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Effect of soil moisture and agrochemical levels on root volume and water productivity of direct seeded rice

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Abstract
A field experiment was planned and carried out with entitled "Effect of soil moisture and agrochemical levels on root volume and water productivity of direct seeded rice" for two successive years from 2017-18 to 2018-19 at Agricultural Research Farm of Banaras Hindu University, Varanasi. This experiment was carried out in split plot design with three replications with the objective to study of root volume and water productivity performance under different soil moisture level and agrochemical levels. The result revealed that soil moisture level at 100 per cent DASM had produced significantly higher root volume; among the agrochemical treatments, foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage was found distinctly superior over rest of the treatment in term of root volume at all growth stages except 30 DAS during both the years of mean. Water productivity was found higher in main plot of the treatment of 75 per cent DASM which at par with 50 per cent DASM; among agrochemical treatments, gave significantly higher water use efficiency in the treatment of foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage over the rest of treatments except foliar spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage during both the years of mean.

Keywords: DSR, root volume, soil moisture levels, agrochemicals, water productivity etc.

Introduction
Rice is the world's most important crop and is a staple food for more than half of the world's population. Worldwide, rice is grown on 165.21 million hectares, with an annual production of about 756.15 million tons of paddy (Anonymous, 2018) [1]. India has the world's largest area under rice with 43.19 million ha and is the second largest producer (163.70 million tonnes in 2016, (Anonymous, 2018) [1] next only to China. In UP, rice is cultivated on an area of about 5.99 million hectares with the total production of 13.75 million tonnes of rice (Anonymous, 2018) [1].

The challenge of growing water shortage and recurrent occurrence of drought is threatening food security in the eastern region. Eastern states account for 27.26 million ha rice area, out of which nearly 4.28 million hectare area is prone to drought. India has just four per cent of the world's fresh water but accommodates 18% of the global population (Dharminder *et al.*, 2019) [6]. The water use efficiency of rice crop is much lower than of other cereal crops. On average, 2500 litre of water used, ranging from 800 to 5000 liter to produce 1 kg of rough rice (Bouman, 2009) [3]. Declining water resources for rice cultivation has encouraged research on the development measures to increase water use efficiency. On the other hand, water should also be utilized proficiently for getting higher yield per unit of water applied. Thus proper irrigation scheduling should be aimed at abolishing under irrigation and ensuring optimum yields with regards to high water productivity. Soil application of Zn, B and Mn in early stage combined with foliar application in late stage, especially at the flowering stage, is a promising approach to alleviate drought stress (Karim and Rahman, 2015) [7]. The application of zinc and copper are significantly increased root dry weight of upland rice (Fageria, 2002) [9]. Micro-nutrients are helpful for increasing the root volume which is directly related to yield. Keeping above point of view present experiment was planned and conducted.

Method and Material
The present examination entitled "Effect of soil moisture and agrochemical levels on root volume and water productivity of direct seeded rice" was carried out for two consecutive years 2017-18 and 2018-19 at the Agriculture Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The rice was sown as direct seeded on 10th July during both the years.

The experiment was laid out in a split plot design. The main field consist of three treatment, 50 per cent depletion of available soil moisture (I_1), 75 per cent depletion of available soil moisture (I_2) & 100 per cent depletion of available soil moisture (I_3) and subplot had nine treatments i.e. Control (C_1), Seed treatment with Salicylic acid 100 ppm (C_2), Foliar Spray of Salicylic acid (100 ppm) at maximum tillering and panicle emergence stage (C_3), Foliar Spray of KNO_3 (1%) at maximum tillering and panicle emergence stage- K and N adjusted (C_4), Foliar Spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage (C_5), Foliar Spray of ZnSO4 (0.5%) at maximum tillering and panicle emergence stage (C_6), Foliar Spray of FeSO4 (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage (C_7), Foliar Spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage (C_8), Seed treatment with Salicylic acid (100 ppm) & foliar spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage (C_9). The RDF used at the rate of 120 kg nitrogen, 60 kg phosphorus and 60 kg potash per hectare. The six nutrients contains in multi-micronutrient complex are Zn, Fe, B, Mn, Cu, and Mo. Irrigation was given as per treatment of soil moisture levels; one after 50 per cent depletion of available soil moisture (DASM), second after 75 per cent DASM and third 100 per cent DASM. The five centimeter irrigation was applied at each time. The periodical data on root volume was taken. The water productivity was worked out using formula is given below:

$$\text{Water productivity (kg/m}^3\text{ water)} = \frac{\text{Grain yield } (\frac{\text{kg}}{\text{ha}})}{\text{Water applied (m3/ha)}}$$

Average plant root volume was calculated by water displacement method. During the first year of trial (2017), the total rainfall received during crop growth was 469.6 mm and succeeding year total rainfall 736.4 mm was recorded.

