International Journal of Agriculture Sciences
ISSN: 0975-3710&E-ISSN: 0975-9107, Volume 9, Issue 2, 2017, pp.-3643-3646.
Available online at http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217

Research Article

GROWTH AND WATER STRESS PARAMETERS OF RICE (*Oryza sativa L.*) AS INFLUENCED BY METHODS OF CULTIVATION AND IRRIGATION REGIMES IN PUDDLED SOIL

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Received: November 10, 2016; Revised: November 26, 2016; Accepted: January 05, 2017; Published: January 12, 2017

Abstract- A field experiment was conducted at Hyderabad during *kharif* 2014 to study the "Water management for different methods of rice (*Oryza sativa* L.) cultivation in puddled soils". The treatments comprises of three systems of cultivations (direct seeding with drum seeder(DS), transplanting with machine (MTP) and conventional transplanting(CTP) as main treatments and sub treatments with four irrigation regimes *i.e* ,irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (I_1), irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube (I_2), irrigation of 5 cm at 3 days after disappearance of ponded water (I_3), and recommended submergence of 2-5 cm water level as per crop stage (I_4). Significantly higher number of tillers m^{-2} were observed in MTP over DS at all growth stages except 50 DAS. Number of tillers in MTP at 110 DAS and at harvest was on par with CTP. Significantly lower root volume was observed in DS (CTP and at harvest, respectively) than rest of methods of crop establishment at 110 DAS and harvest and was on par with CTP at 80 DAS. However, CTP was on par with MTP at 80 DAS and at harvest, but significantly differed at 110 DAS. Among different irrigation regimes significantly higher number of tillers m^{-2} was recorded with I_4 over I_2 and was on par with I_3 and I_1. The root volume was significantly higher in I_1 at 80, 110 DAS and at harvest. Relative water content and leaf water potential was not varied much among different rice cultivation systems but relative water content and leaf water potential at various stages of crop growth revealed at there was variation in grain yield due to irrigation regimes.

Keywords- Rice cultivation methods, Irrigation regimes, Growth parameters, Water stress

Citation: Sathish A., et al., (2017) Growth and Water Stress Parameters of Rice (*Oryza sativa L.*) as Influenced by Methods of Cultivation and Irrigation Regimes in Puddled Soil. International Journal of Agriculture Sciences, ISSN: 0975-3710 & E-ISSN: 0975-9107, Volume 9, Issue 2, pp.-3643-3646.

Academic Editor / Reviewer: Basavaraj, S K Karthik

Introduction

Rice (*Oryza sativa* L.) is the most important staple food crop for more than half of the world population, including regions of high population density and rapid growth. Conventional transplanting is the most dominant and traditional method of establishment in low land irrigated rice. The area under conventional transplanted rice in the world is decreasing due to scarcity of water and labour. So, there is need to search for alternate crop establishment methods to increase the productivity of rice [1]. Under such circumstances, the mechanical transplanting of rice has been considered most promising option, as it saves labour, ensures timely transplanting and attains optimum plant density that that contributes to high productivity. Another major concern in rice production systems is the dwindling trend of availability of water resources. The water use efficiency of rice is much lower than other crops. On an average, more than 5000 liters of water are used to produce one kilogram of rice. In irrigated wet seeded rice cultivation, water use efficiency on the farm can be increased by applying the amount of water, which is needed to the crop. Among the different methods of water-saving irrigation, the most widely adopted is alternate wetting and drying AWD irrigation method [2].

