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Research Article

Screening of rice (*Oryza sativa* L.) genotypes for root characters related to drought tolerance and its association with yield under aerobic condition

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Abstract

Rice is an important stable food crop consumed throughout the world, but drought is a serious problem in major rice growing areas where there is acute scarcity of water and in rainfed areas where cultivation depends on the seasonal rainfall. So, in order to overcome the scarcity of water for rice cultivation, breeders have made prompt efforts to breed the genotypes which can tolerate the drought stress condition. So, to develop such an efficient breeding programme, selecting the plants with desirable root characters is one of the major objectives that enable plants to with stand stress condition. Hence, the present investigation was carried under aerobic condition to evaluate 21 aerobic genotypes released by recognized agricultural institutes/universities for drought tolerance whose potentiality conferred by root traits and also correlation studies with grain yield by taking field trial involving the same genotypes. The root studies can be done in PVC pipes as well as in polythene bags. Eight genotypes *viz*., MAS-26, MAS-946-1, CRDHAN-204, CRDHAN-206, CRDHAN-210, DRRDHAN-41, DRR DHAN 54, DRR DHAN-55 and one check variety Belgaum Basmati showed significantly superior mean values for most of root traits. The grain yield had positive significant association with root length, root volume, root/shoot ratio and root number indicating the perfect criteria for selection for genetic improvement for drought tolerance. Therefore, for efficient breeding programme suitable for drought tolerance these genotypes can be potential donors in drought tolerance breeding programme.

Keywords: Aerobic rice, drought tolerance, PVC pipes, root traits

1. Introduction

Rice (*Oryza sativa* L.) is the most important food crop of the world and is the staple food of more than three billion people in the world. The cultivation of rice faces many challenges, based on region, climate, and the cultivation system i.e., upland or lowland. In order to overcome challenges, plants have developed multiple mechanisms to respond and adapt to adverse environmental conditions. Drought stress is a major problem in agriculture areas and becoming the largest constraints to productivity of rice across the globe. In rainfed areas, water stress is primary limiting factor for productivity and even in irrigated areas also it is becoming an increasing problem due to shift in raining pattern. So, a number of morphological, physiological and phenological traits have been reported to improve the performance of rice challenged by drought. Root characteristics are essential elements in the mechanisms of dehydration postponement since they regulate plant growth and take water and nutrients from deeper, less-explored soil layers, which are among the many variables enhancing drought resistance (Price *et al.,* 1997 and Toorchi *et al*., 2006).

Aerobic rice production system requires input responsive rice varieties which are grown in non-puddled and non-stagnant water condition (Bouman *et al.,* 2002). Corona pandemic has resulted in acute labour shortage in agriculture especially for rice production. Therefore, there is a quantum of shift to aerobic rice cultivation from conventional transplanted system in India for last 2-3 years. To obtain higher grain yield under aerobic method of cultivation, there is a need to develop new rice varieties which are having drought tolerance, and possess robust root morphological and physiological characters. One such inherited trait that has been identified to help plants cope with water scarcity is deep and thick root system. Within the rice germplasm, there is wide genetic variability in root growth, and variables such as maximum root length, root thickness, root weight and root volume have been demonstrated to have medium to high heritability. Studying root related traits in field condition is a difficult and destructive task with less accuracy. To overcome these problems, the root studies have been carried out in PVC pipes (Kanbar *et al*., 2009 and Ganapathy *et al*., 2010). Among the root morphological traits, root length and root thickness are found to be associated with drought tolerance in aerobic condition. Increased root thickness improves drought tolerance as the roots are capable of increasing root length density and water uptake by producing more and larger root branches.

Breeding strategies for desirable root characteristics associated with drought resistance and comparative association studies with grain yield have been practiced in rice (Chang *et al.,* 1972). Keeping these considerations in view, the present investigation involves the phenotypic screening of twenty-one selected aerobic rice (*Oryza sativa* L.) including two popular varieties in North Karnataka region for the root traits *viz*, root length, root volume, root thickness, root density and root: shoot ratio which are directly associated with drought resistance. Increase in the mean value of the root traits offers drought tolerance and helps the genotypes to overcome stress condition. In order to compare root traits influencing the grain yield, correlation studies were undertaken by conducting field trial involving the same genotypes in Agricultural Research Station, Mugadh University of Agricultural Sciences, Dharwad, Karnataka, India.