Result

Water productivity

The soil moisture levels had its impact during both the years of experiment as well as on mean basis also. During first year of experiment irrigation after 75 per cent DASM was found significantly superior in term of water productivity which was at par with 50 per cent DASM over 100 per cent DASM nevertheless in 2018 irrigation after 75 per cent DASM recorded significantly higher water productivity which was at par with 50 per cent DASM as compare to 100 per cent DASM. Between subplot treatments, foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage had outperformed the rest of treatments with regard to water productivity except foliar spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage in first and second year of mean basis.

Root study

There was distinct variation in root volume was noticed in all crop growth stage from 60 days after sowing (DAS) till harvesting of the crop. The non-significant difference in root length was noticed at 30 DAS in 2017 however, higher root volume was noticed with soil moisture levels with 100 per cent DASM in the main plot; significant difference was found only in year 2018 & mean basis of two years also. With regard to subplot treatment had non-significant influence on root volume during each year of experiment and also on mean basis. Application of seed treatment with salicylic acid (100 ppm) and foliar spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage had detected statistically higher root volume compare to rest of the treatments of subplot.

At 60 DAS, all the factors of treatment were got success in creating a marked difference in root volume of direct seeded rice. In the main plot; statistically, longer root volume was found with irrigation after 100 per cent DASM in year of 2017 & mean of two years. The subplot treatments were also created distinct difference; the utilization of foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage made conducive environment for better growth of root which resulted in higher root volume among subplots which was significantly superior over remaining treatment during both the years of trial except foliar spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage.

In main plot treatments at 90 DAS; artificial application of water after 100 per cent DASM had produced significantly higher root volume than 75 per cent DASM and 50 per cent of DASM during both the year of experiment besides based on two year average. The agrochemical factor of subplot had visible effect on crop root volume; significantly higher root volume was produced with utilization of foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage during both season & also on mean basis and it remained statistically at par with foliar spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage. A similar trend of the results was found in root volume at harvest stage.

Discussion

A critical scrutiny of periodical root volume data it could be concluded that root volume growth was higher with less amount of available water in root vicinity *viz*. treatment 100 per cent DASM water was applied after longer frequency than 75 per cent DASM and 100 per cent DASM hence less water was utilized by treatment 100 per cent DASM; this finding confirmed by Dharminder and Singh (2019) [5]. The carefully examinations of agrochemical data of root volume it may be concluded that application of foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage to field facilitate the root growth compare to other treatments which leads to longer crop root at all the crop growth. This result was in confirmation with Boonchuay *et al*., (2013) [2] and Fageria, 2002 [9]. The higher water productivity was obtained in the treatment of 75 per cent DASM as compare to other remained treatments; this result was in confirmation with Kumari, 2018 [8], she reported that maximum water productivity were obtained with Irrigation at 3 days disappearance of ponded water, over remained treatments but at par with Irrigation at 5 days disappearance of ponded water. Amid sub plot treatment, application of foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage had significantly higher water productivity which at par with foliar spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage as compare to other treatments in basis of two year mean. The experiment result verify by Das *et al.*, 2016 [10], they reported that maximum water productivity (4.38 Rs/m3) was recorded with three foliar application of 1% $FeSO_4$ at tillering, pre flowering and flowering stages level of iron which was at par with foliar application of 2% $FeSO_4$ at tillering, pre flowering and flowering stages level of iron. Maximum water productivity was recorded for soil application of ZnSO4 @ 37.5 kg ha^{-1}

which was significantly superior over foliar application of ZnSO4@ 0.5% at tillering, pre-flowering and flowering and control but was at par with soil application of ZnSO4 @ kg ha^{-1} (Kumari, 2018) [8].

Table 1: Effect of soil moisture levels and agrochemicals on root volume at 30 and 60 DAS

	Treatments	Root volume (cm^3)					
A	**Main plot (Soil moisture levels)**	**30 DAS**			**60 DAS**		
		2017	**2018**	**Mean**	**2017**	**2018**	**Mean**
I_1	50% DSM (depletion of available soil moisture)	6.5	4.91	5.71	6.45	9.5	7.98
I_2	75% DSM	6.1	6.75	6.43	8.35	9.98	9.17
I_3	100% DSM	6.15	9.25	7.70	11.40	10.28	10.84
	SE+	0.26	0.29	0.28	0.29	0.43	0.36
	CD (0.5%)	NS	1.12	1.07	1.13	NS	1.40
B	**Sub plot (Agrochemicals level)**						
C_1	C_1: Control	6.0	6.81	6.41	7.57	8.76	8.16
C_2	Seed treatment with Salicylic acid (100 ppm)	6.35	7.07	6.71	7.83	9.02	8.43
C_3	Foliar Spray of Salicylic acid (100 ppm) at maximum tillering and panicle emergence stage	6.01	6.81	6.41	8.07	9.26	8.66
C_4	Foliar Spray of KNO_3 (1%) at maximum tillering and panicle emergence stage- K and N adjusted	6.09	6.83	6.46	8.29	9.47	8.88
C_5	Foliar Spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage	6.19	6.92	6.56	8.50	9.68	9.09
C_6	Foliar Spray of $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage	6.32	7.03	6.68	8.80	9.99	9.39
C_7	Foliar Spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage	6.33	7.04	6.69	9.84	11.02	10.43
C_8	Foliar Spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage	6.35	7.07	6.71	10.29	11.48	10.88
C_9	Seed treatment with Salicylic acid (100 ppm) and foliar spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage	6.61	7.15	6.88	9.42	10.60	10.01
	SE+	0.21	0.23	0.22	0.22	0.25	0.22
	CD (0.5%)	NS	NS	NS	0.65	0.72	0.64
	I x C	NS	NS	NS	NS	NS	NS