Materials and Methods

A field experiment was conducted during *kharif,* 2014 at Rajendranagar (17°32' N 78°40'E and 542.6 m above mean sea level) Hyderabad, Telangana. The experimental field was sandy loam in texture with a pH of 8.5 and EC of 0.56 dS m^{-1}, low in organic carbon (0.41%) and available nitrogen (166 kg ha^{-1}), high in available phosphorus (82 kg ha^{-1}) and potassium (361 kg ha^{-1}). The experiment was laid out in strip-plot design with three different rice cultivation methods as main plot treatments *viz.,* Direct seeding with drum seeder (DS) (M_1), Transplanting with machine (MTP) (M_2) Conventional transplanting (CTP) (M_3) and four treatments as sub-plot treatments *viz.,* Alternate wetting and drying (AWD) of 5 cm, when water level falls below 5 cm from soil surface in field water tube (I_1), AWD of 5 cm, when water level falls below 10 cm from soil surface in field water tube (I_2), irrigation of 5 cm at 3 days after disappearance of ponded water (DADPW) (I_3) and recommended submergence (RS) of 2-5 cm water level as per crop stage(I_4). Each individual plot was separated with providing buffer channels for proper maintenance of the treatments. The irrigation water measured with the help of water meter.

In different rice cultivation systems sprouted seeds were sown withmanually operated rice drum seeder. It drops the seeds at 20 cm apart in continuous row. In conventional transplanting 25 days old rice seedlings were transplanted, with 2 seedlings per $hill^{-1}$ with spacing of 15 cm x 15 cm and machine transplanting 17 days old rice seedlings raised separate in trays were transplanted, Kobota (NSP-4W) at 30 cm x 12 cm spacing. The crop was fertilized with 120 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1}.The leaf water potential was measured by using pressure bomb techniques as described by [3] and [4].The water content relative to that at full saturation and expressed, as relative water content was determined. The RWC on percentage basis was calculated using the equation of [5].

RWC (%) = (FW- DW/TW-DW) X 100

FW- Fresh Weight   TW- Turgid Weight   DW-Dry Weight

Results and Discussion

Number of tillers m^{-2}

The data on number of tillers (m^{-2})of rice differed significantly at different growth stages due to different methods of cultivation and irrigation regimes except at 50 DAS [Table-1]. Tillernumber m^{-2} increased up to 80 DAS and declined thereafter which might be due to self thinning mechanism, resource constraint or intra-plant competition. These results are supported by [6].

Among different rice cultivation methods, MTP recorded significantly higher number of tillers m^{-2}at 80, 110 DAS and at harvest (475, 339 and 336tillers m^{-2}respectively) compared to DS(392, 290 and 288 tillersm^{-2} respectively) and was on par with CTP (416, 336 and 333 tillersm^{-2}, respectively). Transplanting of early aged seedlings with machine transplanting might have improved tillering efficiency of the crop [7].This could be attributed to better aeration and less competition between plants due to wider spacing for light and nutrient as in case of machine transplanting (30 cm × 12 cm). These results corroborates with findings of [8].

Significantly higher number of tillers m^{-2} was recorded at 80 DAS with recommended submergence of 2-5 cm water level as per crop stage(476 m^{-2}) over AWDI of 5cm submergence when water level falls below 1.0 cm in field water tube (392 m^{-2}) and irrigation of 5 cm at 3 DADPW(412 m^{-2}) and was on par with 5cm submergence with 5 cm drop of water level in field water tube (430 m^{-2}). In turn, the later treatments *i.e* irrigating field with AWDI of 5 cm when water levels falls below 10 cm in field water tube though recorded significantly lower tillers was on par with other AWDI treatments of 5cm irrigation when water level falls below 5 cm in field water tube and irrigation of 5 cm at 3 DADPW.

Tillernumber recorded with recommended submergence of 2-5 cm water level as per crop stage at 110 DAS and harvest(343 and 339 m^{-2} respectively) was significantly higher over AWDI of 5cm submergence with 10 cm drop of water level in field water tube (283 and 280 m^{-2}, respectively) and was on par with AWDI of 5cm submergence with 5 cm drop of water level in field water tube and 3 DADPW (341, 340 and 321, 317 m^{-2} respectively). Lower number of tillers under delayed irrigation could be due to development of water stress in plants, which resulted in reduced cellular growth and lowered down of leaf water potential [9]. The stress caused due to the alternate wetting and drying and irrigation 3DADPW led to lower tillers Frequent irrigations maintenance of 2-5 cm submergence created favorable moisture regimes which enabled the crop plant to grow lavishly by providing conductive micro climate and increase absorption, translocation assimilation of nutrients by the plant for various physiological process [10] and in turn helped the plants to boost their growth through supply of more photosynthates towards reproductive sinks which caused to produce more number of tillers plant^{-1} Similar results were reported by [11].

