The Bioscan 9(1): 45-50, 2014
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EFFECT OF HUMIC ACID ON PLANT GROWTH CHARACTERS AND GRAIN YIELD OF DRIP FERTIGATED AEROBIC RICE (*ORYZA SATIVA* L.)

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KEYWORDS
Humic acid
Drip fertigation
Growth attributes
Yield attributes
Aerobic rice

Received on :
18.08.2013

Accepted on :
20.11.2013

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ABSTRACT

An experiment was aimed to assess the effect of humic acid on plant growth attributes and yield of aerobic rice under conventional, drip and subsurface drip fertigation system allotted to main plot and fertiliser levels (75 and 100% RDF) with and without humic acid kept in sub plots. The results indicated that lengthier root (59.1 m hill^{-1}), high chlorophyll content (2.66 mg g^{-1}), LAD (141 days), more productive tillers (680 tillers m^{-2}) and yield (5645 kg ha^{-1}) were produced under subsurface drip irrigation which was 21.0 percent increase over surface irrigation and 7.7 percent over drip irrigation system. Moreover, 100% RDF (150:50:50 NPK kg ha^{-1}) applied with humic acid recorded maximum root length (58.8 m hill^{-1}), higher chlorophyll content (2.61 mg g^{-1}), LAD (151 days), more filled grain percentage (69.1) and yield (5616 kg ha^{-1}). From this study it can be concluded that subsurface drip + 100% RDF with humic acid plants showed favourable morphological growth characters with improved yield attributes leads higher grain yield. This may be due to humic acid improve plant physiological processes by enhancing the availability of major and minor nutrients as well as enhancing the vitamins, amino acids, and also auxin, cytokinin and ABA contents of the plants.

INTRODUCTION

Subsurface drip irrigation is regularly used to provide water and nutrients to plants while maintaining a dry soil surface (Lamm and Trooien, 2003). Efficient use of water in any irrigation system is becoming important particularly in arid and semiarid region where water is a scarce commodity. However, drip irrigation reduces deep percolation, evaporation and controls soil water status more precisely within the crop root zone. Similarly in fertigation, applied fertilizer through the drip system is placed to the active plant root zone and improves fertilizer use efficiency. The yield of crops with organic materials could be achieved equally as compared to that with the application of NPK fertilizers. Humic acids (HAs) are water soluble organic acids naturally present in soil organic matter, comprising a large family of organic compounds with similar characteristics that are products of organic matter transformations by soil microorganisms. It results from the decomposition of organic matter into humus, which is microbially processed into humic acids.

Humic substances are readily found in soils and influence plant growth both directly and indirectly (Cimrin and Yilmaz, 2005). They have indirect influences on plant growth because they can improve soil properties such as aggregation, aeration, permeability, water holding capacity, hormonal activity, microbial growth, organic matter mineralization and solubilisation and availability of microelements (Fe, Zn and Mn) and some macro (K, Ca and P) elements (Sharif *et al*., 2002). Directly, they affect the processes associated with the uptake and transport of humic substances into the plant tissues (Nardi *et al*., 2002).

Humic substances improve yield and quality of a variety of plants, including grains (Jones *et al*., 2007; Ulukan, 2008). The objective of this paper was to elucidate the effect of humic acid on plant growth characters and yield of aerobic rice under surface drip, subsurface drip and conventional irrigation methods.

MATERIALS AND METHODS

Investigation was carried out during Dry Season (DS) of 2010 in the Wetlands of Tamil Nadu Agricultural University, Coimbatore, India located at 11°N latitude, 77°E longitude and at an altitude of 426.72 m above Mean Sea Level. The experimental plots were dry-ploughed and harrowed. Raised flat beds were formed and laid out with double channels around all the plots to prevent subsoil lateral water flow. The seeds were dry-sown by hand dibbled at 3 cm depth in rows of 20 cm apart at seeding rate of 30 kg ha^{-1} using short duration rice variety PMK (R) 3 spaced at 20 × 10 cm.

The soil of the experimental field was deep clay loam with soil contained 30.1 % clay, 25.4 % silt, 30.2 % fine sand and 9.3 % coarse sand. With the contents of available nitrogen (N), phosphorus (P) and potassium (K) were 332, 24, 387 kg ha^{-1}, respectively with the pH of 8.2. Weekly fertigation schedule indicating the nutrient requirement at different phenological stages were given at the recommended doses of NPK (150:

50: 50 kg ha^{-1}) in the form of water soluble fertilizers starting 21 days after sowing. In the case of surface / conventional method, recommended practices were followed.

