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Influence of Humic Acid on Productivity and Economics of Brinjal (*Solanum melongena* L.) var. KKM1 and Soil Fertility in Alfisol of Thamiraparani Tract

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A three year field experiment was conducted during September-March of 2010-2011 and 2012-2013 at Agricultural College and Research Institute, Killikulam to study the influence of humic acid with graded levels of inorganic fertilizers on productivity, nutrient uptake, economic and soil fertility of brinjal var KKM1. The experiment was carried out in Randomized Block Design (RBD) replicated thrice with 11 treatments. The humic acid was applied through soil and foliar spray with 75 % RDF (N_{75} $P_{37.5}$ $K_{22.5}$). Application of 75 % RDF (N_{75} $P_{37.5}$ $K_{22.5}$) + 10 kg HA (SA) + 0.2% HA (FS) /ha produced significantly higher plant hight (112.0 cm), days to 50 % flowering (56.4), number of branches plant^{-1} (9.4), number of fruits plant^{-1} (25.3), single fruit weight (69.9 g), fruit yield (33.4 t ha^{-1}), total dry matter production (10.08 t ha^{1}), net return (₹ 1,33,131 ha^{-1}) and B:C ratio (4.29), N, P and K uptake (143.1, 33.3 and 148.6 kg ha^{-1}, respectively) compared to control. However, 75 % RDF (N_{75} $P_{37.5}$ $K_{22.5}$) + 10 kg HA (SA) + 0.1% HA (FS) ha^{-1} showed higher plant height, number of branches, days to 50 % flowering, number of fruits per plant, single fruit weight, fruit yield, total dry matter production, net return, B:C ratio, N,P and K uptake. Significant built up of organic carbon (0.92 %), available N (291.5 kg ha^{-1}), available P (25.4 kg ha^{-1}) and available K (293.7 kg ha^{-1}) was registered with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1}.

Key words: Alfisol, Available nutrients, Brinjal fruit yield, Economics, Humic acid, Nutrient content and uptake

Brinjal (*Solanum melongena* L.) is one of the most commonly grown vegetables in India. The area of cultivation is 0.68 million hectares with a production of 11.9 million tonnes (NHB data base, 2011). The national average production of this crop is 17.5 t ha^{-1}. In Tamil Nadu, brinjal is cultivated in 7107 ha with an annual production of 75971 tonnes and the average productivity is 10690 kg ha^{-1} (Season and Crop Report, Gov. of TN, 2005).

Soil fertility is one of the key factor, which decides the yield targets of many crops. The importance of soil organic matter to maintain soil fertility is well recognized. The humic substances applied in soil improve the plant growth through indirect effect on the physico-chemical and biological processes in soil (Schnitzer, 2000). Humic acid contains many elements, which improve the soil fertility and increase their availability, consequently affecting plant growth and yield. The major effect of humic acid on plant growth has long been reported. Humic substances supply growing plants with food, make soil more fertile and productive, increase the water holding capacity of soil. Humic acid reduces other fertilizer requirements, increases yield in crops, improves drainage, increases aeration of the soil and also increases the protein and mineral contents of most of the crops. It would establish a desirable environment for the development of microorganisms (Virgine Tenshia and Singaram (2005).

Brinjal generally requires heavy manuring for its potential production. However, the use of expensive commercial fertilizers as per the crop requirement is not much affordable to the farmers. Therefore, the application of fertilizers combined with humic acid is the newer cost effective method in nutrient management for maintaining sustainable production and productivity. Increased use of chemical fertilizers not only causes concern on declining productivity, but also deteriorates soil health. The present study was conducted to find the influence of humic acid with graded levels of inorganic fertilizers on productivity, nutrient uptake and soil fertility in brinjal.

Materials and Methods

A field experiment was conducted at Agricultural College and Research Institute, Killikulam during 2010 -11 through 2012 - 13. The soil of experimental field was sandy clay loam in texture, nearly neutral in reaction (pH 6.65), low in organic carbon (0.42 %), medium in available nitrogen (266 kg ha^{-1}), available phosphorus (16.8 kg ha^{-1}) and high in available potassium (268 kg ha^{-1}). The cation

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exchange capacity of the soil was 27.4 c mol (p^+) / kg. The bulk density was 1.38 g/cc. The soil was taxonomically grouped as *Rhodustalfs* (Rajavel, 2000).

