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EFFECT OF MOISTURE REGIMES AND LEVELS OF IRON ON GROWTH AND YIELD OF RICE UNDER AEROBIC CONDITION

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ABSTRACT

Leaf area index (4.73), crop growth rate (11.91 g/day/m²), SPAD value at maximum tillering (40.51) and pre-flowering (42.41), no. of panicle/m² (229.6), fertile spikelets/panicle (83.6), and grain yield (37.6 q/ha) were found to be maximum with 10 % moisture depletion of field capacity (I_1) which were significantly superior over 20 % moisture depletion of field capacity (I_2) and 30 % moisture depletion of field capacity (I_3). Maximum plant height (117.0 cm) and water productivity were (4.36 Rs/m³) also recorded with I_1 moisture regime and was statistically comparable to I_2 moisture regime and significantly superior to I_3 moisture regime. Water use efficiency did not vary significantly due to moisture regimes. Similarly, levels of iron had significant influence on growth and yield attributes, grain yield (35.1 q/ha) and water use efficiency (63.34 kg/ha-cm) and these were found to be maximum with F_4. Which was significantly superior over F_1 (Control) and F_2 but was statistically at par with F_3. Maximum water productivity (4.38 Rs/m³) was recorded with F_3 level of iron which was at par with F_4 level of iron. Thus the moisture regimes at 10 % moisture depletion of field capacity and three foliar application of 1 % $FeSO_4$ at tillering, pre-flowering and flowering stages were found to be optimum.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important and widely cultivated crop in the world. Asia is the home of rice as more than two billion people are getting 60-70 % of their energy requirement from rice and its derived products. It plays an important role both economically and in terms of food security as more than 90% world rice is grown and consumed in Asia. India ranked first in area under rice cultivation (43.42 million ha) and second in terms of production (106.54 million tonnes) with an average productivity of 24.54 q/ha. In Bihar rice is cultivated in around 3.29 million ha with a production of 4.99 million tonnes and productivity of 15.17 q/ha (Agricultural Statistics at a Glance, 2013-14).

The present and future food security of most of its population depends on it. However, there are signs that declining water availability is threatening the sustainability of irrigated rice production system. In view of these demands and constraints, the question is – does rice need standing water for optimum production? Can we go for an alternative that reduces this component? As a result, the concept of aerobic rice was first developed in China (Bouman and Tuong, 2001). The term "Aerobic rice" was coined recently by International Rice Research Institute. In aerobic rice system crop established in non-puddled, non-flooded field in unsaturated conditions as upland crop with adequate input and supplementary irrigation when rainfall is insufficient (Rajkumar *et al.*, 2009). Aerobic rice varieties have the ability to maintain rapid growth in soil with moisture content at or below field capacity and can produce yield of 4-6 t/ha with a moderate application of fertilizer under such soil water conditions (Partha sarathi *et al.*, 2012). Thus, the newly upcoming approach of rice cultivation called aerobic rice cultivation reduces water use in rice production and increases the water use efficiency. Production practices for rice cultivation are shifting from low-land rice to aerobic rice to make more efficient use of irrigation water. This shift has brought about increases in iron deficiency in rice, a new challenge depressing iron availability in rice and reducing iron supplies to humans. Current crop management strategies addressing iron deficiency include foliar application of iron bearing fertilizers, soil application and plant breeding for enriched iron crop species and varieties, and selection of cropping systems (Zuo and Zhang, 2011). Aerobic rice is facing two problems viz. water stress and iron deficiency (Prasad 2011). Iron deficiency is the most difficult and expensive micronutrient deficiency to correct under field conditions, because soil application of inorganic ferrous-salts are often in-effective in controlling iron deficiency except when application rates are extraordinarily large. In most of studies, foliar application of Fe had an edge over soil application. Foliar feeding is a relatively new and controversial technique of feeding plants by applying liquid fertilizer directly to their leaves (Mahdi *et al.*, 2011). Therefore, the present investigation was planned to study the effect of moisture regimes and levels of iron on growth and yield of rice under aerobic condition.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season of 2014 at Crop Research Centre, Department of Agronomy, RAU, Pusa, situated at 25° 59' North latitude and 85°48´ East longitude with an altitude of 52.9 meters above mean sea level. Climate of the study site was sub-tropical and sub humid type with mean annual rainfall of 1276 mm, out of which nearly 1026.0 mm is received during the monsoon between June to September. The main plot treatments were I_1 (Irrigation at 10 % moisture depletion of field capacity), I_2 (Irrigation at 20 % moisture depletion of field capacity) and I_3 (Irrigation at 30 % moisture depletion of field capacity) and sub plot treatments were F_1 (Control), F_2 (Basal application of 25 kg $FeSO_4$ +5 t FYM/ha), F_3 (3 foliar application of 1 % $FeSO_4$ at tillering, pre flowering and flowering stages) and F_4 (3 foliar application of 2 % $FeSO_4$ at tillering, pre flowering and flowering stages). The experiment was laid out in split plot design with three replications. A short duration rice cultivar 'RAU-4' was taken as test crop. The Soil of the experimental plot was sandy loam in texture, pH 8.6 (Glass electrode pH meter, Jackson, 1973), EC 0.42 dS/m (Conductivity bridge, Jackson,1973), low in available nitrogen 155 kg/ha (alkaline permanganate method, Subbaiah and Asija 1956), P_2O_5 20.2 kg/ha (Olsen's method (1954) Jackson1973), K_2O, 120 kg/ha (Neutron Normal ammonium acetate method, Flame, Jackson, 1973) and available iron 6.7 ppm using DTPA extracting solution (Lindsay and Norvell, 1978). The crop was fertilized with 120-60-40-25 kg/ha N- P_2O_5-K_2O and $ZnSO_4$ respectively. Application of 25 kg $FeSO_4$ + 5 t FYM/ha, 1 % $FeSO_4$ and 2 % $FeSO_4$ at tillering, pre-flowering and flowering stages were applied as per treatment. The amount of irrigation water applied was measured through using 7.5 cm throat size Parshall flume, applying 3 cm of water at each irrigation. The rainfall receive during the cropping season was 1276.1 mm with 1026.0 received during the monsoon June to September. The data collected from the experiment were subjected to statistical analysis by using 'ANOVA' as suggested by Fisher (1962).

