EFFECT OF MACRONUTRIENTS AND HUMIC ACID IN FODDER BASED INTERCROPPING SYSTEM

P. DHAMODHARAN[1]*, M. RAGURAMAKRISHNAN[2], N. ARIVUKKUMAR[3], K. KIRUTHIKA[4] AND G. GUNALARASI[5]

[1,2&3]Department of Agronomy, AC&RI, TNAU, Coimbatore (Tamil Nadu), India
[4]Department of Agronomy, Vanavarayar Institute of Agriculture, Pollachi (Tamil Nadu), India
[5]Department of Agronomy, Dhanalakshmi Srinivasan University, Trichy (Tamil Nadu), India
(e-mail: dhambala199@gmail.com)

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SUMMARY

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 primary objective was to assess how varying doses of humic acid, in addition with the recommended fertilizer dose, affected the growth and physiological characteristics of African Tall fodder maize and CO 9 fodder cowpea under intercropping system. The study was structured by using randomized block design with 12 treatment combinations, each replicated three times. The study's results highlighted that applying 125% of the recommended fertilizer dose, supplemented with enriched farmyard manure at a rate of 750 kg/ha, and applying 20 kg/ha of humic acid with addition of foliar spray treatments comprising 1.0% Urea and 0.5% $CaCl_2$ (Treatment 8) were found to yield the highest plant height, number of leaves per plant, branches per plant, and increased dry matter production. Furthermore, this approach demonstrated superior physiological attributes, including agronomic growth rate, relative growth rate, and net assimilation rate at various crop growth stages. Notably, this treatment also exhibited the largest leaf area when compared to control treatments (Treatment 12).

Keywords: Humic acid, intercropping, fodder production, physiological traits

India, with approximately 17% of the world's total livestock population, thrives in diverse agro-climatic conditions. Livestock husbandry emerges as an economically viable livelihood, ensuring a steady stream of income throughout the year. Remarkably, nearly two-thirds of the overall expenses in livestock farming are allocated to feed. Currently, there exists a significant deficit in feed resources, with approximately 35.6% deficiency in green fodder, 10.95% in dry fodders and residues, and 44% in concentrate feed constituents (Ghosh *et al.,* 2016). The challenge is compounded by seasonal and regional scarcities, making it impractical to transport available fodder over long distances. Achieving higher livestock productivity hinges on providing high-quality feed, essential nutrition, and proper healthcare. To bolster fodder crop availability, strategies such as increasing productivity (Kumar *et al.,* 2012) and expanding cultivation areas through innovative approaches like multiple cropping, intercropping, and relay cropping (Kumar *et al.,* 2010), as well as supplying high-quality nutritional fodder (Singh *et al.,* 2010), are imperative. While the cultivation of fodder crops can be expanded, the escalating demand for agricultural land for food and cash crops is an ongoing concern. Thus, the focus is on augmenting feed availability and reducing production costs to enhance livestock farming.

Intercropping cereal fodder with fodder legumes has demonstrated the potential to enhance land use productivity and elevate fodder quality. The manipulation of crop spacing in intercropping has opened avenues for diverse intercropping patterns to bolster productivity (Kumar and Narmadha, 2018). Maize, a cereal crop utilized for both grain and fodder, proves adaptable to varying agro-climatic conditions. It is a voracious consumer of nutrients and particularly suited for fodder production due to its rapid growth, succulent nature, high palatability, and absence of anti-nutritional factors. Fodder cowpea, a short-duration crop, seamlessly integrates with maize in intercropping setups owing to its swift early-stage growth, palatability, impressive yield, and protein content. Legumes, through their symbiotic relationship with the bacterium *Rhizobium leguminosarum* (Acikgoz *et al.,* 2009), fix atmospheric nitrogen, thereby enhancing soil nutrient availability, which translates into increased yields for both the legumes and intercropped crops. Augmenting this, the incorporation of organic substances like enriched farmyard manure (FYM) and humic acid further elevates crop productivity by bolstering soil nutrient content and facilitating soil moisture conservation.