The experiment comprising eleven treatments as T_1- absolute control, T_2- 100 % recommended dose of fertilizer (RDF) *i.e.* 100-50-30 kg of N-P-K ha^{-1}, T_3 - 75 % RDF *i.e.* 75-37.5-22.5 kg of N-P-K ha^{-1}, T_4 – 75 % RDF (75-37.5-22.5 kg of N-P-K ha^{-1}) + 10 kg HA ha^{-1} (SA), T_5 – 75 % RDF (75-37.5-22.5 kg of N-P-K ha^{-1}) + 20 kg HA ha^{-1} (SA), T_6 –75 % RDF (75-37.5-22.5 kg of N-P-K ha^{-1}) + 0.1 % HA ha^{-1} (FS), T_7 –75 % RDF (75-37.5-22.5 kg of N-P-K/ha) + 0.2 % HA ha^{-1} (FS), T_8 –75 % RDF (75-37.5-22.5 kg of N-P-K/ha) + 0.3 % HA ha^{-1} (FS), T_9 –75 % RDF (75-37.5-22.5 kg of N-P-K ha^{-1}) + 10 kg HA (SA) + 0.1 % ha^{-1} HA (FS), T_{10} -75 % RDF (75-37.5-22.5 kg of N-P-K ha^{-1}) + 10 kg HA (SA) + 0.2% /ha HA (FS) and T_{11} -75 % RDF (75-37.5-22.5 kg of N-P-K/ha) + 10 kg HA (SA) + 0.3 % ha^{-1}HA (FS) was carried out in randomized block design (RBD) with three replications. The brinjal variety KKM1 was taken as test crop for three years in the same location during September -March of 2010-2011 through 2012-2013. Planting of brinjal was done during December of every season with a spacing of 60 × 75 cm.

The cultivation practices were followed as per the guidance of crop production guide of Tamil Nadu Agricultural University (CPG-TNAU, 2004). The fertilizer sources used were urea for N (46 % N), single super phosphate for P (16 % water soluble P_2O_5), muriate of potash for K (60 % of K_2O) and commercial form of humic acid (Humicil). The foliar spray of humic acid was given on 60, 90 and 120 days after planting. Growth and yield attributes were recorded as per standard procedures. Five representative samples of each plot were collected and observations on biometric and yield attributes such as plant height, number of branches, number of fruits per plant, fruit weight, fruit yield and dry matter production were statistically analysed. The nutrient content and uptake by plant were analysed through prescribed laboratory procedures. The post harvest soil samples were collected from 0-30 cm depth for analysing physical and chemical parameters and available nutrient status. Soil samples were analysed for alkaline permanganate, oxidizable N, 0.5 M $NaHCO_3$-extractable P and 1 N NH_4OAC-exchangeable K. Two-way analysis of variance (ANOVA) was performed for each trait for all seasons and combined (pooled) over seasons after testing error variance homogeneity, according to the procedure outlined by Gomez and Gomez (1984). Significant difference between the treatments were compared with the critical difference at ± 5% probability by LSD.

Results and Discussion

Growth and yield attributes

The plant height was measured and recorded at harvest (Table 1). The height of the plant significantly differed for various treatments. It ranged from 69.6 to 112.0 cm at final harvest. At harvest, the tallest plant with 112.0 cm average height was recorded in the treatment (T_{10}) with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1}, followed by treatment (T_9) with 75 % RDF + 10 kg HA (SA) + 0.1% HA (FS) ha^{-1} (102.2 cm). The increase in plant height due to the humic acid application might have been attributed to the better rooting and absorption of nutrients by the plants and may be due to the auxin activity of humic acid on plant growth as indicated by Nardi *et al.* (2002). The shortest plant (69.6 cm) was recorded in absolute control (T_1). The maximum (9.4) and minimum (4.9) number of branches per plant was recorded with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1} and control. Similar results were reported by Arancon *et al.* (2006) and Obsuwan *et al.* (2011).

