International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2023; SP-8(6): 24-28

www.veterinarypaper.com
Received: 16-09-2023
Accepted: 22-10-2023

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Response of macronutrient and humic acid on physiological attributes of fodder cereal-pulse intercropping system

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Abstract
In the summer season of 2021, a research study was conducted at the Department of Agronomy, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Killikulam. The study aimed to investigate the impact of different fertilizer doses, in conjunction with varying levels of humic acid, on the growth and physiological characteristics of fodder maize (African Tall) and fodder cowpea (CO 9) intercropping. The research employed a randomized block design with 12 treatment combinations, each replicated three times. The application of 125% of the recommended dose of fertilizer (RDF) in combination with enriched farmyard manure (FYM) at the rate of 750 kg/ha and 20 kg/ha of humic acid (HA), along with foliar spray of 1.0% Urea + 0.5% $CaCl_2$ (T_8), resulted in the most favorable outcomes for intercropping fodder maize and fodder cowpea under the paired row system. This treatment led to maximum plant height, highest number of leaves per plant, greatest number of branches per plant, enhanced dry matter production. The application of 100% RDF along with enriched FYM and 20 kg/ha of HA, combined with foliar spray of 1.0% Urea + 0.5% $CaCl_2$ (T_7), also yielded positive results. This treatment exhibited better physiological attributes, including agronomic growth rate, relative growth rate, and net assimilation rate at different crop growth stages. These findings suggest that the specific combination of fertilizers, humic acid, and foliar spray described in treatments T_8 and T_7 can significantly enhance the growth and physiological attributes of fodder maize and fodder cowpea intercropping. These results can be valuable for farmers and researchers aiming to optimize crop production in similar agroecological contexts.

Keywords: Humic acid, fodder maize, fodder cowpea, growth rate, intercropping, physiological

1. Introduction

Fodder production in India is of significant importance due to its critical role in supporting the country's livestock sector, which is one of the largest in the world. Fodder serves as a primary source of nutrition for dairy animals, cattle, goats, sheep, and other livestock. It contributes to milk, meat, and other animal product production, making it a crucial component of Indian agriculture. Fodder production in India is influenced by seasonal variations in climate and rainfall. Different regions of the country have specific cropping patterns based on monsoon seasons (kharif and rabi). Farmers often cultivate summer fodder crops during the dry months to ensure a steady supply of green fodder. In addition to providing fresh green fodder, farmers in India also make silage and hay to preserve fodder for the dry seasons. Silage is made by fermenting chopped green fodder in anaerobic conditions, while hay is made by drying and storing grasses for later use. Fodder production directly impacts the livestock economy in India. The quality and quantity of fodder available can influence the productivity of dairy animals and other livestock, which, in turn, affects the livelihoods of millions of rural households. Despite efforts to promote fodder production, there are challenges such as water scarcity, land availability, and pest and disease issues that can hinder the growth of the fodder sector. Climate variability and unpredictability also pose challenges to consistent fodder production. Sustainable and efficient fodder production is crucial for India's growing livestock sector, as it directly contributes to food security, rural employment, and income generation. Efforts to improve fodder quality and availability remain a priority for Indian agriculture and animal husbandry.

India, with approximately 17% of the world's population, is home to diverse agroclimatic conditions. Livestock husbandry is a viable and profitable livelihood, providing a steady source of income throughout the year. However, it's essential to recognize that a significant portion of the cost in livestock farming, roughly two-thirds, is attributed to feed expenses. Currently, India faces deficiencies in various types of feed:

- Green fodder is deficient by approximately 35.6%.
- Dry fodders and residues are deficient by around 10.95%.
- Concentrate feed constituents face a significant deficiency of approximately 44% (Ghosh *et al*., 2016) [5].