RESULTS AND DISCUSSION

Growth characters

The growth of rice plant measured in terms of plant height, leaf area index and crop growth rate varied significantly under varying moisture regimes and levels of iron (Table-1). The maximum plant height (117.0 cm) at harvest was recorded with irrigation at 10 % moisture depletion of field capacity (I_1) which was significantly superior over I_3 but was statistically at par with I_2 moisture regime. This might be due to adequate water supply to crop which maintained good establishment of roots and various metabolic processes that perform better nutrient mobilization, and nutrient availability throughout crop

Table 1: Effect of moisture regimes and levels of iron on growth and SPAD Value of rice under aerobic condition

Treatments	Plant height (cm)	Leaf area index	CGR (g/day/m²)	SPAD Value at Maximum tillering	SPAD Value at Pre flowering
Moisture regimes					
I_1- 10% moisture depletion of field capacity	117	4.73	11.91	40.51	42.41
I_2- 20% moisture depletion of field capacity	107.2	4.07	10.25	35.05	37.39
I_3- 30% moisture depletion of field capacity	94.4	3.38	8.51	30.56	31.75
S. Em (±)	2.97	0.11	0.21	1.16	0.9
CD (P=0.05)	11.7	0.44	0.81	4.56	3.55
levels of iron					
F_1- Control	98.7	3.67	9.25	30.12	31.11
F_2- Basal application of 25 Kg $FeSO_4$ + 5 t/ha FYM	104	3.97	10	34.98	36.48
F_3- 3 foliar application of 1% $FeSO_4$ at tillering, pre flowering and flowering stages	108.4	4.24	10.69	37.54	39.23
F_4- 3 foliar application of 2% $FeSO_4$ at tillering, pre flowering and flowering stages	113.5	4.35	10.95	37.87	40.58
S. Em (±)	1.73	0.07	0.17	0.61	0.53
CD (P=0.05)	5.1	0.2	0.51	1.81	1.58

Table 2: Effect of moisture regimes and levels of iron on yield attributes, WUE, water productivity, and yield of rice under aerobic condition