Table 2: Effect of soil moisture levels and agrochemicals on root volume at 90 DAS and at harvest

	Treatments	Root volume (cm^3)					
A	**Main plot (Soil moisture levels)**	**90 DAS**			**At harvest**		
		2017	**2018**	**Mean**	**2017**	**2018**	**Mean**
I_1	50% DSM (depletion of available soil moisture)	8.56	9.74	9.15	9.80	10.61	10.21
I_2	75% DSM	11.23	12.58	11.91	13.34	14.40	13.87
I_3	100% DSM	15.20	16.96	16.08	18.35	19.70	19.02
	SE+	0.47	0.53	0.49	0.66	0.74	0.70
	CD (0.5%)	1.83	2.07	1.94	2.61	2.90	2.75
B	**Sub plot (Agrochemicals level)**						
C_1	C_1: Control	10.50	11.93	11.22	12.67	13.74	13.20
C_2	Seed treatment with Salicylic acid (100 ppm)	10.76	12.19	11.48	12.93	14.00	13.47
C_3	Foliar Spray of Salicylic acid (100 ppm) at maximum tillering and panicle emergence stage	11.00	12.43	11.72	13.17	14.24	13.70
C_4	Foliar Spray of KNO_3 (1%) at maximum tillering and panicle emergence stage- K and N adjusted	11.22	12.65	11.93	13.38	14.46	13.92
C_5	Foliar Spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage	11.43	12.86	12.14	13.59	14.67	14.13
C_6	Foliar Spray of $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage	11.73	13.16	12.45	13.90	14.97	14.43
C_7	Foliar Spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage	12.77	14.20	13.48	14.93	16.01	15.47
C_8	Foliar Spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage	13.22	14.65	13.94	15.39	16.46	15.92
C_9	Seed treatment with Salicylic acid (100 ppm) and foliar spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage	12.35	13.78	13.06	14.51	15.59	15.05
	SE+	0.25	0.28	0.26	0.29	0.31	0.30
	CD (0.5%)	0.73	0.81	0.76	0.82	0.90	0.85
	I x C	NS	NS	NS	NS	NS	NS

Table 3: Effect of soil moisture levels and agrochemicals on water productivity

	Treatments	Water productivity (kg/m3)		
A	**Main plot (Soil moisture levels)**	**2017**	**2018**	**Mean**
I_1	50% DSM (depletion of available soil moisture)	0.602	0.505	0.553
I_2	75% DSM	0.646	0.522	0.584
I_3	100% DSM	0.518	0.423	0.470
	SE+	0.025	0.020	0.013
	CD (0.5%)	0.072	0.056	0.036
B	**Sub plot (Agrochemicals level)**			
C_1	C_1: Control	0.504	0.416	0.460

C_2	Seed treatment with Salicylic acid (100 ppm)	0.541	0.445	0.493
C_3	Foliar Spray of Salicylic acid (100 ppm) at maximum tillering and panicle emergence stage	0.561	0.460	0.510
C_4	Foliar Spray of KNO_3 (1%) at maximum tillering and panicle emergence stage- K and N adjusted	0.574	0.471	0.522
C_5	Foliar Spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage	0.585	0.479	0.532
C_6	Foliar Spray of $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage	0.605	0.495	0.550
C_7	Foliar Spray of $FeSO_4$ (1%) and $ZnSO_4$ (0.5%) at maximum tillering and panicle emergence stage	0.642	0.526	0.584
C_8	Foliar Spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage	0.665	0.546	0.605
C_9	Seed treatment with Salicylic acid (100 ppm) and foliar spray of $FeSO_4$ (1%) at maximum tillering and panicle emergence stage	0.623	0.509	0.566
	SE+	0.033	0.026	0.016
	CD (0.5%)	0.067	0.053	0.032
	I x C	NS	NS	NS

Conclusion

Based on two year experimental data it may be concluded that 100 per cent DASM performance was better in term of root volume whereas 75 per cent DASM closely at par with 50 per cent DASM had utilized the water more efficiently & better yield. The foliar spray of multi-micronutrient complex (1%) at maximum tillering and panicle emergence stage was found more suitable for root volume and water productivity.

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