Effect of humic substances (humic, fulvic acid) and chemical fertilizers on nutrient uptake, dry matter production of aerobic rice (Oryza sativa L.)

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Abstract

The pot culture experiment was conducted in green house, college of agriculture during kharif 2016 to study the effect of humic substances and chemical fertilizers on nutrient uptake, dry matter production of aerobic rice (Oryza sativa L.). Humic and fulvic acid was applied along with iron as Fe-fulvate and Fe-humate in 1:1.5 molar ratio along with Fe-chelate and FeSo₄ @ 2.5 mg/kg as soil application and 0.25% as foliar application at vegetative and panicle initiation stage with recommended dose of fertilizers. The results concluded that nutrient uptake, dry matter production was increased with foliar application of FeSo₄ @ 0.25% at vegetative and panicle initiation stage among other imposed treatments.

Keywords: humic acid (HA), Fulvic acid (FA), Nutrient uptake, dry matter production.

Introduction

Rice (Oryza sativa L.) is the staple food grain crop in Asia Island. India is the second largest producer of rice next to China producing 106.54 mt with an average productivity of 2424 kg ha⁻¹ from an area of 43.95 m ha. In Telangana rice is cultivated in 1.6 m ha with a production of 13.43 mt and an average productivity of 3330 kg ha⁻¹ (India stat, 2014-15). Aerobic rice is a renewed way of growing rice in non-submerged unpuddled condition in aerated soils. It is grown like any other crops like maize or sorghum on dry soils with surface irrigations provided when necessary with intensive agronomic practices. Aerobic rice is projected as sustainable rice production methodology for the immediate future to address water scarcity and environmental safety in the scenario of global warming (www.aerobicrice.org). Aerobic rice requires less labour (55%) than low land puddle rice and can be mechanized (Wang et al., 2002) [20]. Aerobic rice is an alternate system that requires less water and high external inputs (Booman et al., 2002) [3].

Micronutrients are essential for plant growth and play an important role in balance crop nutrition. Micronutrient deficiencies especially zinc and iron is considered as one of the major causes of the declining productivity trends observed in rice growing regions. The reduction of iron (Fe) availability with aerobic cultivation of rice is a serious problem because Fe is an essential nutrient for plants; Fe is required for respiration and photosynthesis. Insufficient Fe uptake leads to intercellular chlorosis in leaves and reduced yield (Terry, 1981) [16]. Iron deficiency is often a nutritional problem for crops in upland soils and is one of the primary limitations to rice production in aerobic areas (Barbosa and Yamasa 2002; Tuong and Bouman 2003) [12, 18]. Although the total amount of Fe in the rhizosphere soil is often 10,000 times greater than the Fe content of the plant itself, Fe deficiency is still common in agricultural production. This anomaly is due to low availability of Fe in the presence of oxygen, especially at moderate and high soil pH (Graham and Stangoulis 2003) [7]. It remains unclear how Fe nutrition of aerobic rice is affected by high pH caused by the shift from flooded to aerobic cultivation.

Application of humic substances in agriculture as fertilizer and soil conditioner were tried on limited scale. Significant impact of these humic substances on soil structure and plant growth was reported earlier by Ihsanullah and Bakhashawin (2013) [9], El-Razek et al. (2012) [4] and Fong et al. (2007) [5]. HA in proper concentration can enhance plant and root growth (Ahmed et al., 2013) [1]. Humic substances (humic, fulvic acid) attracts positive ions, forms chelates with micronutrients and releases them slowly when required by plants. According to Kadam et al. (2010) [11] the humic substances act as chelating agents there by prevents formation of precipitation, fixation, leaching and oxidation of micronutrients in soil. The following research study was taken up to prevent the loss of micronutrients in aerobic rice.