Installation of drip system, from sub-main, in-line laterals were laid at a spacing of 0.8 m with 4 lph emitters spaced at 0.6 m such that one lateral could cover four rows of 20 cm each. In case of subsurface drip irrigation, the laterals were buried to a depth of 10 cm in the soil. The treatments consisted of three irrigation methods (conventional irrigation, surface and subsurface drip irrigation at 125 % PE level) along with 75 and 100 % Recommended Dose of Fertilizer (RDF) (Vanitha, 2008). HA was biogated @ 500 mL ha^{-1} through drip irrigation to the respective treatments during tillering, panicle initiation and flowering stages two days after fertigation. In case of conventional irrigation treatment, irrigation was scheduled at 1.25 IW/CPE ratio throughout the crop growth. For conventional irrigation, HA was applied as a foliar spray @ 500 mL ha^{-1}.

Sampling and data collection

Morphological characters

The plant height of each plant was measured from the base of the shoot to the longest leaf and expressed in cm. The total root length was calculated by using the weight of the total roots at the same moisture level as follows: Total root length (m) = (Length of sample roots (cm) x Weight of total roots (g)) / Weight of sample roots (g). Number of tillers in selected plants in each treatment was counted. Then, the average number of tillers was worked out and based on that tiller density per m^2 was derived.

Chlorophyll estimation

Contents of chlorophyll 'a', 'b' were estimated in a fully expanded young leaf at specified time intervals and the total content (a + b) was arrived at and expressed in mg g^{-1} fresh weight (Yoshida *et al.,* 1971).

Growth attributes

Leaf area was measured by using Leaf Area Meter (Model LI-3100 of LI-COR Inc., Lincoln, Nebraska, USA) and the Leaf Area Index (LAI) was calculated by employing the formula of Williams (1946). Leaf Area Duration (LAD) was determined by using the formula of Power *et al.* (1967) and the values expressed in days. Specific Leaf Weight (SLW) was calculated by using the formula of Pearce *et al.* (1969) and expressed in mg cm^{-2}. Crop Growth Rate (CGR) was estimated by using the formula of Watson (1956) and the values expressed in g m^{-2} d^{-1}. The total dry matter accumulation (TDMA) was arrived at by summing up the dry weights of leaf, culm, root and panicles and values expressed as g m^{-2}.

Yield and yield components

For assessing the relationship between yield and its components, according to Yoshida *et al.* (1971) the yield components were recorded at the time of harvest. Grain yield per hectare was calculated from the mean plot yield and expressed in kg ha^{-1} at 14 % moisture content.

Statistical analysis

The data collected were subjected to statistical analyses in the split plot design using ANOVA Package (AGRES version 7.01) following the method of Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Drip biogation effects on morphological characters

In general, comparing transplanted rice system, the lower amount of water supplied in the aerobic method reduced plant height in different cultivars (Russo, 2000). These observations were confirmed in the present investigations also especially for the drip irrigation treatments such as subsurface drip irrigation (SDI) and conventional drip irrigation (DI) were recorded moderate plant height of 96.7 and 96.9 cm than surface irrigation (SI: 98.6 cm).

Interestingly, plant height was found to be increasing with HA treatment irrespective of the fertilizer levels tried (Table 1). In biogation treatments, 75% RDF showed smaller plants of 91.6 cm while increase the fertilizer level to 100% RDF recorded increased plant height of 98.5 cm. In adding together supplement with HA performed better (100% RDF + HA: 101.6 cm) than 75% RDF + HA (97.7 cm). Bing *et al.* (2009) also showed increased plant height in rice with HA compound fertilizer. Interactively, surface irrigation at 100% RDF + HA (102.3 cm), DI at 100% RDF + HA (101.6 cm) and SDI at 100% RDF + HA (101.0 cm) were believed to be as the better competitor than the rest of the interactions for conventional irrigation, surface and subsurface drip system respectively. Humic acid assimilates minor and major elements, activates or inhibits enzyme, carry changes in membrane permeability, results in protein synthesis and activate biomass production which stimulates plant growth and ultimately increase plant growth (Stevenson, 1994). Humic substances may be absorbed by roots and translocated to shoots thereby enhancing plant growth.