These shortages are further exacerbated by seasonal and regional scarcities, making it challenging to transport available fodder over long distances. Achieving higher livestock productivity hinges on providing quality feed, ensuring essential nutrition, and delivering proper healthcare. To address these challenges and enhance fodder availability, efforts should be made to boost the productivity of fodder crops (Kumar *et al*., 2012) [12]. Utilize various technologies such as multiple cropping, intercropping, and relay cropping to maximize the total area under fodder cultivation. Focus on producing high-quality nutritional fodder to meet the dietary needs of livestock (Singh *et al*., 2010) [14]. However, expanding the cultivated area for fodder crops faces competition with the growing demand for agricultural land for food and cash crops. Therefore, it is essential to find innovative solutions to increase feed availability and reduce the cost of production in order to ensure the prosperity of livestock farming in India.

Humic acid can have several positive effects on the physiological growth of crops. Its impact on plant growth and development is primarily attributed to its ability to enhance nutrient availability, improve soil structure, stimulate root growth, and promote beneficial microbial activity. Humic acid can chelate or complex with essential nutrients in the soil, making them more available for plant uptake. This enhanced nutrient availability allows crops to access a broader range of essential elements, leading to healthier and more vigorous growth. Humic acid has been shown to stimulate root growth and branching. Healthy and well-developed root systems enable crops to explore a larger soil volume, increasing their access to nutrients and water. Humic acid can enhance chlorophyll production and photosynthesis in plants. Improved photosynthesis leads to greater energy production, which, in turn, results in increased biomass production and overall crop yield. Crops treated with humic acid may exhibit increased tolerance to various abiotic stresses, including drought, salinity, and temperature extremes. Humic acid can help plants cope with stress by promoting the accumulation of compatible solutes and antioxidants, which protect plants from oxidative damage and water stress. Humic acid can stimulate beneficial microbial activity in the soil. These microorganisms play a vital role in nutrient cycling, organic matter decomposition, and disease suppression. As a result, crops treated with humic acid may benefit from improved nutrient mineralization and disease resistance. Humic acid can reduce nutrient interference or competition among different ions, particularly in soils with imbalanced nutrient ratios. This means that nutrients are less likely to be blocked from absorption by other ions with similar charges. Humic acid applications may lead to improvements in the quality of crops. For example, in the case of fruits and vegetables, humic acid-treated plants may have better fruit color, taste, and nutritional content.

2. Materials and methods

Experimental site and treatment details

This field experiment was conducted at the Agricultural College and Research Institute in Killikulam during the summer season of 2021 (March to May). The initial soil analysis revealed the following characteristics:

- pH value: 7.3 (nearly neutral)
- Electrical conductivity: 0.08 dSm-1
- Availability of nutrients: Low nitrogen (202 kg ha^{-1}), medium phosphorus (14 kg ha^{-1}), and medium potassium (240 kg ha^{-1})
- Initial organic carbon content: 0.458

The experimental design employed a randomized block layout with three replications. The primary intercrops were fodder maize (African tall) and fodder cowpea (CO 9), grown under a paired row system (2:2) with a spacing of 90/45 x 10 cm (additive series) to increase plant population.

The study included the following treatment details:

T_1 - 100% RDF + Foliar application of 1.0% MAP + 0.5% $CaCl_2$

T_2 - 100% RDF + Enriched FYM + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_3 - 75% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_4 - 100% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_5 - 125% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_6 - 75% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_7 - 100% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_8 - 125% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T_9 - 75% RDF

T_{10} - 100% RDF

T_{11} - 125% RDF

T_{12} - Absolute control

Humic acid was applied before sowing along with enriched farmyard manure (750 kg ha^{-1}). Different doses of NPK fertilizers, at 75%, 100%, and 125% of the recommended levels (60:40:20 kg ha^{-1}), were applied to the treatment plots. Nitrogen fertilizer was split into two doses, applied as a basal dose and at 30 days after sowing (DAS) to optimize fertilizer use efficiency. Foliar applications of 1.0% MAP, 1.0% urea, and 0.5% $CaCl_2$ were carried out at 30 DAS and 45 DAS. Fodder cowpea and fodder maize were harvested either at 55 DAS and 65 DAS or when they reached the 50% flowering stage. Various biometric plant observations, including plant height, number of leaves and branches per plant, growth indices, and physiological parameters, were recorded at 30 DAS, 45 DAS, and at the time of crop harvest.