2. Materials and Methods

The present investigation involves evaluation of twenty one rice (*Oryza sativa* L.) genotypes for root traits and was conducted at University of Agriculture Sciences, Dharwad (15.4E;75.01N;750mMSL) during *Kharif*, 2021. The experimental materials consisted of 19 aerobic drought tolerant genotypes *viz*., CR Dhan-200, CR Dhan- 201, CR Dhan-202, CR Dhan-203, CR Dhan-204, CR Dhan-205, CR Dhan-206, CR Dhan-207, CR Dhan-209, CR Dhan-210 which were released by ICAR–National Rice Research Institute, Cuttack and DRR Dhan-41, DRR Dhan- 54, DRR Dhan-55 which were released from ICAR Indian Institute of Rice Research, Hyderabad and MAS-26, MAS-946-1 from University of Agricultural Sciences, Bangalore and two check varieties Indrani and Belgaum Basmati (Table1). All these genotypes were suitable for aerobic condition and sown in vertically standing PVC pipes of 1.0m long with a diameter of four inches.

Table1: List of twenty one genotypes used under present investigation

Sl. No.	Genotypes	Pedigree
1	CRDHAN– 200	UPLRI5×IR-12979-24-1
2	CRDHAN– 201	IRRI105×IR-72022-46-2-3-2
3	CRDHAN– 202	IRRI148×IR-78877-208-B-1-1
4	CRDHAN-203	IR78877× IRRI132
5	CRDHAN– 204	IRR76569-259-1-2-1×CT6510-24-1-2
6	CRDHAN– 205	N22×SWARNA

7	CRDHAN– 206	BRAHMANAYAKI×NDR 9930077
8	CRDHAN– 207	IR71700-247-1-1-1-2×IR57514-5-B-1-2
9	CRDHAN– 209	IR72022-46-2-3-2 × IRRI105
10	CRDHAN– 210	IRB717002-247-1-1-2×IR77080B-34-1-1
11	DRRDHAN-41	RP5311-PR26703-3B-PJ7
12	DRRDHAN– 54	RP5124-11-4-3-2-1×IR78877-208-B-1-1.
13	DRRDHAN– 55	MTU1010/×IR79915-B-83-4-3
14	PAUSTIC–1	BPT5204 ×HPR 14
15	PAUSTIC–7	BPT5204 ×HPR 14
16	PAUSTIC–9	BPT5204 ×HPR 14
17	MAS– 26	IR64× AZUCENA
18	MAS-946-1	IR64× AZUCENA
19	BPT-5204	GEB24 ×TN1 × Mahsuri
20	BELGAUMBASMATI©	Check cultivar
21	INDRANI©	Check cultivar

The experiment was laid in Completely Randomized Design (CRD) with two replications. Each genotype was accommodated in one pipe. The pipes were filled with well mixed laterite sandy soil and vermin compost in 1:4 proportion. Five to six seeds were dry direct seeded in each PVC pipe (Figure 1) and thereafter aerobic condition was maintained in the pipes by giving irrigation using rosecan without allowing water stagnation. After germination, only three seedlings were allowed to grow in one pipe. After 15 days of sowing, excess seedlings were removed so that only one seedling is retained in each pipe. All the genotypes were exposed to moisture stress by withholding irrigation for a period of 8 days during tillering stage starting on 60^{th} day after sowing. On 69^{th} day the experiment was irrigated to recover from drought. On 80^{th} day after sowing (Figure2), the pipes were removed carefully and soaked in water alongwith plants overnight to loosen the soil. Next day, roots were cleaned and seven important root traits *viz.,* root length, root volume, root length density, total number of roots, root thickness and root: shoot ratios were recorded as follows (Figure 3 and 4): (Shashidhar *et al.*, 2012)

a. Root length (RL): After soaking entire PVC pipe in water over night, next day whole soil column taken out into sieve and washed gently in water so that soil get separated from root. After thoroughly washing soil, the root is separated out and the maximum root length of the longest root was recorded in centimetre.

b. Root volume (RV): Root volume was determined in 'cc' using upward displacement of water method.

Root density (RD): Root density was worked out by dividing the root length with root volume and expressed as cm/cm^3

Total number of roots: Total number of roots per plant at crown region were counted and recorded.