The number of days required for 50 % flowering of the crop were assessed in all the treatments and presented in Table 1. Among the treatments, T_{10} with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1} had

Table 1. Effect of humic acid with inorganic fertilizers on growth, yield attributes, yield and economics of brinjal (pooled mean of 2011-2013)

Treatment	Plant height (cm)	Branches $plant^{-1}$	Days to 50% flowering	Fruits $plant^{-1}$	Fruit weight (g)	Fruit Yield (t ha^{-1})	Total DMP (t ha^{-1})	Cost of cultivation (×103 ha^{-1})	Net return (×103 ha^{-1})	B:C ratio
Control (T_1)	69.6	4.9	67.7	12.7	52.3	17.0	5.99	30.4	52.9	1.74
100 % RDF (T_2)	90.2	7.1	60.8	21.9	57.4	25.3	8.13	39.6	85.3	2.15
75 % RDF (T_3)	82.9	6.5	62.1	17.4	59.4	23.4	7.50	29.7	83.5	2.81
75 % RDF + 10 kg HA ha^{-1} (SA) (T4)	79.4	6.5	63.8	15.8	61.9	25.7	8.25	30.5	94.9	3.11
75 % RDF + 20 kg HA ha^{-1} (SA) (T5)	96.9	8.3	59.9	20.8	60.0	28.1	8.98	31.7	104.0	3.28
75 % RDF + 0.1 % HA ha^{-1} (FS) (T6)	75.2	6.6	63.0	16.4	58.7	25.7	8.23	30.0	94.0	3.14
75 % RDF + 0.2 % HA ha^{-1} (FS) (T7)	73.3	6.5	65.5	17.6	58.4	26.8	8.46	30.2	100.1	3.31
75 % RDF + 0.3 % HA ha^{-1} (FS) (T8)	73.9	7.4	65.0	16.3	60.3	25.5	7.85	30.5	88.1	2.89
75 % RDF + 10 kg HA (SA) + 0.1 % ha^{-1} HA (FS) (T9)	102.2	8.3	58.2	22.4	68.1	30.8	9.45	30.8	117.7	3.82
75 % RDF + 10 kg HA (SA) + 0.2% ha^{-1} HA (FS) (T10)	112.0	9.4	56.4	25.3	69.9	33.4	10.08	31.0	133.1	4.29
75 % RDF + 10 kg HA (SA) + 0.3 % ha^{-1} HA (FS) (T11)	101.1	7.8	61.2	21.3	63.0	28.3	9.16	31.3	99.6	3.18
SEm±	2.05	0.31	1.13	0.93	3.04	0.78	0.87			
CD (P=0.05)	4.26	0.65	2.36	1.94	6.40	1.64	1.81			

RDF: Recommended dose of fertilizer for brinjal (100:50:30 kg NPK ha-1); HA: Humic acid; SA: Soil application; FA: Foliar application

shown 50 % flowering at the earliest (56.4 days), followed by 75 % RDF + 10 kg HA (SA) + 0.1% HA (FS) ha^{-1} (T_9), which reached 50 % flowering in 58.2 days. However, both the treatments were found to be on par to each other. The 50 % flowering period was late (67.7 days) in control (T_1). Pal *et al.* (2002) and Sat and Saimbhi (2003) also made similar observations.

Other yield attributes like number of branches per plant, number of fruits, weight of single fruit were significantly influenced by various treatments. Among all the treatments, the maximum number of fruits / plant (25.3) as in Table 1, was recorded when 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1} (T_{10}) was applied followed by the application of 75 % RDF + 10 kg HA (SA) + 0.1% HA (FS) ha^{-1} (T_9), which recorded 22.4 fruits /plant on an average. However, these treatments were found to be on par with each other. The minimum number of fruits /plant (12.7) was registered from absolute control (T_1). Similar results were reported by Pal *et al.* (2002), Sat and Saimbhi (2003) and Arancon *et al.* (2006). The maximum weight of single fruit (69.9 g) was recorded in the treatment (T_{10}) with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1}, followed by T_9 with the application of 75 % RDF + 10 kg HA (SA) + 0.1% HA (FS) ha^{-1}, which recorded 68.1 g fruit on an average. But, both the treatments were found to be statistically on par. The minimum single fruit weight (52.3 g) was registered with absolute control (T_1).

