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The macronutrient and humic acid connection: Boosting growth in cereal-pulse intercropping

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Abstract
The research study detailing the effect of recommended dose of fertilizers supplied along with humic acid at varied levels on the growth of fodder maize (African Tall) and fodder cowpea (CO 9) based intercropping was carried out at Agricultural College and Research Institute, Killikulam during summer season (March- May) of 2021. The experiments contains 12 treatment combinations laid down with Randomized Block Design (RBD) having three replications. Experimental results concluded that the application of 125% RDF along with enriched farmyard manure and humic acid @ 20 kg ha^{-1} and foliar spray of 1.0% Urea + 0.5% $CaCl_2$ (T_8) under fodder maize and fodder cowpea intercropping recorded more plant height (237.4 & 181.4 cm), number of leaves per plant in fodder maize (16.3), branches per plant in fodder cowpea (23.3), dry matter production (71.4 & 47.06 g/plant) at harvest stage which was followed by application of 100% RDF along with enriched FYM and HA @ 20 kg ha^{-1} and foliar spray of 1.0% Urea + 0.5% $CaCl_2$ (T_7) when compared with control treatments (T_{12}).

Keywords: Humic acid, fodder maize, fodder cowpea, intercropping, NPK, macronutrients, growth

Introduction
Globally, forage grasslands are generally preferred for feeding livestock and accounted for approximately 26% of land area, and 70% of agricultural area (FAO, 2010) [11]. Generally, forage crops can be fed directly to cattle either by partial drying or pre-digestion processing. Livestock feed supplement can be classed as bulky feeds or concentrates. Feed which consumed in larger proportion is generally called as Bulky feeds, also known as fodder, are made available from the crops of grasses, cereals, and legumes. Livestock can be fed with bulky feeds either directly by grazing on pasture land or indirectly through processed forms such as hay or dry (pelleted) biomass. Whereas concentrates are feed supplements given in small amounts with rich nutrient contents mostly byproducts of processed cereals, oilseeds, and legume seeds, enriched agricultural molasses and animal byproducts.
The ability to generate significant annual cash revenue makes livestock management, the most feasible and lucrative occupation. Feed makes up about two-thirds of the overall expense of raising animals. According to Ghosh *et al*. (2016) [12], the current feed deficiency is approximately 35.6% for green fodder, 10.95% for dry fodders and residues, and 44% for concentrate feed ingredients. Due to the difficulty of moving available fodder over vast distances, seasonal and regional scarcities are regarded as being more significant. By providing high-quality feed, necessary nutrients, and correct medical care, cattle can be kept healthier and more productive.
The quality of the fodder was improved and the productivity of the land was boosted when fodder legumes were intercropped with cereal fodder. The diverse intercropping patterns were made possible by the adjusted crop spacing of intercrops (Kumar and Narmadha 2018) [17]. Maize is a cereal crop that can adapt to various agro climatic conditions and is mostly used for grain and feed. Due to its rapid growth, crop duration, succulent quality, and greater palatability without any antinutritional components, it consumes more nutrients than any other crop and is better suited for the production of fodder. *Rhizobium leguminasorum*, a bacterium, helps legumes fix more atmospheric nitrogen through their root nodules, increasing their production and intercrop yield. By making more nutrients available in the soil and helping to maintain soil moisture, the addition of organic materials like enriched farm yard manure (FYM) and humic acid (HA) increased crop output. (Albayrak and Camas, 2005; Akman, 2004) [3, 2]
Therefore, a forage-based diet for livestock is an option, as is a forage diet supplemented with concentrate. Concentrate feed supplements is used to compensate the nutritional deficiencies