Root thickness: Root thickness was measured using screw gauge and recorded in 'mm'

Root: Shoot ratio: The root weight of plant was recorded as mentioned above. The shoot weight was recorded separately. Root: Shoot ratio was worked out by dividing root weight by shoot weight.

Duncan's Multiple Range test was employed to know significant differences and to compare multiple traits of different genotypes and to identify the superior genotypes with respective mean values for different traits (Table 2).

The similar field trial was conducted at Agricultural Research Station, Mugadh involving the same genotypes direct seeded in field with spacing 30 × 20 cm involving three replications using Random Completely Block Design (RCBD). All morphological observations were taken involving yield and yield attributing traits to know the effects of the other characters and also to compare the root characteristics with yield. After physiological maturity stage, harvesting was done and grain yield / plant was taken (Table 3). Correlation studies were carried out with root traits influencing grain yield (Table 4). Since we know that correlating genetic information with physio-morphological traits especially grain yield with root traits helps us to develop drought tolerant rice cultivars through indirect selection.

3. Results and Discussion:

Genotypic variation among the germplasm is pre requisite for selection. In our study, we used Duncan's Multiple Range test and Analysis of variance to find out the variation among the genotypes for different root and yield related traits. It revealed significant differences among twenty-one genotypes for all the characters studied. The mean performance of the genotypes for yield and root characters is given in Tables 2 and 3.

The drought tolerance is directly proportional to prolific root traits. In present study, the genotype MAS-26 had highest root length 30.96cm, highest root volume 3.96cm^3 and highest root thickness 1.27mm followed by CR Dhan-210 h which had higher mean values for four root characters out of six characters *viz.*, root number (67.55), root thickness (0.63mm), root volume (3.87cm^3) and root length (27.13cm) which are having superior mean values for majority of root traits. Another promising genotype MAS-946-1 had better root length of 29.91cm, root volume of 3.67cm^3 and root thickness 0.73mm while other genotypes like DRR Dhan-41, DRR Dhan-54, DRR Dhan-55 and CR Dhan - 206 had shown higher mean values for similar root traits *viz.*, root length, root volume, root: shoot ratio. Check variety named Belgaum basmati had higher mean for root length (29.91cm), root number (62.85) and root thickness (0.55mm) similar to CR Dhan204 which had higher mean in addition to root density along with above mentioned root traits. Two high nutrient quality grain varieties *viz.,* Paustic-1 and Paustic-7 had higher mean values for root number of 57.43 and root density of 18.2cc (Table 1). Variation for different root traits is detailed in table 2. In addition, among 21 genotypes screened for root characteristics, MAS-26, CR Dhan 210, Belgaum Basmati and MAS-946-1 had higher mean values for majority traits, out of selected root traits considered for the study. Similar results were reported by Babu *et al.* (2011), Desai *et al.* (2011) and Kumar *et al.* (2014) indicated superior performance of MAS 946-1 when tested along with other genotypes under aerobic system for different root traits.

With respect to grain yield/plant which was taken at an experimental trial conducted in main field at Agricultural Research Station, Mugadh. MAS-26 had highest grain yield/plant

21.97g followed by MAS-946-1 (20.67g). Other genotypes which yielded better under aerobic cultivation are CR Dhan 210 (19.3g), DRR Dhan 54 (17.93g), DRR Dhan 41 (17.17g) and Belgaum basmati (15.23g). All these genotypes are known to tolerate water stress and the intermittent drought condition and are known to possess superior root characteristics like higher root length, highest number of root and higher root volume which penetrates deep in the layers and absorb necessary water and nutrients and hence do not affect the growth of the plant.

Among the twenty-one genotypes studied, four genotypes produced significantly higher root length especially the genotypes MAS-26, CR Dhan210, MAS-946-1 and Belgaum basmati which means they have deep rooted system that are able to penetrate deep in the soil layers and extract nutrients and water and supports growth of plant without much affecting the grain yield when it is subjected to drought stress. Pictures and graph (Figure 1 to 5) depicted below clearly emphasizes on the phenotypical parameters. Similar findings of deep-rooted system for drought resistance were reported by Chang *et al* (1972). Similarly high variations were observed for remaining root traits and susceptible cultivars are known to have lesser root length.

