Induced Radicle Rooting : An alternative Technique for Rapid and Mass screening of Rice Genetic Accessions for Deep Root system

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Abstract

Drought is a recurrent phenomenon in the fragile crop production environments. Drought resistant crop varieties strike roots deeper into the soil to withstand drought spells during the crop growth period better than the shallow rooted varieties. Thus the deeper they strike roots under stress, the better their survival. Plant breeding for less than ideal condition is very difficult especially for breeding resistance to drought. The existing screening techniques are based on lateral root or fibrous root development for monocots like rice or barley. This paper explains a new innovative approach called Induced Radicle Rooting (IRR) technique which is a novel technique in which radicle root is allowed to grow by suppressing the growth of the lateral roots. The induction of radicle rooting is achieved in three steps viz. (i) by allowing to touch the radicle of the germinated seed on the water level keeping other parts above. (ii) by reducing the water level of the well periodically then and there when the radicle starts growing (iii) by allowing the growth of the radicle down deeper in the capillary tube in such a way by arresting crown and lateral roots. As the moisture stress is artificially simulated right from the beginning in the capillary tubes, the varieties tend to put forth roots as deep as the water level is. The varietal difference in the radicle root length is so sharp that the shallow rooted varieties are differentiated from the deep rooted ones remarkably. It is a non destructive method and significantly correlated to field data ($r = 0.951$). This technique a first of its kind shall be useful as a valuable tool to the scientific community engaged in searching for deep roots.

Introduction

Rice is the staple food for more than half the World's population and is extensively grown by more than half of the world's farmers. Although originating in swampy areas of the tropics, rice is now grown globally in diverse ecologies and thus suffers a wide range of abiotic stresses (Hasina Khatun, 2016; Peyman Sharifi 2010). Drought is a recurrent phenomenon in the fragile rice production environments and statistics show that one long drought wave with the length of 18–30 days strikes at least once in the crop life cycle and plants necessarily have to endure the long drought spell to escape (IRRI, 1996). Genetically enriched drought resistant rice varieties were bred from time to time exclusively for cultivation in drought prone pockets with drought escape mechanism. (Arraudeau, 1989). Usually the plants built up drought resistant genes escape and make good harvest in the dry land agriculture. Drought resistant rice varieties strike roots deeper into the soil to withstand drought spells during the crop growth period better than the shallow rooted varieties, which do not bear the brunt of even the shortest moisture stress period. As the soil moisture gets depleted to the lower horizons during water scarcity, the truly upland varieties need to strike roots deeper to trace the scarce moisture. Thus the deeper they strike roots under stress, the better their survival (Yoshida *et al.*, 1982). In one end repatterning the plant canopy for ideal environment and in the other end infusing resistance for less than ideal condition through hybridization by selective mating or through irradiation with radio isotopes is progressing. Plant breeding for less than ideal condition is very difficult especially for breeding resistance to drought. Because inheritance of drought tolerance is a complex phenomenon and drought seems to be the interaction of various climatic factors viz., precipitation, air temperature, relative humidity, evaporation, transpiration from plants, wind, air flow, soil

moisture and plant conditions. Lack of a perfect method for the determination of drought tolerance in plants remains a bottle neck for the identification of tolerant plants. Even though many screening techniques are available to measure the rooting pattern of the genetic accessions each technique carries its own merits and demerits. (Atlin et al., 2008; Blum, 2002; Pushpam *et al.*, 2017). The most commonly employed techniques and their short comings are briefly summarized below:

Pot culture method

Growing the seeds in pots and stopping the irrigation and create drought artificially and selecting the accessions surviving in pots. This method is costly, laborious and slow. Only limited accessions can be employed. It occupies large space in the green house. (Gomathinayagam *et al.*,1988).

Root pulling method

This method involves growing the genotypes in the field and creates moisture stress in the field and pulling out the seedling/plant with a device which measures the force required to uproot the plant. This is also a costly, time consuming and slow method. Further, the genotypes with a strong well spread shallow root system (an undesirable character for upland rice) imitates a deep root accession in terms of force required to uproot. Hence the data is not always dependable. Besides It is not possible to uproot the full length from the deep layer of the soil without root damage (Ekanayake et al., 1985)

Root box method

This method describes growing the seeds in wooden box containing sand or saw dust and growing the plant. The root length is measured without any damage by dismantling the wooden box. The demerit of this method is the adventitious root formation hinders the exposure of the true potential of the radicle root length. It is laborious and costly method. Screening is subjected to limited entries.