Regarding irrigation methods, subsurface drip irrigation is evidence for favourable morphological characters such as total root length (59.1 m $hill^{-1}$), tiller density (701 m^{-2}) and total chlorophyll content (2.66 mg g^{-1}) than the surface and conventional irrigation method (Table 1). Thus, the beneficial effect of drip fertigation might have been vested with the more number of functional leaves, leaf area, increased tiller number and rate of photosynthesis which ultimately led to taller plants (Shrirame *et al.*, 2000).

Concerning biogation treatments, 100% RDF fertigation with HA treatment recorded significantly superior characters such as total root length (58.8 m $hill^{-1}$), tiller density (706 m^{-2}) and total chlorophyll content (2.61 mg g^{-1}) than the rest of the treatments tried. HA treatment recorded 58.2 m $hill^{-1}$ for total root length and extending the root growth to the subsurface layer might thus alleviate the temporary plant dehydration occurring between irrigation events in aerobic rice culture (Kato and Okami, 2010). It was reported that the incorporation of HAs into soils stimulated root growth (Cooper *et al.*, 1998) as well as stimulated the proliferation, branching and initiation of root hairs and could partially be attributed to enhanced nutrient uptake (Atiyeh *et al.*, 2002).

Table 1: Morphological characters as influenced by humic acid biogation

Parameters	Irrigation methods (I)/biogation(B)	Surface irrigation	Drip irrigation	Sub surface drip	Mean	CD (0.05)
Plant height(cm)	75% RDF	97.5	88.5	88.8	91.6	I (1.00**)
	75% RDF + HA	95.7	97.5	100.0	97.7	B (2.13**)
	100% RDF	98.7	99.1	97.7	98.5	I × B (3.35**)
	100% RDF + HA	102.3	101.6	101.0	101.6	B × I (3.70**)
	Mean	98.6	96.7	96.9	97.4	
Total root length(m hill^{-1})	75% RDF	54.8	56.7	58.1	56.5	I (0.581**)
	75% RDF + HA	55.6	57.9	59.4	57.6	B (1.263**)
	100% RDF	55.1	57.5	58.9	57.2	I × B (1.977**)
	100% RDF + HA	57.7	58.9	59.9	58.8	B × I (2.188**)
	Mean	55.8	57.8	59.1	57.5	
Tiller density (No m^{-2})	75% RDF	615	652	692	653	I (6.6**)
	75% RDF + HA	623	683	702	669	B (14.9**)
	100% RDF	641	688	690	673	I × B (23.2**)
	100% RDF + HA	684	715	719	706	B × I (25.8**)
	Mean	641	685	701	675	
Total chlorophyll(mg g^{-1})	75% RDF	2.12	2.55	2.56	2.41	I (0.023**)
	75% RDF + HA	2.20	2.62	2.61	2.48	B (0.053**)
	100% RDF	2.20	2.64	2.66	2.50	I × B (0.083**)
	100% RDF + HA	2.31	2.72	2.79	2.61	B × I (0.093**)
	Mean	2.21	2.63	2.66	2.50	

Table 2: Growth characters as influenced by humic acid biogation

Parameters	Irrigation methods (I)/biogation(B)	Surface irrigation	Drip irrigation	Sub surface drip	Mean	CD (0.05)
LAI	75% RDF	3.92	4.13	4.15	4.07	I (0.044**)
	75% RDF + HA	4.83	4.91	5.08	4.94	B (0.108**)
	100% RDF	4.91	5.11	5.26	5.09	I × B (0.167**)
	100% RDF + HA	5.08	5.25	5.45	5.26	B × I (0.186**)
	Mean	4.69	4.85	4.99	4.84	
LAD (days)	75% RDF	112.0	126.0	101.5	113.2	I (1.25**)
	75% RDF + HA	136.5	129.5	148.8	138.3	B (3.03**)
	100% RDF	143.5	124.3	155.8	141.2	I × B (4.71**)
	100% RDF + HA	138.3	157.5	155.8	150.5	B × I (5.25**)
	Mean	132.6	134.3	140.5	135.8	
SLW(mg cm^{-2})	75% RDF	8.82	9.85	9.99	9.55	I (0.098**)
	75% RDF + HA	9.07	10.47	10.95	10.16	B (0.225**)
	100% RDF	9.21	9.84	10.45	9.83	I × B (0.350**)
	100% RDF + HA	10.03	10.32	12.51	10.95	B × I (0.389**)
	Mean	9.28	10.12	10.98	10.13	
CGR(g m^{-2} d^{-1})	75% RDF	16.96	15.52	16.25	16.24	I (0.150**)
	75% RDF + HA	16.99	13.35	12.87	14.40	B (0.361**)
	100% RDF	22.03	15.17	15.80	17.67	I × B (0.561**)
	100% RDF + HA	18.73	16.45	14.19	16.46	B × I (0.625**)
	Mean	18.68	15.12	14.78	16.19	
TDMA (g m^{-2})	75% RDF	1038	1138	1207	1128	I (11.4**)
	75% RDF + HA	1116	1238	1294	1216	B (26.8**)
	100% RDF	1141	1243	1273	1219	I × B (41.7*)
	100% RDF + HA	1209	1305	1354	1289	B × I (46.5*)
	Mean	1126	1231	1282	1213	