MATERIALS AND METHODS

A field experiment was conducted at the Agricultural College and Research Institute, Killikulam, Tamil Nadu during the summer season, from March to May 2021. The soil samples taken at the outset revealed a nearly neutral pH value of 7.3 and an electrical conductivity of 0.08 dSm^{-1}. Soil analysis indicated low status of available nitrogen (202 kg/ha), medium status of available phosphorus (14 kg/ha) and potassium (240 kg/ha), while the initial organic carbon content stood at 0.458. The experimental setup followed a randomized block design, replicated thrice, with intercrops comprising African Tall fodder maize and CO 9 fodder cowpea. The paired row system (2:2) was adopted with a spacing of 90/45 cm × 10 cm (additive series) to increase plant population.
The treatment details were as follows:

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 HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$
T_4: 100% RDF + Enriched FYM + 10 kg/ha HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$
T_5: 125% RDF + Enriched FYM + 10 kg/ha HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$
T_6: 75% RDF + Enriched FYM + 20 kg/ha HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$
T_7: 100% RDF + Enriched FYM + 20 kg/ha HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$
T_8: 125% RDF + Enriched FYM + 20 kg/ha 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 in conjunction with prepared enriched farmyard manure at a rate of 750 kg/ha. Different doses of nitrogen, phosphorus, and potassium fertilizers at 75%, 100%, and 125% of the recommended levels (60:40:20 kg/ha) were applied to the respective treatment plots. Nitrogen fertilizer was administered in two split doses, as a basal dose and at 30 days after sowing (DAS), to maximize fertilizer use efficiency. Foliar applications of 1.0% MAP, 1.0% urea, and 0.5% $CaCl_2$ were performed at 30 DAS and 45 DAS, respectively. Fodder cowpea and fodder maize were harvested at 55 DAS and 65 DAS, respectively, or at the time of 50% flowering stage. Biometric observations such as plant height, number of leaves and branches per plant, growth indices, and physiological parameters were recorded at 30 DAS, 45 DAS, and at the crop harvest stage.

RESULTS AND DISCUSSION

Physiological Attributes

Growth rates indicate the increase in a plant's dry weight (in grams) over a unit of time (t). Here, we examine the growth rates of fodder maize and fodder cowpea under various treatments.

For Fodder Maize : The rate of growth per unit dry matter, known as RGR, was notably higher in Treatment 8 (T8) at 30, 45 days after sowing (DAS), and the harvest stage, with values of 41.01, 34.58, and 28.52 mg g^{-1} day^{-1}, respectively. NAR (Net Assimilation Rate) exhibited differences at different crop stages, particularly at 30 DAS (control), 45 DAS, and the harvest stage (T2). The trend for AGR (Absolute Growth Rate) and CGR (Crop Growth Rate) showed an increase as the crop matured, with the highest growth rate observed in T8 at all crop stages.

For Fodder Cowpea : The rate of growth per unit dry matter, RGR, showed higher values at 30 DAS, 45 DAS, and the harvest stage, with rates of 37.89, 34.53, and 30.41 mg g^{-1} day^{-1}, respectively. Maximum NAR was attained at various crop stages, including 30 DAS, 45 DAS (T1), and the harvest stage (control).

It's worth noting that the growth rate increased more gradually as the crops matured. Increasing nitrogen levels had a direct impact on the AGR, regardless of the quantity of humic acid applied (Iqbal *et al.,* 2018; Motaghi and Nejad 2014). A higher

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/plant)			RGR (mg/g/day)			NAR ($g/cm^2/day$)			Leaf area duration (days)			AGR (g/day/plant)			RGR (mg/g/day)			NAR (g/cm^2 /day)			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
T7	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			
C. D. (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			

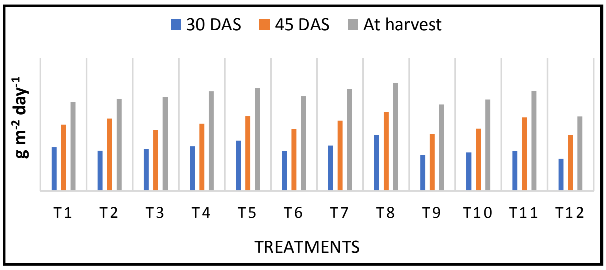

Fig. 1. Effect of HA, RDF and foliar treatment on CGR of fodder maize.

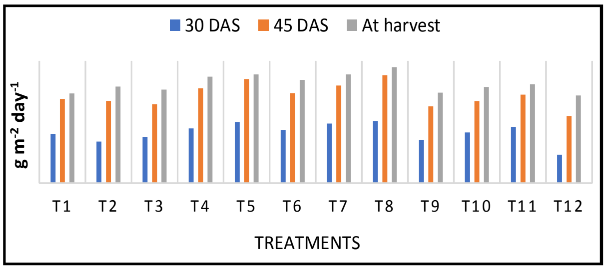

Fig. 2. Effect of HA, RDF and foliar treatment on CGR of fodder cowpea.

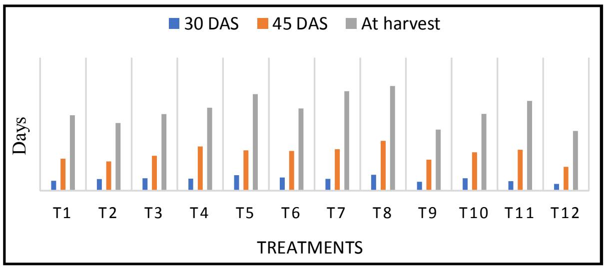

Fig. 3. Effect of HA, RDF and foliar treatment on LAD of fodder maize.