Aeroponics method

This is an advanced technique growing seeds in a tall big metal container by intermittent spraying the nutrient solution automatically from the base of the container and allow the root to grow in the air space of the container. It is a costly screening method. Here the root growth is based on promoting fibrous root growth *ie.*, the radicle root growth is suppressed.

Herbicide root screening method

This method involves growing the seeds on the sand bed for a depth of 30 cm. The bottom layer is spread with herbicide. The fast rooting genetic accession which touches the herbicide layer will be killed and identified as the deep root accession. It is a destructive method of screening. The screening is based on classical or traditional way of allowing the crown and lateral root growth.

Sand bed method

This is also a traditional way of screening by allowing the root growth into the sand. The demerit of this method is it is laborious and can be done with limited accession. This method follows the screening based on the principle of allowing the lateral or secondary root growth.

Line - source gradient field approach

A field screening approach to select drought resistance varieties. By irrigating with sprinkler or through water channels through a gradient soil slope in such a way that the drought is created artificially to the test materials grown. This a labour intensive technique. It is a slow method as one has to wait until maturity to assess the genetic potential of the accession. This method is not considering the radicle root behavior.

Hydroponic method

Growing the seed on a water float on the surface of the solution containing with nutrients or without nutrients. The demerit of this method is the young roots are not exposed to drought or moisture stress. Often the susceptible genotypes show better rooting than a true drought resistant accession. (Chang et al., 1974; Fukai et al., 1999)

Molecular technique

Searching the drought resistant gene itself is a difficult task as the drought tolerance is a complex, genetical, physiological and biochemical phenomena. Marker Aided Selection (MAS) has to go a long way of research. (Pushpam *et al.*, 2017 ; Zheng et al., 2000). Besides, this technique is a costly affair to a low income group countries.

In all the above methods the screening follows usual procedure of measuring fibrous root growth and growth by radicle rooting is neglected. Besides, published reports on this line is not available or the radicle root behavior is not well studied.

Materials And Method

Local land races, native, indigenous and exotic varieties were collected under drought prone area and evaluation was carried out with genetic materials. Native land races were collected from interior pockets of small villages and germplasm was enriched and tested in the location specific sites. Laboratory analysis was taken up to screen deep rooted entries for germplasm. It was a challenge to identify the resistant donor for drought resistance breeding from vast gene pool. The data generated at one season or at one year was found contrary to subsequent season data due to erratic monsoon. It was found very difficult to get two successive climatic seasons in uniform which is conducive for drought screening. Past season data is found ambiguous if too much rainfall is noticed in one season or extreme drought occurred. So field screening is depending on the seasonal climate. Excess rainfall or extreme drought often results into a contradictory conclusion when two seasonal data were compared; a loss of valuable genetic materials in the field is inevitable during extreme climate (Arraudeau, 1989). Under this

circumstances an alternative screening technique based on induced radicle rooting is developed and discussed below:

InducedRadicleRooting (IRR) Technique

This novel technique promotes root elongation by allowing the growth of only one root *viz.*, the radicle and the true genetic potential of a genotype can be assessed in a week time. Others with shallow root or poor elongation ability shall be identified or eliminated. The uniqueness of this technique is as the lateral root growth is suppressed the radicle rooting is very fast to many folds and hence it is rapid. Due to this phenomenon the differential growth between a shallow rooted genotype and a deep rooted genotype is very wider and hence, screening is simple, easy and dependable.

The induction of radicle rooting was achieved in the following way: The test entries or the genotypes were pre germinated and were kept on a cotton net and only the tip of the radicle was allowed to touch the water in the capillaries and kept undisturbed. After a brief period , it was seen that radicle has grown out well in all the jars. There was no growth of secondary roots as the seeds were suspended in the net. The native upland land races put forth its long single elongated radicle upto the bottom level of the jar. This was the case for most of the native land races. But in case of low land rice like IR 20 and others the growth of the radicle was very less, just only passed half way of the capillary tube length or less.

It was observed that a tiny rice plant of one week old put forth more than one foot long root. Usually one has to wait till its maturity (120 days) to get 1 foot long deep root in field. Further test with more number of native land races and wetland varieties brought similar effect . The native land races put forth long radicle root. Wet land paddies put forth short radicle roots. A few of the improved genetic lines exclusively bred for upland tract have also shown long root. The genotypes which had the tendency to induce radicle root or to elongate further in search of water, survived well. All the genotypes started to spend energy towards rooting than shooting. Thus, a real rooting potential of a genotype can be identified.