Several studies showed that humic acid increase root length, root number and root branching. Stimulation of root growth is generally more apparent than shoot growth (Nardi *et al.*, 2002) and the reason for this can be because of the hormone-like activity of humic substances (Mayhew, 2004). Chlorophyll pigments play decisive role in plant productivity, as they are the only pigments responsible for photosynthesis. Karakurt *et al.* (2009) further elaborated that the change in total chlorophyll content in response to HA treatment was mainly due to the change in chlorophyll 'b' content. In case of combined effects, the three irrigation methods with normal fertigation along with HA treatment performed better in terms of total root length, tiller density and total chlorophyll content than deal with rest of the combinations.

Drip biogation effects on growth attributes

LAI is the area of leaf surface per unit area of land surface. The variation in LAI is an important physiological parameter for realization of crop yield (Gautam and Sharma, 1993). The growth attributes like LAI (4.99), LAD (140.5 days), SLW (10.98 mg cm^{-2}) and TDMA (1281.8 g m^{-2}) point up with superior in confirmation with subsurface drip irrigation respectively. Belder *et al.* (2005) reasoned out that the increase in LAI due to increased N supply might also be ascribed to the N-induced

Table 3: Yield and yield components as influenced by humic acid biogation

Parameters	Irrigation methods (I)/biogation(B)	Surface irrigation	Drip irrigation	Sub surface drip	Mean	CD (0.05)	
Panicle number m^{-2}	75% RDF	577	616	659	617	I	(6.2**)
	75% RDF + HA	591	657	688	645	B	(14.3**)
	100% RDF	615	656	676	649	I × B	(22.3*)
	100% RDF + HA	652	698	695	682	B × I	(24.8*)
	Mean	609	657	680	648		
Filled grain%	75% RDF	66.43	68.29	68.86	67.86	I	(0.695**)
	75% RDF + HA	67.12	67.51	69.34	67.99	B	(1.499*)
	100% RDF	67.75	68.2	68.88	68.28	I × B	(2.348*)
	100% RDF + HA	68.07	69.51	69.66	69.08	B × I	(2.597*)
	Mean	67.34	68.38	69.19	68.30		
Test weight(g)	75% RDF	22.04	22.74	22.89	22.56	I	(0.232*)
	75% RDF + HA	22.87	22.92	23.01	22.93	B	(0.504*)
	100% RDF	22.81	23.17	23.15	23.04	NS	
	100% RDF + HA	23.08	23.03	24.11	23.41	NS	
	Mean	22.70	22.97	23.29	22.99		
Grain yield(kg ha^{-1})	75% RDF	4205	4769	5255	4743	I	(47.0**)
	75% RDF + HA	4586	5258	5705	5183	B	(115.2**)
	100% RDF	4747	5256	5576	5193	I × B	(178.7*)
	100% RDF + HA	5121	5686	6042	5616	B × I	(199.5*)
	Mean	4665	5242	5645	5184		
Harvest Index (%)	75% RDF	40.52	41.91	43.55	41.99	I	(0.425**)
	75% RDF + HA	41.08	42.48	44.08	42.55	B	(0.938*)
	100% RDF	41.62	42.3	43.81	42.58	I × B	(1.465*)
	100% RDF + HA	42.34	43.56	44.64	43.51	B × I	(1.624*)
	Mean	41.39	42.56	44.02	42.66		

filled grain percentage and harvest index were given as a transformed values

enhancement of leaf area. SLW was a strong positive correlation with leaf photosynthesis in several crops (Lugg and Sinclair, 1980). Under aerobic conditions, the rice plants showed increased values for SLW (Gowri, 2005).