CGR value indicated greater dry matter accumulation per unit area, influenced by nutrient uptake and the intercropping system (Ram and Singh 2003). The rate of CGR increased during the early stages and declined towards maturity due to factors such as the cessation of vegetative growth, leaf loss, and senescence (Daur and Bakhashwain 2013; Atarzadeh *et al*., 2013). Generally, CGR depends on the canopy area available for photosynthetic activity. The leaf area per plant determines the dry matter accumulation per unit area, and the rate of assimilation decreases as the crop matures. Lower RGR values were obtained due to increased metabolically active tissue and the influence of NAR, as reported by Motaghi and Nejad (2014).

Leaf Area Duration (Days)

For Fodder Maize : The leaf area duration, assessed at various crop growth stages (30 DAS, 45 DAS, and harvest), was significantly influenced by the levels of humic acid, different nutrient rates, and foliar applications in the intercropping system with fodder cowpea. At 30 DAS, the highest leaf area duration (179.7 days) was observed in Treatment 8 (T8), where 125% RDF, enriched FYM, 20 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$ were applied. This was statistically similar to Treatment 5 (125% RDF, enriched FYM, 10 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$), which recorded 174.6 days. The lowest leaf area duration was noted in the absolute control (T_{12}) at 76.5 days. At 45 DAS, Treatment 8 again recorded the maximum leaf area duration (563.4 days), while the absolute control (T_{12}) had the minimum (268.7 days). At harvest, the highest leaf area duration (1330.6 days) was significantly observed in Treatment 8, followed by Treatment 7 (100% RDF, enriched FYM, 20 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$) with 1123.2 days. The lowest leaf area duration at harvest was in the absolute control (T_{12}) at 674.1 days.

For Fodder Cowpea : At 30 DAS, the highest leaf area duration (52.50 days) was significantly observed in Treatment 8 (125% RDF, enriched FYM, 20 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$), followed by Treatment 4 (100% RDF, enriched FYM, 10 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$) and Treatment 5 (125% RDF, enriched FYM, 10 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$), recording 48.30 and 48.60 days, respectively. The lowest leaf area duration at 30 DAS was in the absolute control (T_{12}) at 23.10 days. At 45 DAS, Treatment 8 had the highest leaf area duration (253.35 days), followed by 125% RDF (243 days), while the absolute control (T_{12}) had the minimum (112.95 days). At harvest, the maximum leaf area duration (682 days) was significantly observed in Treatment 8, followed by Treatment 5 (125% RDF, enriched FYM, 10 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$) with 596.75 days, which was similar to Treatment 7 (100% RDF, enriched FYM, 20 kg HA, and Foliar 1.0% Urea + 0.5% $CaCl_2$) at 590.7 days. The lowest leaf area duration at harvest was in the absolute control (T_{12}) at 207.90 days.

The leaf area duration of both fodder maize and cowpea in the intercropping system with paired row planting was positively influenced by the application of humic acid with enriched farmyard manure, fertilizer levels, and foliar treatments. The highest leaf area duration was consistently observed in Treatment 8 (125% RDF, enriched FYM, 20 kg ha^{-1} HA, and foliar spray of 1.0% Urea + 0.5% $CaCl_2$).

Leaf area duration is directly related to the leaf area index and the duration of growth, and higher values indicate increased biomass production of both fodder maize and cowpea (Motaghi and Nejad 2014; Ravi *et al.,* 2012; Sibhatu *et al.,* 2015).

CONCLUSION

The application of humic acid in conjunction with the recommended dose of fertilizer and enriched farmyard manure has had a discernible impact on the growth characteristics, leaf attributes, and physiological traits of both fodder maize and fodder cowpea when cultivated in a paired row system of intercropping. Based on the results of this study, it is recommended that the application of humic acid at a rate of 20 kg/ha, coupled with 125% of the recommended dose of fertilizer and foliar application of 1.0% Urea + 0.5% $CaCl_2$ at 25 and 45 days after sowing (T_8), led to significant improvements in agronomic growth rate, relative growth rate, and net assimilation rate at various stages of fodder crop growth. These positive outcomes were particularly notable when compared to the control treatments (T_{12}). This research highlights the potential benefits of incorporating humic acid into farming practices to enhance the productivity and quality of intercropped fodder maize and fodder cowpea. These findings offer valuable insights for optimizing agricultural strategies and improving fodder production in paired row intercropping systems.

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