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Material and Methods

The pot culture experiment was conducted in green house conditions during kharif 2016 to study the effect of humic substances and chemical fertilizers on nutrient uptake, dry matter production of aerobic rice. An iron deficient inceptisol was used for pot culture experiment. Five kg of soil was filled in every pot. The soil used for pot culture having sandy loam texture with pH 7.75, EC 0.25 dS m⁻¹, organic carbon 0.45%, low available N 220 kg ha⁻¹, medium available P 22.5 kg ka⁻¹, medium available potassium 202.5 kg ha⁻¹ and low in DTPA extractable iron 2.63 mg kg⁻¹. The variety used for pot culture was MTU-1010. The seeds were sown in pots to have five hills per pot. The fertilizer was applied at the rate of 180 kg N, 60 kg P₂O₅ and 40 kg K₂O per ha. Phosphorus and potash was applied as basal and nitrogen was applied in splits. The experiment was laid in completely randomized block design with 11 treatments T₁-Control, T₂-Fulvic acid, T₃-Humic acid, T₄-Soil application of Fe-chelate @ 2.5 mg Fe kg⁻¹ soil, T₅-Soil application of Fe-fulvate @ 2.5 mg Fe kg⁻¹ soil, T₆-Soil application of Fe-humate @ 2.5 mg Fe kg⁻¹ soil, T₇- Soil application of FeSO₄ @ 2.5 mg Fe kg⁻¹ soil, T₈-Foliar application of Fe-chelate @ 0.25% at vegetative stage and panicle initiation stage, T₉-Foliar application of Fe-fulvate @ 0.25% at vegetative stage and panicle initiation stage, T₁₀-Foliar application of Fe-humate @ 0.25% at vegetative stage and panicle initiation stage, T₁₁-Foliar application of FeSO₄ @0.25% at vegetative stage and panicle initiation stage. The rice grown under pot culture in aerobic condition. Iron is major constraint in aerobic rice, to overcome this Fe is applied along with humic and fulvic acid as Fe-humate and Fe-fulvate by stability constants and found that 1:1.5 is suitable molar ratio. Plant samples collected at 30, 60 DAS and harvest were shade dried for 3-4 days, oven dried at 65°C. A known quantity of plant sample was digested with triacid mixture (HNO₃:H₂SO₄: HClO₄) and analyzed for P, K and Fe and for N plant samples were digested with H₂SO₄. Nitrogen content of plant sample was estimated by adopting the modified microkjeldahl method (Jackson, 1973) [10]. Phosphorus content was determined by Barton’s Reagent (Vanado molybdate reagent) phosphoric yellow colour method as described by Piper (1966) [13] using Spectrophotometer at 420 nm and expressed as per cent. The potassium content was determined using flame photometer (Piper, 1966) [13] and expressed as per cent. The iron content in plant samples was determined by using atomic absorption spectrophotometer (AAS) (Lindsay and Norwell, 1978) [12]. The nutrient uptake was calculated by using following formulas.

N uptake = N content (%) x Dry matter production (g pot⁻¹)
P uptake = P content (%) x Dry matter production (g pot⁻¹)
K uptake = K content (%) x Dry matter production (g pot⁻¹)
Fe uptake (µg g⁻¹) = Fe content (µg g⁻¹) x Dry matter production (g pot⁻¹)

Results and Discussion

The data pertaining to uptake of N, P and K at vegetative, panicle initiation and harvest stage of rice are furnished in the Table 1.

Nitrogen

In general, the nitrogen uptake increased with the advancement of the crop from vegetative stage to harvest stage i.e. from 24.11 g pot⁻¹ to 51.96 g pot⁻¹ (Table 1). At vegetative stage, highest nitrogen uptake 24.11 g pot⁻¹ was recorded in the treatment T₁₁ followed by T₇ 18.63 g pot⁻¹ which was on par with T₉ 18.52 g pot⁻¹ and lowest nitrogen uptake was recorded with application of RDF alone 2.83 g pot⁻¹. At panicle initiation stage the highest nitrogen uptake 31.34 g pot⁻¹ was recorded in the treatment T₁ followed by T₇ 26.16 g pot⁻¹ and T₁₀ 21.74 g pot⁻¹ which was on par with T₉ 20.76 g pot⁻¹ and lowest nitrogen uptake was recorded 4.48 g pot⁻¹ with application of RDF alone. Similarly at harvest the highest nitrogen uptake 51.96 g pot⁻¹ was recorded in the treatment T₁₁ followed by T₉ 43.36 g pot⁻¹ and lowest nitrogen uptake 7.59 g pot⁻¹ was recorded with application of RDF alone.