Table 2. Effect of humic acid with inorganic fertilizers on nutrient content and uptake by brinjal (pooled mean of 2011-2013)

Treatment	Nutrient contents in plant (%)			Nutrient uptake by plant (kg ha^{-1})			Nutrient contents in fruit (%)			Nutrient uptake by fruit (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K	N	P	K
Control (T_1)	0.84	0.21	1.24	41.5	6.6	41.9	1.02	0.15	1.17	25.9	4.4	28.8
100 % RDF (T_2)	1.19	0.55	1.37	64.1	8.6	70.0	1.21	0.25	1.26	45.5	10.5	47.6
75 % RDF (T_3)	1.05	0.36	1.45	55.8	7.7	59.0	1.15	0.26	1.24	39.9	9.0	43.8
75 % RDF + 10 kg HA ha^{-1} (SA) (T_4)	1.18	0.43	1.48	65.9	8.8	71.5	1.14	0.22	1.31	44.0	8.5	50.8
75 % RDF + 20 kg HA ha^{-1} (SA) (T_5)	1.29	0.48	1.52	69.2	9.6	75.8	1.31	0.35	1.35	56.0	15.0	55.7
75 % RDF + 0.1 % HA ha^{-1} (FS) (T_6)	1.24	0.44	1.35	56.2	8.0	63.2	1.17	0.23	1.25	43.9	10.0	46.0
75 % RDF + 0.2 % HA ha^{-1} (FS) (T_7)	1.27	0.43	1.36	61.8	8.2	64.1	1.18	0.27	1.26	47.0	11.3	49.8
75 % RDF + 0.3 % HA ha^{-1} (FS) (T_8)	1.27	0.43	1.34	58.6	8	63.7	1.18	0.23	1.25	41.4	9.4	45.0
75 % RDF + 10 kg HA (SA) + 0.1 % ha^{-1} HA (FS) (T_9)	1.39	0.58	1.62	70.9	12.2	74.0	1.38	0.37	1.40	61.5	16.9	62.7
75 % RDF + 10 kg HA (SA) + 0.2% ha^{-1} HA (FS) (T_{10})	1.49	0.62	1.66	74.5	13.5	78.1	1.40	0.41	1.44	68.6	19.5	70.5
75 % RDF + 10 kg HA (SA) + 0.3 % ha^{-1} HA (FS) (T_{11})	1.35	0.56	1.59	69.4	11.4	71.9	1.34	0.36	1.36	57.5	16.5	58.2
SEm±	0.06	0.02	0.02	1.38	0.39	1.52	0.02	0.01	0.02	0.84	0.57	1.12
CD (P=0.05)	0.12	0.04	0.04	2.82	0.79	3.15	0.04	0.03	0.04	1.76	1.20	2.35

Yield

Application of humic acid in brinjal with inorganic fertilizers significantly enhanced the fruit yield and dry matter production as compared to control. The application of 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1} produced the maximum and significantly higher fruit yield and dry matter up to the tune of 33.4 and 10.08 t ha^{-1} over control. The second best treatment was 75 % RDF + 10 kg HA (SA) + 0.1% HA (FS) ha^{-1}, which recorded 30.8 and 9.45 t ha^{-1} of fruit yield and total dry matter, respectively; whereas, the lowest yield of fruit and total dry matter (17.0 and 5.99 t ha^{-1}, respectively) was noticed with control. The increase in fruit yield and dry matter production might have been be due to increased growth and yield attributes. This results corroborate the findings of Sangeetha and Singaram (2007), who reported a significant increase in yield of onion in *typic* haplustalf in Tamil Nadu.

Nutrient content and uptake

To know the influence of humic acid application on NPK content (%) and uptake (kgha^{-1}) in brinjal whole plant and fruit samples were analyzed and the data presented in Table 2. The concentration and uptake of NPK due to combined application of both soil and foliar application of humic acid, influenced the nutrient contents and uptake significantly. The highest content of nitrogen, phosphorus and potassium (1.49, 0.62 and 1.66 %, respectively in plants and 1.40, 0.41 and 1.44 %, respectively in fruits) were recorded in the treatment applied with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1}. The lowest content of NPK both in plants and fruits (0.84, 0.21 and 1.24 %, and 1.02, 0.15 and 1.17 %, respectively) were observed in control (T_1).

Uptake of nutrients also showed similar trends. The highest uptake of NPK in plant (74.5, 13.5 and 78.1 kg ha^{-1}, respectively) and in fruit (68.6, 19.5 and 70.5 kg ha^{-1}, respectively) were recorded in the treatment with 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1}. The lowest uptake of NPK in plant (41.5, 6.6 and 41.9 kg ha^{-1}, respectively) and in fruit (25.9, 4.4 and 28.8 kg ha^{-1}, respectively) were noticed in control. Similar results were reported by Sangeetha and Singaram (2007).