Absolute growth rate: The absolute growth rate was calculated by using the given formula and expressed as gram per day per plant (g day^{-1} $plant^{-1}$).

$$AGR = \frac{W_2 - W_1}{t_2 - t_1}$$

Where,

W_2 and W_1 = Dry weight of whole plant (g) at time T_2 and T_1 respectively.
T_2 and T_1 = Time intervals (days).

Crop growth rate: It can be defined as the rate of dry matter produced per unit land area per unit time. It can be calculated by the given formula and expressed as g dm^{-2} day^{-1}.

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{1}{P}$$

Where,
W_2 and W_1 = Dry weight of whole plant (mg) at time T_2 and T_1 respectively.
T_2 and T_1 = Time intervals (days).
P = Land area (cm^2).

Relative growth rate: Relative growth rate (RGR) is the rate of increase in dry weight per unit dry weight of the plant per unit time and expressed as g g^{-1} day^{-1} and calculated by the following formula,

$$RGR = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where,
W_2 and W_1 = Dry weight of whole plant (mg) at time T_2 and T_1 respectively.
T_2 and T_1 = Time intervals (days). Log_e = Logarithm to base "e".

Net assimilation rate: Net assimilation rate (NAR) is the rate of increase in dry weight per unit leaf area per unit time and was expressed as gram per dm^2 per day (g dm^{-2} day^{-1}) and calculated by

$$NAR = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Log_e L_2 - Log_e L_1}{L_2 - L_1}$$

Where,
L_1 and W_1 = Leaf area (dm^2) and dry weight of whole plant (g) at time T_1.
L_2 and W_2 = Leaf area (dm^2) and dry weight of whole plant (g) at time T_2.
T_2 and T_1 = Time intervals (days).
Log_e = Logarithm to base "e".

Leaf area duration: Leaf area duration (LAD) is the integration of leaf area index over a growth period and expressed in days.

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

Where,
L_1= LAI at time T_1
L_2= LAI at time T_2
$T_2 - T_1$ = Time interval between growth period in days.

3. Results and Discussion

Physiological attributes

In the conducted field experiment, various physiological attributes and growth rates of fodder maize and fodder cowpea under an intercropping system were studied. Here are the key findings:

Fodder Maize

The rate of growth per unit dry matter, known as RGR, was highest in treatment T_8 at 30, 45 DAS, and the harvest stage, with values of 41.01, 34.58, and 28.52 mg g-1 day-1, respectively. Net assimilation rate (NAR) varied at different crop stages, being highest in T_2 at 30 DAS and in T_8 at 45 DAS and the harvest stage. Absolute growth rate (AGR) and absolute crop growth rate (CGR) increased with crop maturity, with the maximum growth rate observed in T_8 at all crop stages. The CGR increased initially and then declined toward maturity due to factors like vegetative growth cessation, leaf loss, and senescence. Lower RGR was observed due to an increase in metabolically active tissue and NAR.

Fodder Cowpea

RGR was highest at 30, 45 DAS, and the harvest stage, with values of 37.89, 34.53, and 30.41 mg g-1 day-1, respectively. Maximum NAR occurred at different crop stages: 30 DAS and 45 DAS in T_1 and the harvest stage in the control group. Growth rates increased slowly with crop maturity. Increasing nitrogen levels directly influenced AGR irrespective of the quantity of humic acid applied.