In conventional irrigation recorded lesser values of LAI (4.69), LAD (132.6), SLW (9.28) and TDMA (1126.1). Decrease in the level of LAI might be due to the insufficient level of nucleic acid synthesis owing to lesser N availability required for the cell division. This is in accordance with the earlier findings (Zhao *et al.*, 2005). The 100% RDF treated plants showed higher LAI which was further increased when plants are biogated with HA (Table 2) and also support favourable growth attributes such as LAD (150.5), SLW (10.95) and TDMA (1289.4).

Interactively, combined effect of subsurface drip irrigation with 100% RDF + HA received improved growth attributes for instance LAI (5.45), LAD (155.8), SLW (12.51) and TDMA (1353.5). The increase in the growth parameters were due to the improvement of soil condition of the root zone which maintain soil nutrients supply compared to conventional surface irrigation. Our results were supported by Suganya and Sivasamy (2006), Selim *et al.* (2009), Buyukkeskin and Akinci (2011), Çelik *et al.* (2011), Tahir *et al.* (2011), Yoon-Ha Kim *et al.* (2012) who have reported that HA increase crop growth and productivity and help in moisture retention and mitigation of stress.

Drip biogation effects on yield and yield attributes

Grain yield in cereals was highly dependent upon the number of productive tillers produced by each plant, constituting an important morpho-physiological trait for grain yield in rice (Tao *et al.,* 2006). Respect to the irrigation methods, subsurface drip irrigated plants recorded higher panicle number (680), filled grain % (69.19), test weight (23.29) which direct the grain yield (5645) and harvest index (HI: 44.02) than drip and conventional irrigation. The panicle number was increased in case of subsurface drip irrigation, which were 3.5 and 11.6 percent increase over drip irrigation and conventional method of irrigation. This was further confirmed with subsurface drip through 100% RDF+HA treatment recorded 698 panicles than the rest of the treatments tried (Table 3).

Humic acid influences plant growth both in direct and indirect ways. Indirectly, it improves physical, chemical and biological conditions of soil. While directly, it increases chlorophyll content, accelerates plant respiration and hormonal growth responses, increases penetration in plant membranes, etc. These effects of humic acid operate singly or in integration. Regarding the biogation treatments, 75% RDF registered lesser panicle number (617), filled grain % (67.86), test weight (22.56) and grain yield (4743) and HI (41.99). When additional supplement 75% RDF with HA biogation showed 4.5, 1.6, 9.3 and 1.3 percent increase in panicle number, test weight, grain yield and HI over 75% RDF respectively. In case of 100% RDF recorded panicle number (649), filled grain % (68.28), test weight (23.04) and grain yield (5193) and HI (42.58). Again further supplement 100% RDF with HA biogation showed 5.1, 1.2, 1.6, 8.1 and 2.2 percent increase in panicle number, filled grain %, test weight, grain yield and harvest index respectively over 100% RDF. The combination effects in all the three irrigation methods with 100% RDF + HA treatment performed better in expressions of yield and its attributes than rest of the combinations.

Among the combinations, subsurface drip with 100% RDF + HA treatment evidenced its superiority with panicle number

(695), filled grain % (69.66), test weight (24.11), grain yield (6042) and HI (44.64). Present study also confirmed with subsurface drip irrigation treatment recorded higher filled grain %, test weight which leads to higher grain yield and HI, which was further increase with biogation treatment given by 100% RDF + HA.

The above discussion clearly validates the suitability of humic acid as a beneficial fertilizer product. The application of humic acid alone and/or in combination with other fertilizers has significant beneficial effect on the growth and yield of mustard (David and Samule, 2002). Similarly, Albayrak (2005) reported that humic acid significantly affected most of the yield components of *Brassica raya*. In another study Chris *et al.* (2005) reported that both the foliar and soil application of humic acid significantly improved seed yield and oil content of mustard. MacCarthy *et al.* (2001) concluded that humates enhance nutrient uptake, improve soil structure, and increase the yield and quality of various oilseed crops.

The improvement in higher fruit and stover yield with humic acid and NPK fertilizer could be ascribed to the promoted cell division and cell elongation (Donnel, 1973 and Vaughan, 1974). Further, the humic acids are known to form chelates with micronutrients and thus it improves translocation of the nutrient cations within the plant system. The increased bhendi yield due to the application of humic acids and NPK fertilizer have already been well documented by Sangeetha and Singaram (2005) and Munazza Rafigue *et al.* (2010).

ACKNOWLEDGEMENTS

The first author is grateful to the funding agency M/s. Jain irrigation Systems Ltd., Coimbatore, India to carry out part of this research work.

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