Materials required:

- A Borosil capillary tube of 375 mm in length with 8 mm OD- 50 numbers.
- Borosil glass container 390 mm in height and 70 mm in diameter to hold capillary tubes with a vent.
- Cotton fiber mesh (70 mm in diameter)
- Bottom metal wire mesh(70 mm in diameter)
- Thick walled water tank with outlet.
- Soft water.

Procedure:

- Pre germinate the seeds of each accession with identity by soaking in water for 12 hours between filter papers and keep it in dark over night.
- Select 2 or more pre germinated seeds with uniform radicle protrusion for each accession.

- Place each seed on the cotton fiber mesh just above the capillary tube mouth.
- Adjust the water level in the tank in such a way that the pre germinated seed is touching the water level in the capillary tube.
- Wait for 24 hours for elongation of the radicle into the capillary tube.
- Keep the set up in a glass house undisturbed in normal temperature under sunlight.
- Observe for the elongation of radicle every day and adjust the water level in the capillary tube in such a way that only 2cm length of the radicle root alone immersed in the water level of the capillary well. By this way the radicle root is inducted to grow further.
- Repeat the exercise every 24 hours and allow only 2cm length of radicle root be immersed in the water level of the capillary tubes. Repeat the induction for 7 successive days.
- Slow rooting accessions will be eliminated due to its poor rooting to reach the downward moving water table. Observe the accessions with short radicle root or slow grown radicle roots drying up.
- Identify the accession with longest radicle root as the deep root accession at the end of the week. Observe the downward growth of the radicle root and allow only the accessions with long radicle root to be dipped in the capillary well.
- Continue the procedure until you identify an efficient deep rooted accession. (Usually 7- 10 induction is sufficient).
- If a small tank holding 3 capillary tube holders and each contains 50 capillary tubes, it is possible to screen 50 rice accessions with 3 replications within 7-10 days. It is possible to screen one thousand accessions by using 1000 capillaries by a single individual on a normal work table. (Fig1; Plates 1-5)

Plate 1

Borosil capillary tubes of 375 mm in length with 8mm outer diameter (OD) is employed in the Radicle rooting screening technique.

Plate 2

A tall glass transparent glass container holding about 50 numbers of capillary tubes is employed in the screening technique. A water hole /vent is provided at the lower wall for free flow of water between the water tank and the glass cylinder.

Plate 3

Pregerminated seed accessions were grown through capillary tubes. The water level in the container is reduced by every 24 hours in such a way that only 2 cm of the radicle root of the maximum elongated accessions is kept immersed and allowed to grow further.

Plate 4

Capillary tubes holding differential radicle root growth of genetic accessions. Maximum root elongation in the extreme right (Varappu kudanjana) and minimum root elongation in the extreme left (IR 20) is graded based on radicle root length.

Plate 5

Induced radicle root growth of genetic accessions removed out from the capillary tubes and graded .

Results And Discussion

Forty five rice accessions comprising traditional upland cultivars, improved varieties, improved lines and lowland varieties were subjected to this experiment. The test entries were replicated thrice in the laboratory as well as in the field. The experiment revealed that the length of the radicle root varied from 8.7cm to 24.8cm. All the local varieties under the test showed the values above mean. The maximum radicle root length was observed in the local variety Varappu kudanjana (24.8 cm). PMK 1, an improved upland variety and the promising lines MW 10, PM 1409 and IET 7975 are found registered radicle root length of 22.8, 22.1 and 20.2cm respectively. A shallow root growth was observed in lowland varieties viz., Jaya, IR 50 , IR 20 and Basmati (Table 1).

In the field experiments, the length of the roots was measured for each entries at maturity. The root length varied from 15.0cm to 29.5cm. The maximum field root length was shown by a local variety Varappu kudanjana (29.5 cm). All the other local varieties under the field condition showed the value above mean. PMK 1, an improved variety has showed a maximum root length of 29.4 cm. The entry, which has shown a long radicle root, expressed a proportionate longer root length at field level at maturity. The accession with long radicle root put forth deepest root at field level (Parao *et al.*, 1977; Yoshida *et al.*, 1982) .The accession with short radicle root put forth shallow root at field level. Similar trend was observed in the genetic test materials viz., improved varieties, promising lines and lowland varieties. A strong correlation was noticed (Fig.2 $r = 0.951$) between induced radicle root length of the seedling and field root length at maturity . This indicates that by following the radicle rooting one can predict its field root performance well in advance without waiting to maturity. This radicle rooting character is not associated with plant height at maturity (Fig.3 $r = 0.0513$)) or duration (Fig.4 $r = -0.339$). A very poor correlation was noticed and highly scattered . This indicates that deep rooting is a trait independent of its height (Tall or Short) or duration (Short or long duration) according to Chang *et al.*, 1974.