Phosphorus

In general the phosphorus uptake increased with the advancement of crop from vegetative to harvest stage 3.26 g pot⁻¹ to 5.64 g pot⁻¹ (Table 1). At vegetative stage highest phosphorus uptake was recorded in the treatment T₁₁ 3.26 g pot⁻¹ followed by T₇ 2.74 g pot⁻¹ which was on par with T₃ 2.68 g pot⁻¹ and lowest phosphorus uptake was recorded 0.53 g pot⁻¹ with application of RDF alone. At panicle initiation stage highest phosphorus uptake was recorded in the treatment T₁₁ 4.31 g pot⁻¹ followed by T₃ 3.66 g pot⁻¹ which was on par with T₇ 3.49 g pot⁻¹ and lowest phosphorus uptake was recorded with application of RDF alone 0.80 g pot⁻¹. Similarly at harvest highest phosphorus uptake was recorded in the treatment T₁ 5.64 g pot⁻¹ followed by T₇ 4.65 g pot⁻¹ and lowest phosphorus uptake 1.16 g pot⁻¹ was recorded with application of RDF alone.

Potassium

In general the potassium uptake increased with the advancement of crop from vegetative to harvest stage i.e. 15.72 g pot⁻¹ to 47.81 g pot⁻¹ (Table 1). At vegetative stage highest potassium uptake was recorded in the treatment T₁₁ 15.72 g pot⁻¹ followed by T₇ 14.47 g pot⁻¹ and lowest potassium uptake 3.71 g pot⁻¹ was recorded with application of RDF alone. At panicle initiation stage highest potassium uptake 20.49 g pot⁻¹ was recorded in the treatment T₁₁ followed by T₇ 17.66 g pot⁻¹ which was on par with T₉ 17.50 g pot⁻¹ and lowest potassium uptake was recorded with application of RDF alone 5.06 g pot⁻¹. Similarly at harvest stage highest potassium uptake was recorded in the treatment T₁₁ 47.81 g pot⁻¹ followed by T₇ 40.12 g pot⁻¹ which was on par with T₉ 38.66 g pot⁻¹ and lowest potassium uptake 9.17 g pot⁻¹ was recorded with application of RDF alone. The above results indicated that among all the treatments imposed FeSO₄ showed higher nutrient N, P and K uptake by rice. This could be due to the increased solubility of Fe from FeSO₄ than that from Fe-complexes and higher availability to crop plants. Among humic substances, fulvic acid showed higher nutrient uptake over humic acid and this could be due to the formation of more soluble fulvic - metal complexes as fulvic acid is more soluble in water, whereas humic acid tend to produce more insoluble metal complexes. These results are in conformity with those of Gondar et al. (2006) [6]. Similarly Sathiyanabam (2009) [14] also earlier reported increased nutrient uptake with increase in humic acid concentration due to the positive influence of these substances on protein and nucleic acid synthesis (Guminski, 1968) [8]. Humic acid also influence the plant growth directly either through its effect on ion uptake or by more effects on growth regulation of the plant (Vaughan and Linehan, 1976) [19].

Uptake of Fe

In general the iron uptake increased with advancement of crop
from vegetative stage to harvest stage from 54.68 to 187.70 µg pot⁻¹ (Table 1). At vegetative stage highest iron uptake 54.68 µg pot⁻¹ was recorded in the treatment T₁ followed by T₅ 49.31 µg pot⁻¹ and lowest iron uptake 5.20 µg pot⁻¹ was recorded with application of RDF alone. At panicle initiation stage highest iron uptake 80.23 µg pot⁻¹ was recorded in the treatment T₁ followed by T₅ 64.04 µg pot⁻¹ which was on par with T₃ 62.63 µg pot⁻¹ and lowest iron uptake 9.09 µg pot⁻¹ was recorded with application of RDF alone. Similarly at harvest highest iron uptake 187.70 µg pot⁻¹ was recorded in the treatment T₁ followed by T₅ 151.92 µg pot⁻¹ which was on par with T₅ 145.14 µg pot⁻¹ and lowest iron uptake 24.73 µg pot⁻¹ was recorded with application of RDF alone. Similarly at harvest highest iron uptake 24.73 µg pot⁻¹ was recorded in the treatment T₁ followed by T₅ 26.19 µg pot⁻¹ which was on par with T₃ 28.88 µg pot⁻¹ and in turn it was on par with T₁₀ 15.44 g pot⁻¹ and lowest dry matter production 6.33 g pot⁻¹ was recorded with application of RDF alone.

