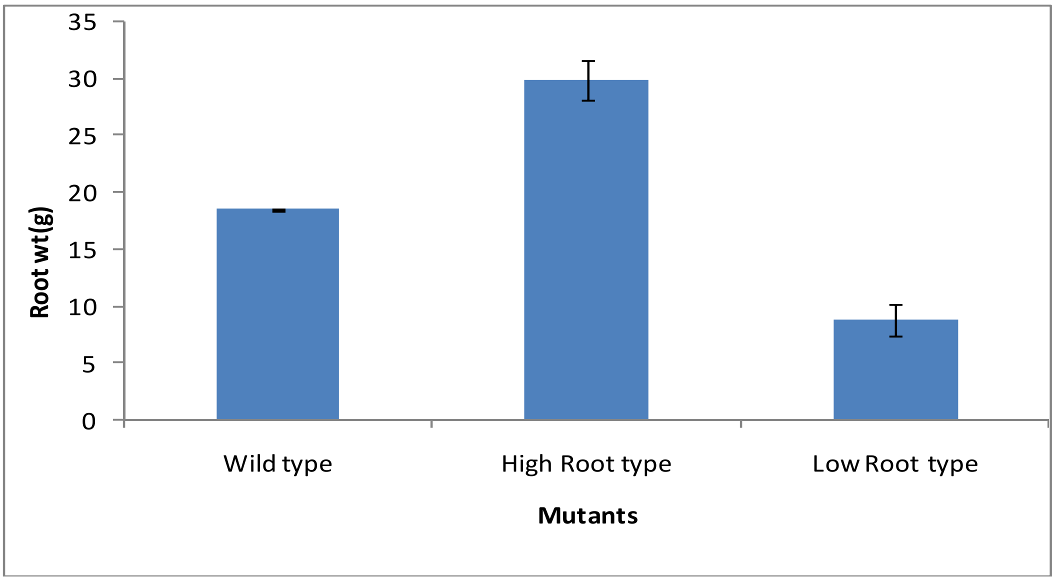

Fig. 2. Variation in root weight in high and low mutants of rice in comparison to wild type

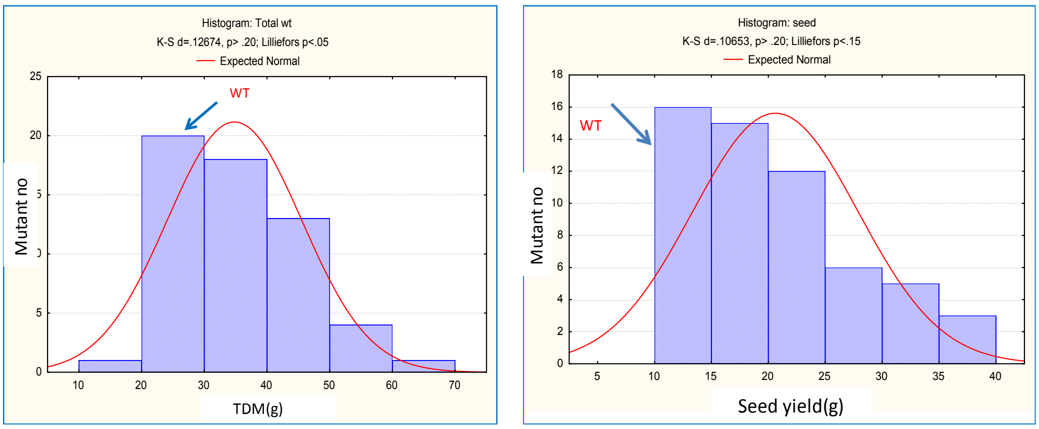

Fig 3. Frequency distribution of mutants for Total dry matter production (TDM) and seed yield

4. CONCLUSION

The study was concluded that considerable amount of variations for root traits among the mutants of Rice were noticed. Some mutants recorded higher plant height, high root weight and root length along with more total dry matter production as compared to wild type. These mutants with higher growth character associated with root traits are potential mutant lines for further crop improvement programme.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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