The following care were taken through out the Experiment:

1. Uniform pre germinated seed with radicle was taken into account.
2. The radicle root was allowed to dip by 2 cm. in the well of the capillary tube. Leakage in the tank may drain the water from the capillary tube and hence, leak proof tank is to be used.
3. Normally, screening may be completed by allowing radicle root growth up to 30cm. This length is sufficient to grade the test entries or genetic accessions. If rigid screening required, radicle root may

allowed to dip by 1.5 cm and the root growth may be allowed upto 37.5 cm. to the full length of the capillary tube, for a remarkable varietal difference.

Conclusion

Plant breeding for less than ideal condition is very difficult especially for breeding resistance to drought. Because inheritance of drought tolerance is a complex phenomenon and drought seems to be the interaction of various climatic factors *viz.*, precipitation, air temperature, relative humidity, evaporation, transpiration from plants, wind, air flow, soil moisture and plant conditions.

Unique Character of Upland rice

Drought resistant rice varieties strike roots deeper into the soil to withstand drought spells during the crop growth period better than the shallow rooted varieties, which do not bear the brunt of even the shortest moisture stress period. As the soil moisture gets depleted to the lower horizons during water scarcity, the truly upland varieties need to strike roots deeper to trace the scarce moisture. Thus the deeper they strike roots under stress, the better their survival (Yoshida *et al.*, 1982).

Among the various defence mechanisms like wax bloomed leaves, semi erect droopy leaves, narrow leaves, stomatal closure ability the trait deep root plays a major role to protect the variety better during the time of severe moisture stress. This unique character has been observed in the best drought tolerant land races in rice.

Requirement for alternate screening method

During the breeding program , identifying the deep rooted segregating population and forwarding to next generation shall give fruitful results. However, lack of a perfect method for the determination of drought tolerance in plants remains a bottle neck for the identification of tolerant plants. Even though many screening techniques are available to measure the rooting pattern of the genetic accessions each technique carries its own merits and demerits.

The root system being less accessible and more complex than other agronomic traits, achieving the ambitious goal of breeding the roots of the future requires a coordinated effort and joint resources. Hence, designing new genetic screening methods based on a better knowledge is required.(Ahmadi *et al.*, 2014).

Induced Radicle rooting (IRR)

On this line, this article discusses about a novel technique which promotes root elongation by allowing the growth of only one root *viz.*, the radicle and the true genetic potential of a genotype can be assessed in a short time about a week or so. Others with shallow root or poor elongation ability are eliminated.

Rapid Technique

The uniqueness of this technique is as the lateral root growth is suppressed, the radicle rooting is very fast to many folds and hence this technique is rapid. Due to this phenomenon the differential growth between a shallow rooted genotype and a deep rooted genotype is very wider and hence, screening is simple, easy and dependable.

Principle

The principle behind this technique is a thirsty plant uses all its energy towards root development rather than other traits to catch the moisture available at deeper soil profile through its root elongation ability under rainfed environment; the plants lacking this character dries up and thus the fittest one survives.

IRR experiment with native land races and wetland rice varieties demonstrated that native land races put forth long radicle root. Wet land paddies put forth short radicle roots. A few of the improved genetic lines exclusively bred for upland tract have shown medium to long roots depending upon the genetic background or pedigree of the parents involved. The genotypes which had the tendency for root elongation to cope up with downward moving water table survived better. Those genotypes start to spend stored energy towards rooting than shoot development. In this way an efficient rooting potential of a genotype can be identified.

Importance and Relevance

As the moisture stress is artificially simulated right from the beginning in the capillary tubes, the varieties tend to put forth roots as deep as the water is. Virtually drought resistant varieties strike roots as quick as possible than the susceptible ones which show slower root elongation. Root comparison among varieties is easier because the adventitious roots are arrested during the test and the single radicle root growth is measured easily. The varietal difference in the root length is so sharp that the shallow rooted varieties are differentiated from the deep rooted ones remarkably. It is a non destructive method; any capillary tube can be removed out at any time, rooting pattern may be compared or grown separately and flexible in handling as the roots are grown inside the cavity of the transparent capillaries.