Table 2. Mean Performance of aerobic genotypes for different root traits

Sl. No.	Genotypes	RL (cm)	RV (cm^3)	RN	RS	RT (mm)	RD (cm/cc)
1	CRDHAN200	17.03^{gh}	1.53^{def}	55.82^{de}	0.45^{bc}	0.4^{cd}	13.245^{efg}
2	CRDHAN201	16.76^{gh}	1.00^{gh}	48.92^{f}	0.49^{abc}	0.46^{bcd}	19.297^{b}
3	CRDHAN202	16.03^{h}	1.33^{efg}	36.32^{l}	0.48^{abc}	0.49^{bcd}	12.753^{fg}

4	CRDHAN203	17.68^{g}	1.18^{efg}	32.85^{m}	0.47^{bc}	0.45^{bcd}	16.547^{cd}
5	CRDHAN204	20.47^{ef}	1.02^{gh}	46.55^{gh}	0.59^{abc}	0.47^{bcd}	25.786^{a}
6	CRDHAN205	19.55^{f}	1.4^{efg}	39^{k}	0.39^{bc}	0.55^{bcd}	15.744^{cde}
7	CRDHAN206	21.23^{e}	1.88^{d}	57.9^{c}	0.44^{bc}	0.74^{bc}	11.587^{fgh}
8	CRDHAN207	17.45^{gh}	1.13^{fg}	44.6^{i}	0.49^{abc}	0.71^{bcd}	17.653^{bc}
9	CRDHAN209	17.6^{g}	1.38^{efg}	45.65^{hi}	0.4^{bc}	0.56^{bcd}	12.801^{fg}
10	CRDHAN210	27.13^{c}	3.87^{a}	67.55^{a}	0.44^{bc}	0.63^{bcd}	6.786^{j}
11	DRRDHAN41	20.63^{ef}	3.35^{bc}	48^{fg}	0.51^{abc}	0.48^{bcd}	12.404^{fg}
12	DRRDHAN54	25.75^{d}	2.98^{c}	42.3^{j}	0.63^{ab}	0.57^{bcd}	13.554^{efg}
13	DRRDHAN55	25.06^{d}	3.08^{c}	57.3^{cd}	0.54^{abc}	0.39^{d}	11.177^{ghi}
14	PAUSTIC1	17.75^{g}	1.18^{efg}	57.43^{c}	0.38^{bc}	0.51^{bcd}	13.762^{efg}
15	PAUSTIC7	11.23^{i}	0.68^{h}	36.1^{l}	0.35^{bc}	0.76^{b}	18.2^{bc}
16	PAUSTIC9	16.82^{gh}	1.6^{de}	39.93^{k}	0.48^{abc}	0.58^{bcd}	12.372^{fg}
17	MAS-26	30.96^{a}	3.96^{a}	62.85^{b}	0.63^{ab}	1.27^{a}	8.801^{ij}
18	MAS-946-1	29.91^{ab}	3.67^{ab}	55.45^{e}	0.76^{a}	0.73^{bcd}	8.818^{ij}
19	BPT 5204	16.5^{gh}	1.53^{def}	42.8^{j}	0.48^{abc}	0.55^{bcd}	12.615^{fg}
20	INDRANI	12.43^{i}	1.09^{gh}	45.95^{hi}	0.32^{c}	0.59^{bcd}	14.118^{def}
21	Basmathi	28.8^{b}	3.39^{bc}	58.28^{c}	0.6^{abc}	0.71^{bcd}	9.25^{hij}
	Grand mean	20.32	2.01	48.65	0.52	0.60	13.68
	Coefficient of variation (%)	3.78	11.34	1.83	16.6	15.5	10.4
	S.E	0.54	0.48	1.86	0.18	0.36	2.98
	CD at 5%	1.60	0.65	2.54	0.25	0.49	4.06

RL: Root length, RV: Root volume, RN: Root number, RS: Root to shoot ratio, RT: Root thickness, RD: Root Density

Adoptability to aerobic system requires modification in root system and also in physiological resilience in rice. Among the different genotypes studied, three genotypes MAS-26 (21.97g/plant), MAS-946-1 (20.67g/plant) and CR Dhan 210 (19.30g/plant) exhibited higher grain yield/plant while the checks Belgaum Basmati and Indrani yielded 15.77g/plant respectively under aerobic system of rice cultivation. These genotypes possessed better root parameters which indicate well developed deep root system helps the plant to mitigate drought stress by maintaining water and nutrient status (Kato *et al.*, 2008). The information regarding grain yield/plant is represented in Table 2. The increased number of grains in these genotypes is contributed towards increase in yield. Other morphological traits like increase in number of tillers or panicles, increase in number of secondary roots, increase in root length and root volume all contributed to yield under aerobic system (Figure 6). These parameters can be utilized in selection process for realizing higher grain yield and adoptability to aerobic system.