Treatments	No. of panicle /m²	Fertile spikelets /panicle	Water use efficiency (kg/ha-cm)	Water productivity (Rs/m³)	Grain Yield (q/ha)
Moisture regimes					
I_1- 10% moisture depletion of field capacity	229.6	83.6	62.31	4.36	37.6
I_2- 20% moisture depletion of field capacity	197.7	72	59.6	3.65	32.4
I_3- 30% moisture depletion of field capacity	173.2	63.1	55.26	2.81	28.4
S. Em (±)	7.42	1.77	2.2	0.32	1.2
CD (P=0.05)	29.2	7	NS	1.26	4.8
levels of iron					
F_1- Control	175.1	63.8	51.62	3.3	28.7
F_2- Basal application of 25 Kg $FeSO_4$ + 5 t/ha FYM	198.2	72.2	58.47	2.84	32.4
F_3- 3 foliar application of 1% $FeSO_4$ at tillering, pre flowering and flowering stages	212.7	77.5	62.8	4.38	34.8
F_4- 3 foliar application of 2% $FeSO_4$ at tillering, pre flowering and flowering stages	214.6	78.1	63.34	3.89	35.1
S. Em (±)	3.9	1.18	0.18	0.18	0.64
CD (P=0.05)	11.6	3.5	0.52	0.52	3.3

growth which resulted in maximum plant height. It is in conformity with the result of Singh and Ingram (1995), Anusha *et al*. (2015) and Ramakrishna *et al*. (2007). This was attributed to continuous supply of water there by maintaining optimum water and nutrient availability throughout crop growth. The maximum plant height (113.5 cm) was recorded at harvest with treatment F_4 level of iron which was significantly superior over F_1 and F_2 but was statistically at par with F_3 levels of iron. The increase in plant height under F_4 might be owing to adequate quantity of iron supplied to the crop as per need during the critical growth stage which leads towards on increase in plant height. Lowest value of plant height was observed under F_1 (Control). The similar type of results was also reported by Habib (2012).

The highest value of LAI (4.73) at 90 DAS was recorded at I_1 moisture regime which was significantly superior over I_3 but was statistically at par with I_2 moisture regime. This might be due to adequate moisture supply which favours the growth of leaves and more number of larger sized leaves. It was also observed that LAI increased up to 60 DAS thereafter it decreased tillers mortality and leaf senescence increased toward maturity of the crop. These results are in accordance with findings of Zhao *et al*. (2007) and Anwar *et al*. (2011). Levels of iron significantly affected the LAI at 90 DAS. The maximum LAI (4.35) was recorded with F_4 (3 foliar application of 2 % $FeSO_4$ at tillering, pre flowering and flowering stages) closely followed by F_3 (3 foliar application of 1 % $FeSO_4$ at tillering, pre flowering and flowering stages) compared to other treatments and minimum value of LAI was observed with control plot. This results confirms the findings of Muhammad *et al*. (2012). This might be due to availability of iron involved in metabolism and formation of chlorophyll leading to better expansion of leaves (Yawalkar *et al.,* 2002 and Russel, 1961).

Crop growth rate is influenced by various growth parameters as well as bio-chemical and physiological activity of plant. Highest value of CGR (11.91g/day/m^2) at harvest was recorded with I_1 moisture regime which was significantly superior over other treatments. This might be due to maximum plant height, more number of tillers and more number of leaves. Maximum CGR (10.95 g/day/m^2) was observed with 3 foliar application of 2 % $FeSO_4$ at tillering, pre flowering and flowering stages compared to control and basal application of 25 Kg $FeSO_4$ + 5 t/ha FYM but was statistically at par with 3 foliar application of 1 % $FeSO_4$ at tillering, pre flowering and flowering stages. This was possible due to better availability of iron which involves in enzymatic reaction in metabolism and formation of chlorophyll. This result is in accordance with finding of Yawalkar *et al*. (2002).

SPAD value significantly influenced due to moisture regimes and levels of iron. The maximum SPAD value (42.41) at pre flowering was recorded with I_1 which was significantly superior to I_2 and I_3 moisture regimes. Similar trend was also found at maximum tillering stage. This might be due to adequate supply of water which increased the chlorophyll content of leaves and higher SPAD value indicated the higher chlorophyll content in leaves. While at a moisture stress condition for a long period photosynthetic activity were reduced owing to closure of stomata which reduced the chlorophyll content in leaves. The decrease in chlorophyll content due to water stress in rice has been reported by several workers (Deka and Baruah, 2000). Levels of iron also significantly affected the SPAD value. Highest value (40.50) was observed with F_4 levels of iron as compared to other treatments but remained statistically at par with F_3 levels of iron and least value were found with F_1 plot. This might be due to maintaining chlorophyll in leaves at threshold levels throughout the crop growth period Johankutty and Palaniappan (1996).