Leaf Area Duration (LAD)

Fodder Maize

LAD was influenced by humic acid levels, nutrient rates, and foliar applications in intercropping with fodder cowpea. At 30 DAS, the highest LAD (179.7 days) was found in T_8, followed closely by T_5 (125% RDF with enriched FYM and 10 kg ha^{-1} HA). At 45 DAS, T_8 recorded the maximum LAD (563.4 days), while the control (T_{12}) had the minimum (268.7 days). At harvest, T_8 again had the highest LAD (1330.6 days), followed by T_7 and the control (T_{12}).

Fodder Cowpea

At 30 DAS, the highest LAD (52.50 days) was observed in T_8, followed by T_4 and T_5. At 45 DAS, T_8 also recorded the maximum LAD (253.35 days), followed by T_1 and T_{12}. At harvest, T_8 had the highest LAD (682 days), followed by T_5 and T_7.

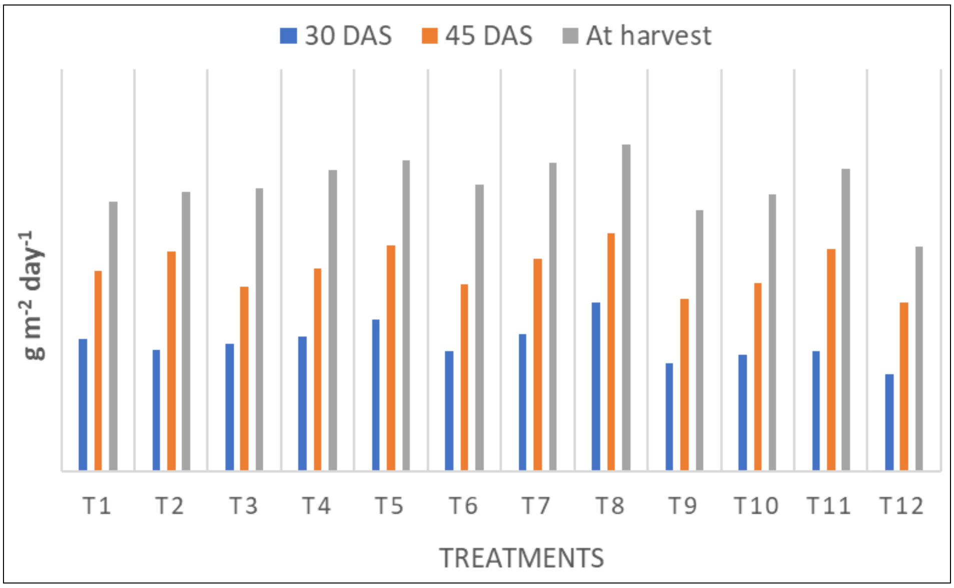

Fig 1: Effect of HA, RDF and foliar treatment on CGR of fodder maize

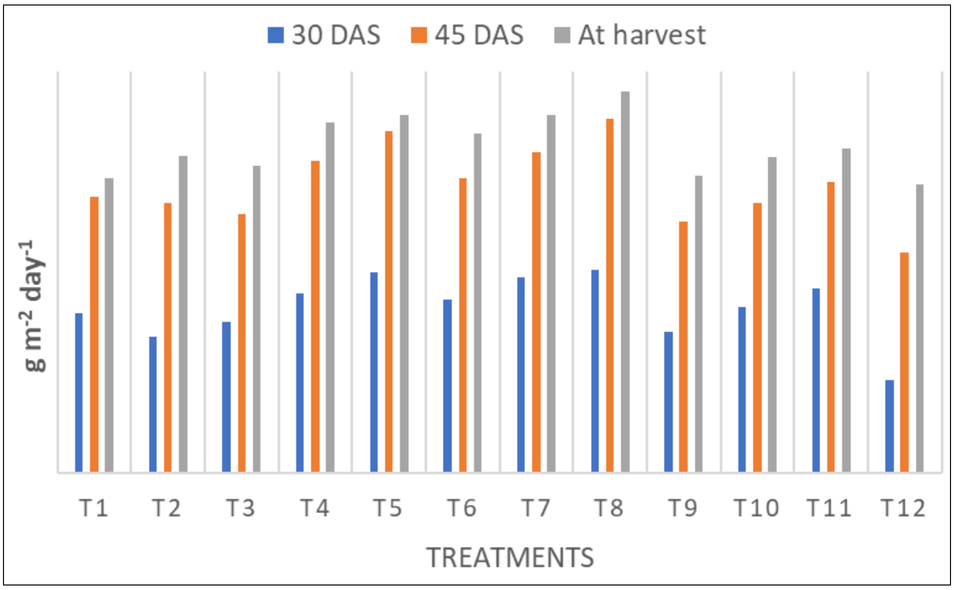

Fig 2: Effect of HA, RDF and foliar treatment on CGR of fodder cowpea

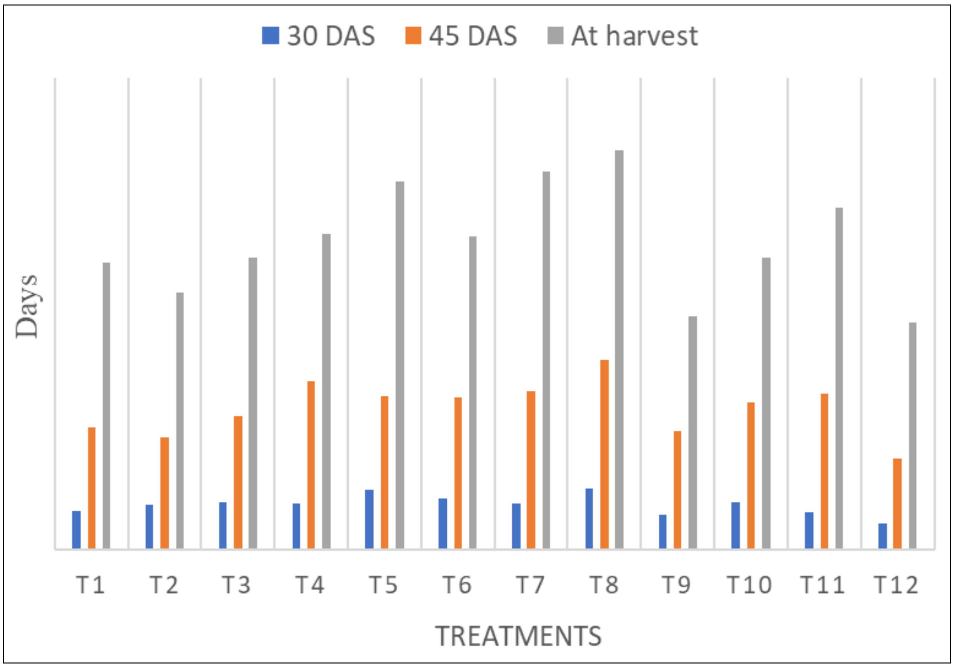

Fig 3: Effect of HA, RDF and foliar treatment on LAD of fodder maize

Table 1: Effect of humic acid, fertilizer levels and foliar treatments on fodder maize under intercropping with fodder cowpea