Root volume (cc hill^{-1})

The root volume (cc hill^{-1}) was found to increase progressively with advancement of crop growth stage up to 110 DAS or 90 DAT and decreased slightly at harvest. [Table-2]

Among different rice cultivation methods, machine transplanting recorded significantly higher root volume 29.0, 48.9 and 46.8 cc hill^{-1} at 80, 110 DAS and at harvest respectively over drum seeding at all growth stages except 50 DAS and was on par conventional transplanting at 80 DAS and at harvest. Further the formers treatment was significantly higher than later treatment at 110 DAS. Significantly lower root volume was observed in drum seeding (25.3, 31.0 and 29.7 cc hill^{-1} at 80, 110 DAS and at harvest, respectively) than rest of treatments at 110 DAS and harvest and was on par with CTP at 80 DAS. However, CTP was on par with machine transplanting at 80 DAS and at harvest, but significantly differed at 110 DAS. This might be due to lesser spacing and more number of hill m^{-2} that led to higher intra plant competition and lesser root growth in drum seeding and more spacing (30×10 cm) and less number of hill m^{-2} in MTP, which enhanced the root volume.

The root volume did not differ significantly among irrigation regimes at 50 DAS [Table-2]. At 80, 110 and at harvest significantly higher root volume was observed in irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube 80, 110 DAS and at harvest (28.4, 43.8 and 43.9 cc hill^{-1} respectively) over irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube and was on par with irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube and irrigation of 5 cm at 3 DADPW than rest of the treatments at all stages and was significantly inferior at 80 DAS over rest of treatments. However the lower root volume was observed in irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube (24.9, 38.9 and 27.2 cc hill^{-1} at 80, 110 DAS and at harvest respectively). Root volume recorded with irrigation of 5 cm at 3 DADPW and irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube were on par with each other at all crop stages of growth. Favorable root growth in terms of root volume was observed under irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube method of irrigation and was numerically higher than recommended submergence of 2-5 cm water level as per crop stage (I_4) treatment though statistically at par at 80 DAS and 110 DAS and significantly higher at harvest. It kept the soil with optimum moisture and aerated condition, so that roots had access to both oxygen and water and increased root oxidation activity and root source cytokinins in intermediate irrigation. This might have promoted better root growth in the current investigation and similar findings were reported by[12].

Water stress parameters

Relative water content

Relative water content (RWC) was not varied much among different rice cultivation methods. The relative water content at various stages of crop growth revealed at there was reduction due to irrigation regimes.

There was not much variation in RWC in recommended submergence of 2-5 cm water level as per crop stage of irrigation (99.6 %) and irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (98.5 %) and irrigation of 5 cm at 3 DADPW (97.6 %) treatments but shown high variation with irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube (91.3 %).This could be due to the differential absorption of water by the plants and governed in part by soil factors such as water content and unsaturated conductivity. When the soil dries, water uptake by the roots becomes more difficult and uptake declines. This reduction in water used eventually results in the development of a water deficit in the shoot as a result relative water content decreased. The decreased RWC in irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube plants might be due to decreased in plant vigour. The plants of the irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube and irrigation of 5 cm at 3 DADPW treatments absorbed water from the deeper soil surface as well as that water present on the root surfaces. However, during the irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tubecreate water stress period, the water available to the root zone of the plants of was limited and deceased as the surfaces soil and root surfaces dried out. These results are agreed with the findings of [13].