Yield attributing characters

Yield attributes were significantly influenced by both moisture regimes and levels of iron (Table-2). Maximum number of panicle (229.6/m^2) was recorded where irrigation was provided at 10 % moisture depletion of field capacity and minimum panicles (173.2/m^2) with 30 % moisture depletion of field capacity. This might be due to higher number of tillers with adequate moisture supply with I_1 moisture regime. Minimum panicles was observed with I_3 moisture regime which attributed stress at tillering increasing the mortality of productive tillers and reducing the number of panicles /hill. The results are in confirmation with the findings of Lu *et al*. (2002). The maximum number of fertile spikelets /panicle was counted with I_1 (83.5) moisture regime followed by I_2 (72.0) and minimum with I_3 (63.1). This might be due to regular supply of moisture at I_1 as compared to rest of treatments. The highest number of panicles (214.6/m^2) and fertile spikelets/panicle (78.1) were observed with F_4 level of iron as compared to other treatments and minimum value were found in control plot. This might be due to higher chlorophyll content and photosynthesis may be due to more availability of micro nutrients by foliar spray at different interval during growing period of crop.

Grain yield

Grain yield was influenced significantly due to moisture regimes and maximum value (37.6 q/ha) was recorded with I_1 moisture regime which was significantly superior over remaining treatments (Table-2). Better yield may be due to sufficient availability of water under with I_1 moisture regime which received four irrigations. This result is in accordance with finding of Sonit *et al*. (2015).

The grain yield of a crop is the combined effect of various growth and development parameters. In the present investigation almost all the growth and development characters seemed to be affected by increasing moisture regimes while, at moisture stress condition for a long period, the photosynthetic activity were reduced owing to closure of stomata which resulted in reduced supply of CO_2 and the capacity of protoplasm to carry out photosynthesis efficiency and reduced translocation might have hindered the further accumulation of the end products, while it was reverse in case of treatment receiving sufficient water throughout the growing period. This finding corroborates the results of Patjoshi and Lenka (1999) and Chauhan *et al*. (1999). Minimum values were obtained with 30% moisture depletion of field capacity moisture regimes receive only one irrigation during the crop period. Limited water supply during reproductive and ripening phases appeared to affect the reproductive physiology by interfering with the pollination, fertilization and grain filling. This results are in agreement with the results of (Wann, 1978). Significantly more grain yield (35.1 q/ha) was recorded under

3 foliar application of 2 % $FeSO_4$ at tillering, pre flowering and flowering stages as compared to control were also reported by Roosta and Hamidpour (2011). Positive effect of iron application by foliar spray on grain yield of rice might be due to increase in chlorophyll content of leaves of rice which might have increased photosynthesis and resulted in more dry matter, tillers /m^2 and LAI hence led to more capture of solar radiation that resulted in enhanced values of growth parameter and yield attributing characters and finally resulted in higher grain yield.

Water Studies

Data with respect to WUE and water productivity have been presented in Table 2. WUE varied from 55.26 to 62.31 kg/ha-cm and water productivity from 2.81 to 4.36 Rs/m^3 of water use for moisture regimes. WUE was not influenced by moisture regimes. However, maximum value of WUE was recorded with I_1 (62.31 kg/ha-cm) followed by I_2 (59.60 kg/ha-cm) and I_3 (55.26 kg/ha-cm). This revealed that water use efficiency was increased with increase in number of irrigation. This might be due to the fact that increase in yield was relatively higher than increase in quantity of irrigation water. Similarly, the maximum water use efficiency (63.34 kg/ha-cm) was recorded with F_4 levels of iron which was significantly superior to F_1 and F_2 but was statistically at par with F_3 level of iron. Higher grain yield resulted from higher iron supply either with F_4 (Three foliar application of 2 % $FeSO_4$ at tillering, pre flowering and flowering stages) and F_3 (Three foliar application of 1 % $FeSO_4$ at tillering, pre flowering and flowering stages) at same water use resulted in higher WUE as compared to F_1 and F_2. Water productivity decreased with increase in moisture stress from I_1 to I_3. This might be due to lower net return due to low availability of soil moisture. Water productivity with I_1 was found to be the maximum (4.36 Rs/m^3) which was significantly superior to I_3 but was statistically at par with I_2. Water productivity decreased with increase in moisture stress from I_1 to I_3. The maximum value of water productivity was recorded with F_3 (4.38 Rs/m^3) which was statistically at par with F_4 and both were significantly superior to F_1 and F_2. This might be due to higher net return under $F_{3.}$

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