Treatments	Fodder maize												Fodder cowpea											
	AGR (g day^{-1} $plant^{-1}$)			RGR (mg g^{-1} day^{-1})			NAR (g cm^{-2} day^{-1})			Leaf area duration (days)			AGR (g day^{-1} $plant^{-1}$)			RGR (mg g^{-1} day^{-1})			NAR (g cm^{-2} day^{-1})			Leaf area duration (days)		
	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	At harvest	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	At harvest
T_1	0.44	0.67	0.90	37.46	32.92	27.22	8.11	6.45	6.05	112.2	360.9	852.8	0.36	0.62	0.66	34.45	32.14	28.38	43.22	35.04	18.47	33.30	121.50	334.40
T_2	0.41	0.74	0.94	36.21	33.77	27.46	7.60	8.63	6.39	132.0	331.2	763.8	0.31	0.61	0.71	32.13	31.91	28.96	40.52	29.24	16.84	29.70	145.80	404.25
T_3	0.43	0.62	0.95	36.91	32.09	27.55	6.90	5.69	5.83	141.0	395.1	864.5	0.34	0.58	0.69	33.62	31.50	28.71	33.37	29.76	15.54	42.30	135.90	427.35
T_4	0.45	0.68	1.01	37.78	33.05	27.96	7.69	5.22	5.87	136.8	500.0	937.3	0.40	0.70	0.79	36.09	33.28	29.74	35.38	27.21	15.70	48.30	186.75	490.05
T_5	0.51	0.76	1.04	39.49	34.06	28.17	6.69	6.21	5.20	174.6	455.9	1091.4	0.45	0.77	0.80	37.68	34.19	29.91	39.27	25.08	13.47	48.60	228.60	596.75
T_6	0.40	0.63	0.96	36.09	32.26	27.63	6.10	5.08	5.66	149.7	450.0	928.9	0.39	0.66	0.76	35.61	32.77	29.49	42.09	33.87	15.41	37.80	136.35	482.90
T_7	0.46	0.71	1.04	38.00	33.48	28.13	7.18	5.71	5.41	134.1	468.9	1123.2	0.44	0.72	0.80	37.35	33.58	29.90	39.65	24.20	13.59	46.80	221.40	590.70
T_8	0.57	0.80	1.10	41.01	34.58	28.52	7.04	5.69	4.60	179.7	563.4	1183.6	0.46	0.80	0.86	37.89	34.53	30.41	37.32	23.75	12.77	52.50	253.35	682.00
T_9	0.36	0.58	0.88	34.58	31.44	27.03	9.15	5.04	5.75	101.1	349.7	691.0	0.32	0.57	0.67	32.59	31.24	28.45	40.81	29.31	18.08	30.60	134.10	345.95
T_{10}	0.39	0.63	0.93	35.61	32.33	27.39	6.24	6.07	5.61	140.7	434.7	867.8	0.37	0.60	0.71	34.97	31.89	28.93	37.78	22.79	15.69	40.80	193.95	436.15
T_{11}	0.40	0.75	1.02	36.09	33.92	28.00	8.91	5.79	5.71	108.0	463.1	1013.4	0.41	0.70	0.73	36.45	33.27	29.15	37.45	21.60	13.46	46.50	243.00	535.70
T_{12}	0.33	0.57	0.76	33.04	31.26	26.02	9.23	7.78	6.16	76.5	268.7	674.1	0.21	0.49	0.65	26.64	29.93	28.20	34.20	29.67	27.29	23.10	112.95	207.90
S.Ed	0.01	0.01	0.02	0.71	0.77	0.58	0.16	0.13	0.08	3.27	9.20	19.49	0.01	0.06	0.01	0.74	0.73	0.53	0.78	0.63	0.39			
CD (p=0.05)	0.02	0.03	0.04	1.48	1.59	1.21	0.32	0.28	0.17	6.78	19.09	40.43	0.02	0.13	0.03	1.54	1.52	1.10	1.61	1.30	0.80			

4. Conclusion

The application of humic acid along with recommended doses of fertilizer and enriched farmyard manure positively influenced the growth and physiological attributes of fodder maize and cowpea in a paired row intercropping system. It is recommended to apply humic acid at a rate of 20 kg ha^{-1} along with 125% RDF and foliar application of 1.0% Urea + 0.5% $CaCl_2$ at 25 and 45 DAS (T_8) for improved agronomic growth rate, relative growth rate, and net assimilation rate at different stages of fodder crop growth in intercropping systems, as compared to control treatments (T_{12}).

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