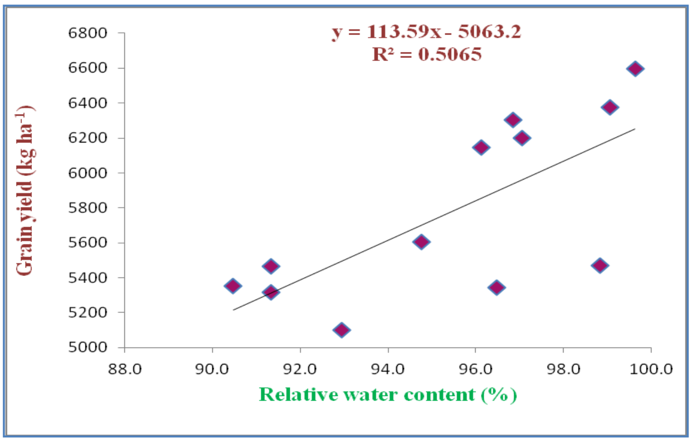

Fig-1 Regression of grain yield (kg ha^{-1}) on Relative water content

It was generally observed that the higher the RWC, the higher was the yield. There was a positive correlation (R^2=0.50, P<0.001) between yield and relative water content [Fig-1]. This result similar with the findings of [14].

Leaf water potential

Leaf water potential (LWP)of rice plant did not vary much indifferent rice cultivation methods. The leaf water potential (LWP)at various stages of crop growth revealed that there was variation due toirrigation regimes LWP decreased from -12.0 Bar to -18.0 Bar with increasing water stress. Under irrigation of 5 cm, when water level falls below 10 cm from soil surface in field water tube condition, the solute concentration in the root zone may be increased which decreased the permeability of the roots and reduced water uptake by the roots as a results declined leaf water potential over irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube, irrigation of 5 cm at 3 DADPW treatments. Highest leaf water potential recorded under the recommended submergence of 2-5 cm water level as per crop stage. Similar observation was also made by [14] in rice, [15] in wheat.

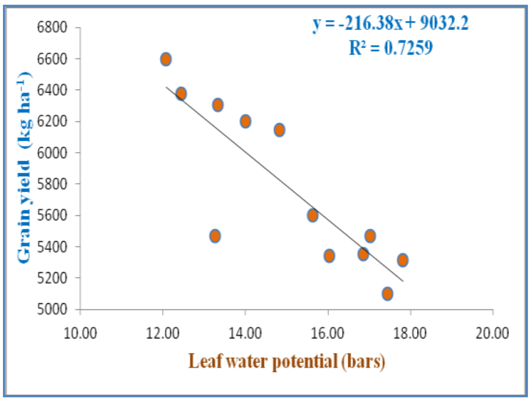

Fig-2 Regression of grain yield (kg ha^{-1}) on Leaf water potential

Table-1 *Number of tillers m^{-2} of rice as influenced by different systems of cultivation and irrigation regimes at different growth stages*

Treatment	50 DAS*	80DAS**	110DAS #	At harvest
Main plot - systems of cultivation (M)				
M_1- Direct seeding with drum seeder (DS)	278	392	290	288
M_2-Transplanting with machine (MTP)	288	475	340	336
M_3-Conventional transplanting (CTP)	342	416	336	333
SEm ±	15	14	10	9
C.D (P=0.05%)	NS	53	39	34
Sub plot - Irrigation regimes (I)				
I_1-Irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (AWDI)	305	430	341	340
I_2-Irrigation of 5cm, when water level falls below 10 cm fromsoil surface in field water tube(AWDI)	289	392	283	280
I_3- Irrigation of 5 cm at 3 days after disappearance of ponded water(DADPW)	304	412	321	317
I_4-Recommended submergence(RS) of 2-5 cm water level as per crop stage	312	476	343	339
SEm ±	13	16	10	10
C.D (P=0.05)	NS	54	35	34
Interaction of different systems of cultivation and Irrigation regimes				
Irrigation regimes at same level of systems of cultivation				
SEm±	30	32	17	16
C.D (P=0.05)	NS	NS	NS	NS
Different systems of cultivation at same level of irrigation regimes				
SEm ±	32.7	38	18	18
C.D (P=0.05)	NS	NS	NS	NS

DAS: Days after sowing, DAT: Days after Transplanting, AWD: Alternate wetting and drying
NS: Non Significant
*30 DAT, **60DAT, # 90 DAT, for MTP and CTP