Correlation studies of different root traits with grain yield under aerobic system helps us to know influence of root character on grain yield (Figure 6). Correlation among yield and root traits is shown in table 3. Significant positive correlation was noticed for characters *viz*, root length (rp=0.72), root volume (rp=0.71), root/shoot ratio (rp=0.57) and root number (rp=0.41) with grain yield under aerobic condition which indicates indirect selection and offers genetic improvement of genotypes for drought tolerance. Negative correlation was noticed with root density (rp=-0.48) that indicates no much influence of root density on grain yield. Similar results were reported by Gireesha *et al.* (2000) indicated positive correlation of different root traits *viz*, root length, root volume and root thickness with grain yield and negative correlation with root density.

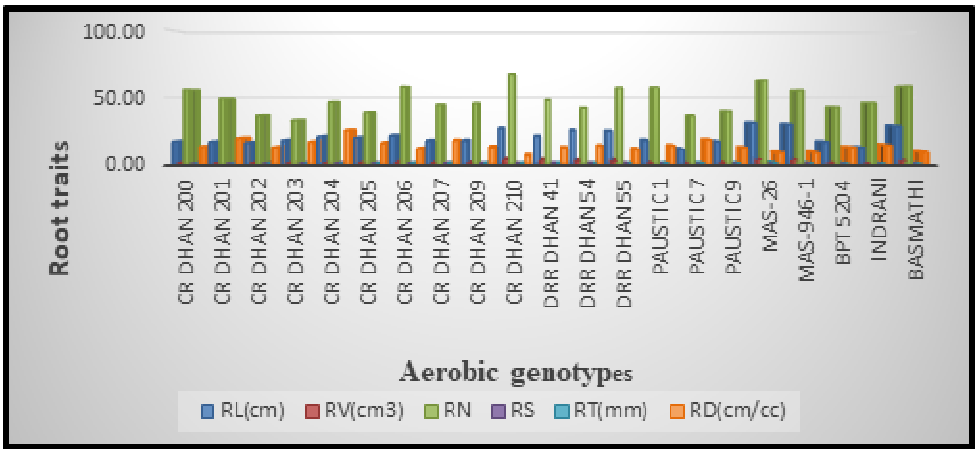

Figure 5. Graph depicting comparison among different genotypes with root traits

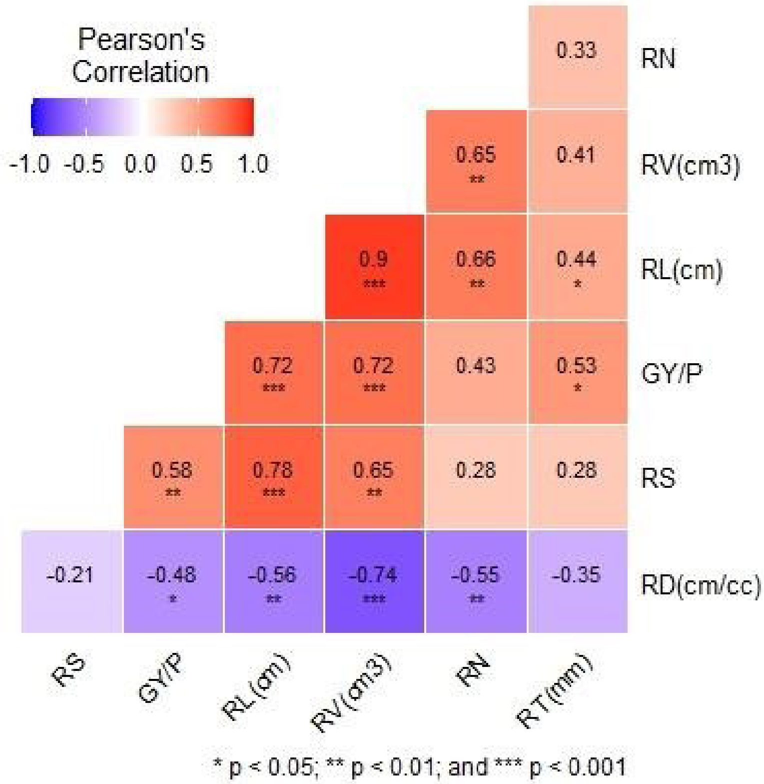

Figure 6: Pictorial representation of correlation between root traits and grain yield