Summary Illustrations:

A thick walled transparent glass water tank consists of 3 or more glass cylinders to hold capillary tubes. Each capillary tube is 375 mm in length and 8 mm in diameter. Pre germinated seeds of rice genetic accessions are placed on the cotton fiber net (mesh) in such a way that the radicle root is kept immersed in the cavity of the capillary tube. In similar way, the pre germinated test materials are loaded in the capillary tubes. On the first day and throughout the experiment the water level in the outer tank and the water level inside the glass cylinder and the water level in the capillary tube shall be on the same level. The radicle root growth of each accessions inside the capillary tube is observed everyday. After every 24 hours the water level in the tank may be reduced down in such a way that about 2 mm radicle root tip alone should be allowed and kept immersed or to touch the water level. This can be done by controlling the water outlet and draining the water from the water tank. Some accessions which have the tendency

for quick rooting put forth more rooting and capture the depleting moisture or downward moving water level. Other accessions which have the tendency for slow rooting or Intermediate rooting shall be identified as illustrated.

A strong correlation is observed ($r=0.951$) between induced radicle root length of the seedling and root length of the matured plants grown under field condition; this indicates that by following the radicle rooting one can predict its field root performance well in advance without waiting until maturity. In other words, the longest radicle rooted accession produces deep root under field condition.

A weak correlation is observed ($r= 0.0513$) between induced radicle root length of the seedling and plant height at maturity grown under field condition ; this indicates that radicle rooting trait is not associated with plant height. In other words tall plants need not to produce deep roots; dwarf plants may have the potential to produce deep roots than a tall one.

A weak correlation is found ($r= -0.339$) between induced radicle root length of the seedling and duration of fully matured plant under field condition; this indicates that radicle rooting trait is independent or not associated with duration . In other words long duration rice genetic accessions need not to put forth deep roots always; short duration rice plants may also have the potential to produce deep roots than a long duration plant.

As mentioned by Weiming and Shihua (2014) , the combination of conventional approaches with molecular approach would make it possible to develop further grain yield varieties with ideal type root system in the near future. The basic premise is, this trait is quantitative in nature and will require teamwork and collaborative research across multiple environments. No individual or team is expected to be successful working alone.(John C O'Toole,2002). Accordingly, the simplicity and rapidity of this technique shall make the test unique in drought screening as a low cost screening technique shall be useful as a valuable tool to the scientific community engaged in searching for deep roots.

Abbreviations

MAS: Marker Aided Selection; IET: Initial evaluation trial; IRR: Induced Radicle Rooting; OD : Outer diameter.

Declarations

Ethical Approval and Consent to participate

Not Applicable

Consent for publication

Not Applicable

Availability of supporting data

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Both authors contributed to collect information and write the manuscript.

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Tables

Table 1. Mean comparison of rice accessions for parameter induced by radicle root length (7th day) with root length at maturity, plant height and total duration.

Entries	Parentage	Mean radicle Root Length(cm) On 7 th day (X)	Mean Root Length at Maturity in Field Condition (cm) (Y1)	Plant Height at maturity (cm) (Y2)	Duration at maturity (days) (Y3)
VarapppuKudanjan	Local land race (Traditional variety)	24.8	29.5	85.5	130
MW IO	MTV 15/Yaikyakun nan toku	22.8	29.4	86.5	120
PM 1409	IR 30/T 815	22.1	29.2	85.5	115
Norungan	Local land race (Traditional variety)	21.8	29.0	88.4	130
PMKI	CO 25/ADT 31	21.6	29.4	75.5	115
Noortripathu	Local land race (Traditional variety)	21.0	28.9	79.2	110
Poongar	Local land race (Traditional variety)	20.5	28.9	61.5	90
Sornavalai	Local land race (Traditional variety)	20.3	28.8	75.2	120
IET 7975	AICRIP	20.2	26.4	77.5	119
Kallurundaikar	Local land race (Traditional variety)	19.5	26.5	74.8	135
TKM9	TKM7/IR 8	19.5	26.6	50.8	108
PM 5884	ASD 4/IR 8	19.5	25.5	76.7	110
IET 9807	AICRIP	19.3	25.2	79.1	115
IET 8887	RP 143- 3/Phalguna	19.2	24.6	80.2	110
Chitraikar	Local land race (Traditional variety)	19.1	24.7	73.2	121
Vanakar	Local land race	18.6	24.8	72.0	124