Humic substances (humic acid) attracts positive ions, forms chelates with micronutrients and releases them slowly when required by plants. According to Kadam et al. (2010) [11] the humic substances act as chelating agents there by prevents formation of precipitation, fixation, leaching and oxidation of micronutrients in soil.

**Dry matter production**

Dry matter production is the expression of growth and development of different morphological components and it is directly related to the yield.

In general the dry matter production of rice crop increased from age of plants from vegetative to harvest stage i.e. from 15.25 g pot⁻¹ to 21.42 g pot⁻¹ respectively (Table 1). At vegetative stage highest dry matter production 15.25 g pot⁻¹ was recorded in the treatment T₁ followed by T₃ 14.44 g pot⁻¹ and lowest dry matter production 5.17 g pot⁻¹ was recorded with application of RDF alone. At panicle initiation stage highest dry matter production 18.16 g pot⁻¹ was recorded in the treatment T₁ followed by T₅ 16.62 g pot⁻¹ which was on par with T₅ 16.11 g pot⁻¹ and in turn it was on par with T₁₀ 15.44 g pot⁻¹ and lowest dry matter production 6.33 g pot⁻¹ was recorded with application of RDF alone.

**References**


Table 1: Uptake of N, P, K (g pot⁻¹) and Fe (µg pot⁻¹) at different stages of rice as influenced by different treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Crop Stages</th>
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<th>Crop Stages</th>
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<tr>
<td></td>
<td>Nitrogen (g pot⁻¹)</td>
<td>Phosphorus (g pot⁻¹)</td>
<td>Potassium (g pot⁻¹)</td>
<td>Iron (µg pot⁻¹)</td>
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<td>8.80</td>
<td>18.24</td>
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<td>19.37</td>
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</tr>
<tr>
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<td>26.16</td>
<td>43.63</td>
<td>2.68</td>
</tr>
<tr>
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<td>21.74</td>
<td>32.81</td>
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<td>0.42</td>
<td>0.80</td>
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<tr>
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<td>1.24</td>
<td>2.36</td>
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</tbody>
</table>

C₅₁- Control, C₅₂- Fulvic acid, C₅₃- Humic acid, T₁- Soil application of Fe-chelate @ 2.5 mg Fe kg⁻¹ soil, T₅- Soil application of Fe-fulvate @ 2.5 mg Fe kg⁻¹ soil, T₅₃- Soil application of Fe-humate @ 2.5 mg Fe kg⁻¹ soil, T₇- Soil application of FeSO₄ @ 2.5 mg Fe kg⁻¹ soil, T₉- Foliar application of Fe-chelate @ 0.25% at vegetative stage and panicle initiation stage, T₉₅- Foliar application of Fe-fulvate @ 0.25% at vegetative stage and panicle initiation stage, T₉₅₃- Foliar application of Fe-humate @ 0.25% at vegetative stage and panicle initiation stage, T₉₅₇- Foliar application of FeSO₄ @ 0.25% at vegetative stage and panicle initiation stage.

Veg-Vegetative stage, PI-Pancile Initiation stage, Harv-Harvest stage.

**Conclusions**

The above results indicated that among all the treatments imposed FeSO₄ showed higher nutrient N, P and K uptake by rice. This could be due to the increased solubility of Fe from FeSO₄ than that from Fe-complexes and higher availability to crop plants. Among humic substances, fulvic acid showed higher nutrient uptake over humic acid and this could be due to the formation of more soluble fulvic - metal complexes as fulvic acid is more soluble in water, whereas humic acid tend to produce more insoluble metal complexes. Humic substances (humic acid) attracts positive ions, forms chelates with micronutrients and releases them slowly when required by plants and act as chelating agents there by prevents formation of precipitation, fixation, leaching and oxidation of micronutrients in soil. Humic substances (humic acid and fulvic acid) with its auxin activity induce hormonal effect on catalytic activity cell permeability and increases nutrient uptake and dry matter yield.