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Table 3. Mean performance of genotypes for yield and yield contributing characters

Genotypes	DF	DM	PH	PL	NTP	NPM	NPTP	GY/P
CRDHAN200	85.00	139.33	83.20	22.03	13.60	288.33	11.40	14.01
CRDHAN201	90.00	139.33	82.83	20.07	14.37	312.67	11.67	13.30
CRDHAN202	87.00	136.33	90.60	21.33	14.43	286.33	13.30	13.37

CRDHAN203	87.00	138.33	85.00	18.87	12.17	274.67	11.93	16.52
CRDHAN204	87.00	132.33	95.33	22.17	13.87	312.00	13.47	13.77
CRDHAN205	85.00	133.67	83.37	22.23	16.20	227.67	14.00	14.03
CRDHAN206	85.00	136.67	90.70	19.07	15.03	323.00	13.97	15.73
CRDHAN207	93.00	140.67	79.03	21.90	13.30	331.67	12.77	16.83
CRDHAN209	91.00	141.67	96.83	20.67	15.33	357.00	13.83	14.43
CRDHAN210	90.00	141.33	82.90	21.27	19.93	372.67	18.70	19.30
DRRDHAN41	90.00	140.67	81.47	19.53	17.03	269.33	15.13	17.17
DRRDHAN54	85.00	140.33	86.17	22.33	18.43	378.67	18.23	17.93
DRRDHAN55	90.00	141.67	87.67	21.30	15.80	362.00	14.00	12.50
POUSTIC1	91.00	140.33	78.43	20.83	11.83	282.00	11.20	11.87
POUSTIC7	90.00	139.00	65.00	17.73	11.47	242.67	9.10	9.23
POUSTIC9	91.00	135.67	57.73	18.57	11.47	272.33	10.27	14.03
MAS-26	80.00	134.67	68.60	22.10	19.70	577.00	19.63	21.97
MAS-946-1	82.00	134.00	79.23	21.30	19.33	474.67	17.97	20.67
BPT5204	100.00	141.00	84.40	20.00	10.63	268.67	9.37	12.03
INDRANI	101.00	138.67	76.10	19.67	12.00	365.67	10.50	15.77
Basmathi	90.00	137.67	85.47	21.30	14.73	316.33	12.30	15.30
S.E.m	0.386	0.392	1.267	0.487	0.577	11.60	0.611	0.749
C.V	0.546	0.554	1.792	4.080	6.750	6.11	7.854	8.517
Mean	89.00	138.25	81.91	20.68	14.36	328.35	13.46	15.23
C.D at 5%	1.108	1.125	3.645	1.398	1.654	33.27	1.751	2.148

Table 4. Correlation between grain yield/plant and selected root characters

	RL	**RV**	**RN**	**RS**	**RT**	**RD**	**GY/P**
RL	1.000	0.904**	0.662**	0.779**	0.444*	-0.562**	0.717**
RV		1.000	0.653**	0.645**	0.411	-0.743**	0.716**
RN			1.000	0.276	0.335	-0.554**	0.428
RS				1.000	0.282	-0.206	0.577**
RT					1.000	-0.351	0.533*
RD						1.000	-0.483*
GY/P							1.000

RL = Root length; RV = Root volume; RN = Root number; RS = Root-shoot ratio; RT = Root thickness; RD = Root diameter; GY/P = grain yield per plant.

Root Morphological study for drought tolerance

Figure 1. Seedlings at 20 DAS

Figure 2. Seedlings at 80 DAS

Figure 3. Roots after harvest in Replication 1

Figure 4. Roots after harvest in Replication2

Author Contributions

Collection of literature: SSQ, SNN and UGR; Preparation & writing of manuscript SSQ, UGR, RHV and KL; Proof reading & finalisation of manuscript SSQ, SNN, UGR, RHV, KL and AMS.

Ethical Approval

NA.

Conflicts of Interest

The authors declare no conflict of interest.

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