	(Traditional variety)				
Murungankar	Local land race (Traditional variety)	18.6	24.8	87.5	125
IET 9799	AICRIP	18.6	24.7	76.5	120
Kuruvaikalanjium	Local land race (Traditional variety)	18.5	24.7	90.4	133
PM 1390	IR 13564/ASD 4	18.5	24.8	90.5	130
IET 10410	CO 41/CO 39	18.4	24.4	85.5	134
IET 10406	IET 7613/Dular	18.1	24.5	88.5	130
IR 47686-1-4B	IRAT 104/Palawan	18.1	24.5	90.5	135
Rasi	T (N) I/CO 29	17.5	23.7	88.0	120
PM 5883	Chandikar/IR 34	17.5	23.7	87.5	125
IET 10400	Rasi/Gajgour	17.4	22.2	90.4	130
IET 9831	IET 7564/IR 50	17.1	22.4	86.7	120
PM 5864	IR 13564/IR 6228	17.1	22.4	90.7	130
PM 5862	IR 13564/IR 6228	16.5	22.4	90.5	127
ADT36	Tiruveni/IR 20	16.5	22.4	75.5	120
IET 9816	IR 50/Phalguna	15.4	21.5	77.0	116
PM 5858	Norungan/ IR 13564	14.7	21.5	76.9	120
IET 10408	CO 37/IR 50	14.5	21.4	77.5	130
IET 9793	IR 9219-77-1-3/IR 1917-76-7	14.5	21.4	85.5	130
IET 9208	T3 mutant/Basmati 370	14.4	21.3	74.5	130
IET 9981	IET 7613/Dular	14.2	21.3	79.5	130
JET 10409	JET 2508/TKM 9	13.9	21.2	78.5	128
IR20	IR262/TKM 6	13.5	21.5	90.5	135

PM 5869	Poongaar/C22	13.2	21.5	89.5	130
JET 10398	JET 7613/Dular	13.2	21.0	75.6	130
PM5848	IR 13564/Norungan	12.6	21.0	87.5	135
JET 9225	Mettasanna/Rasi	12.4	15.1	75.7	111
IR50	IR 2153-14-1-6- 2/IR 28/IR 36	11.5	15.1	70.9	115
Jaya	T (N) 1/T 141	8.8	15.9	75.5	130
Basmati	Susceptible check	8.7	15.0	75.2	136
Mean (cm) = 17.1900 SE = 0.5751 CD (0.05) = 1.6163 CV(%) = 5.8200					

Figures

Figure 1

A thick walled transparent glass water tank consists of 3 or more glass cylinders to hold capillary tubes. Each capillary tube is 375 mm in length and 8 mm in diameter. Pre germinated seeds of rice genetic accessions are placed on the cotton fiber net (mesh) in such a way that the radicle root is kept immersed in the cavity of the capillary tube. In similar way, the pre germinated test materials are loaded in the capillary tubes. On the first day and throughout the experiment the water level in the outer tank and the water level inside the glass cylinder and the water level in the capillary tube shall be on the same level. The radicle root growth of each accessions inside the capillary tube is observed everyday. After every 24 hours the water level in the tank may be reduced down in such a way that about 2 mm radicle root tip alone should be allowed and kept immersed or to touch the water level. This can be done by controlling

the water outlet and draining the water from the water tank. Some accessions which have the tendency for quick rooting put forth more rooting and capture the depleting moisture or downward moving water level. Other accessions which have the tendency for slow rooting or Intermediate rooting shall be identified as illustrated.

Figure 2

A strong correlation is observed ($r=0.951$) between induced radicle root length of the seedling and root length of the matured plants grown under field condition; this indicates that by following the radicle rooting one can predict its field root performance well in advance without waiting until maturity. In other words, the longest radicle rooted accession produces deep root under field condition.

Figure 3

A weak correlation is observed ($r = 0.0513$) between induced radicle root length of the seedling and plant height at maturity grown under field condition ; this indicates that radicle rooting trait is not associated with plant height. In other words tall plants need not to produce deep roots; dwarf plants may have the potential to produce deep roots than a tall one.

Figure 4

A weak correlation is found ($r = -0.339$) between induced radicle root length of the seedling and duration of fully matured plant under field condition; this indicates that radicle rooting trait is independent or not associated with duration. In other words long duration rice genetic accessions need not to put forth deep roots always; short duration rice plants may also have the potential to produce deep roots than a long duration plant.