Economics

The application of 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1} fetched significantly higher net returns (1,33,131 ha^{-1}) and benefit cost ratio (4.29) over other treatments (Table 1). The additional net return was up to the tune of 80,261 ha^{-1} due to the application of 75 % RDF + 10 kg HA (SA) + 0.2% HA

Table 3. Effect of humic acid with inorganic fertilizers on soil fertility (pooled mean of 2011-2013)

Treatment	Organic carbon (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Control (T_1)	0.41	185.3	12.9	229.0
100 % RDF (T_2)	0.61	257.5	19.5	272.6
75 % RDF (T_3)	0.54	259.5	17.7	260.0
75 % RDF + 10 kg HA ha^{-1} (SA) (T_4)	0.56	270.7	17.2	262.8
75 % RDF + 20 kg HA ha^{-1} (SA) (T_5)	0.56	275.0	22.3	276.8
75 % RDF + 0.1 % HA ha^{-1} (FS) (T_6)	0.57	261.3	20.7	273.5
75 % RDF + 0.2 % HA ha^{-1} (FS) (T_7)	0.59	264.5	21.2	275.3
75 % RDF + 0.3 % HA ha^{-1} (FS) (T_8)	0.57	262.3	21.4	264.0
75 % RDF + 10 kg HA (SA) + 0.1 % ha^{-1} HA (FS) (T_9)	0.75	285.2	22.4	287.2
75 % RDF + 10 kg HA (SA) + 0.2% ha^{-1} HA (FS) (T_{10})	0.92	291.5	25.4	293.7
75 % RDF + 10 kg HA (SA) + 0.3 % ha^{-1} HA (FS) (T_{11})	0.75	275.3	21.5	277.1
SE m±	0.04	3.73	0.85	7.10
CD (P=0.05)	0.08	7.78	1.78	14.80

(FS) ha^{-1} as compared to control. The second best treatment was 75 % RDF + 10 kg HA (SA) + 0.1 % HA (FS) ha^{-1}, which fetched a net returns of 1,17,701 ha^{-1}. This might be due to higher productivity as well as lower cost of cultivation. These results are in close conformity with the findings of Abd *et al.* (2005).

Soil fertility

Perusal of data presented in Table 2 revealed that the available nutrient status at post harvest stage in the soil was influenced significantly for various treatments. The highest values of organic carbon and nitrogen (0.92 % and 291.5 kg ha^{-1}) were recorded with the application of 75 % RDF + 10 kg HA (SA) + 0.2% HA (FS). Combined application of urea and humic acid might slow down the urease activity and also inhibit the nitrification process to reduce the loss of added nitrogen. The slow rate of nitrogen release would have increased available nitrogen. Virgine Tenshia and Singaram (2005) reported that HA produces ligands capable of complexing nutrient elements; and the complexed elements remain more available to plant roots, as complexation shields them against immobilisation. Inhibition of urease activity by HA led to reduced losses of N by volatilization and increased the availability of nitrogen. The available phosphorus also was the highest (25.4 kg ha^{-1}) for the same treatment. The increase might be due to the addition of humic acid to the soil, which dissolves the phosphorus fixed in soil. The fixed form of insoluble phosphates, such as tricalcium phosphates and flourapatite make slow contributing phosphorus fertilizers to the soil (Sathyabama and Selvakumari, 2001). The highest available potassium (293.7 kg ha^{-1}) was also recorded with the treatment T_{10} (75 % RDF + 10 kg HA (SA) + 0.2% HA (FS) ha^{-1}). Balasubramaniam *et al.,* (2000) reported that potassium rich minerals in the soils might have been destroyed in the presence of humic acid. Potassium, being the major constituent of all soil forming mineral, would have been released into soil solution. The lowest values of available nutrients of OC, N, P and K (0.41 %, 185.3, 12.9 and 229.0 kg ha^{-1}, respectively) were recorded in control.

Conclusion

It is concluded that soil application of HA @ 10 kg ha^{-1}; as well as foliar application @ 0.2 % along with 75 % recommended dose of inorganic fertilizers (RDF) not only improve the brinjal productivity, but also soil fertility status. Application of humic acid both in soil @ 10 kg ha^{-1} and foliage @ 0.2 % increased the yield and benefit cost ratio during brinjal cultivation in Alfisols of Tamil Nadu.

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