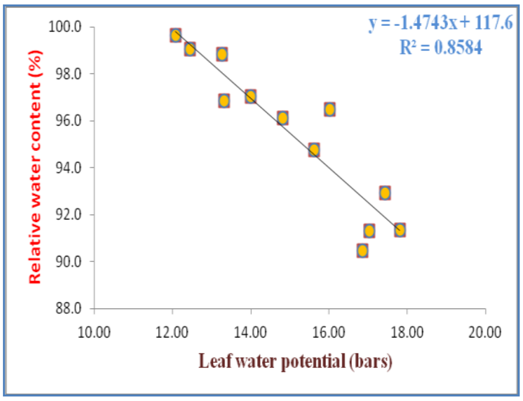

Fig-3 Regression of Relative water content on Leaf water potential

There was a positive correlation between leaf water potential and yield (R^2=0.72, P<.001) [Fig-2]. Similarly, a positive correlation between leaf water potential and leaf relative water content (R^2 = 0.85 P <.001) [Fig-3] and suggested that LWP is also an indicator of water status of plants as also reported by [16].

Table-2 *Root volume (cc hill^{-1}) of rice as influenced bydifferent systems of cultivation and irrigation regimes at different growth stages*

Treatment	50 DAS*	80DAS**	110 DAS #	At harvest
Main plot - systems of cultivation (M)				
M_1- Direct seeding with drum seeder(DS)	20.5	25.3	31.0	29.7
M_2-Transplanting with machine(MTP)	21.6	29.0	48.9	46.8
M_3-Conventional transplanting(CTP)	21.2	27.4	45.8	45.4
SEm ±	0.3	0.6	0.6	0.2
C.D (P=0.05)	NS	2.4	2.3	0.9
Sub plot - Irrigation regimes (I)				
I_1-Irrigation of 5 cm, when water level falls below 5 cm from soil surface in field water tube (AWDI)	21.5	28.4	43.8	43.9
I_2-Irrigation of 5cm, when water level falls below 10 cm from soil surface in field water tube(AWDI)	20.2	24.9	38.9	37.2
I_3- Irrigation of 5 cm at 3 days after disappearance of ponded water(DADPW)	20.4	27.9	43.2	42.0
I_4-Recommended submergence(RS) of 2-5 cm water level as per crop stage	22.3	27.7	41.8	39.4
SEm ±	0.6	0.5	0.9	0.5
C.D (P=0.05)	NS	1.6	3.1	1.9
Interaction between different systems of cultivation and irrigation regimes				
Irrigation regimes at same level of systems of cultivation				
SEm±	1.1	1.6	1.5	1.3
C.D (P=0.05)	NS	NS	NS	NS
Different systems of cultivation at same level of irrigation regimes				
SEm ±	1.3	1.9	1.9	1.6
C.D (P=0.05)	NS	NS	NS	NS

*30 DAT, **60DAT, # 90 DAT, for MTP and CTP

Conclusions

Among different rice cultivation systems, machine transplanting recorded higher number of tillers, root volume compared to drum seeding and was on par with conventional transplanting. Significantly higher number of tillers m^{-2} was recorded at 80 and 110 DAS with I_4 over I_2 and was on par with I_3 and I_1 and was significantly higher over rest treatments at harvest. The root volume significantly higher with I_1 at 80, 110 DAS and at harvest. Relative water content and leaf water potential was not varied much among different rice cultivation systems but relative water content and leaf water potential at various stages of crop growth revealed at there was variation in grain yield due to irrigation regimes.

Abbreviations: Direct seeding (DS), Machine transplanting (MTP), Conventional transplanting (CTP), DAS: Days after sowing, DAT: Days after Transplanting, AWD: Alternate wetting.

Conflict of Interest: None declared

Acknowledgement : Authors are thankful to Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, 500 030, Telangana

Author Contributions:
SATHISH A : Data collection, data analysis and interpretation, drafting the article, critical revision of the article
AVIL LUMAR K: Conception and design of the work, critical revision of the article, final approval of the version to be published
RAGHU RAMI REDDY P. AND UMA DEVI M.: Critical revision of the article, final approval of the version to be published

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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