and shortages in the forage supply, improve livestock performance, or during particularly at sensitive stages, like calving. Since forage is used for feeding almost all the livestock, this review won't cover concentrates and will instead concentrate on the most often utilized crops (Erb *et al*., 2012) [10]. To provide dietary and environmental advantages, forage crops can be cultivated by growing different fodders under mixed farming. Nutritional quality can be enhanced by providing livestock feed with various mixtures of fodder or their combinations. Consider alfalfa can be grown as sole crop planted alone or intercropped with various grass species, as it has the potential legume produces maximum yield and has productivity of more protein per unit area than any other forage legumes. The need of the hour is to increase the supply of fodder crops through increasing their productivity, substantial increase in the total cultivable area and adopting various technologies like multi-cropping, intercropping, intensive cropping and relay cropping, or by providing high-quality nutritional fodder (Singh *et al*., 2010) [21].

2. Materials and Methods

Experimental site and treatment details

The experimental trial was carried out at Agricultural College and Research Institute, Killikulam during summer season (March – May, 2021). The initial pH value and electrical conductivity analyzed from the soil samples was found to be 7.3 (nearly neutral) and 0.08 dSm^{-1} respectively. The soil N, P and K availability was analyzed and found to be lower in Soil N (202 kg ha^{-1}), medium range in Soil P (14 kg ha^{-1}) and medium range in Soil P (240 kg ha^{-1}) respectively and the initial organic carbon content was 0.458. The experiment followed Randomized Block Design (RBD) with three replications. Intercrops of fodder maize (African tall) and fodder cowpea (CO 9) were cultivated under paired row system (2:2) with altered spacing dimension of 90/45 x 10 cm (additive series). The treatment details were T_1 – 100% RDF + Foliar spraying of 1.0% MAP + 0.5% $CaCl_2$; T_2 - 100% RDF + Enriched FYM + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_3 - 75% RDF + Enriched FYM + HA @ 10 kg ha^{-1} + Foliar spray of 1.0% Urea + 0.5% $CaCl_2$; T_4 - 100% RDF + Enriched FYM + HA @ 10 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_5 - 125% RDF + Enriched FYM + HA @ 10 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_6 - 75% RDF + Enriched FYM + HA @ 20 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_7 - 100% RDF + Enriched FYM + HA @ 20 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_8 - 125% RDF + Enriched FYM + HA @ 20 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_9 - 75% RDF; T_{10} - 100% RDF; T_{11}- 125% RDF; T_{12}- absolute control. Soil incorporation of humic acid as per treatment schedule and prepared enriched farmyard manure (750 kg ha^{-1}) was applied before sowing. Different doses such as 75%, 100%, and 125% of NPK fertilizers from recommended levels (60:40:20 kg ha^{-1}) was applied to the treatment plots. Half the dose of N and full dose of P and K were applied as basal dose and remaining dose of N given at 30 DAS. Foliar spraying of 1.0% MAP, 1.0% urea, 0.5% $CaCl_2$ were applied on 30 and 45 DAS respectively. Fodder cowpea harvested at 55 DAS whereas fodder maize harvested at 65 DAS or at the time of 50% flowering stage of both crops. The biometric plant observations were recorded at 30 DAS, 45 DAS and at harvest stage of crops respectively.

The leaf area index (LAI) was calculated by dividing the apparent leaf area to the recommended spacing of the crops.

$$LAI = \frac{\text{Apparent leaf area (cm}^2\text{)}}{\text{Spacing (cm}^2\text{)}}$$

Leaf: stem ratio was calculated by diving the corresponding weights of leaf and stem obtained from each plant of the treatments.

$$L: S = \frac{\text{Leaf weight (g)}}{\text{Stem weight (g)}}$$

3. Results and Discussion

Growth parameters

The non-destructive observations of plant growth parameters include plant height, total number of leaves and total dry matter production (DMP) of the fodder maize under intercropping with fodder cowpea was measured at 30, 45 DAS and harvesting of crop respectively. The maximum plant height at 30 DAS (80.8 cm), 45 DAS (175.5 cm) and at harvest stages (237.4 cm) were observed by the application of 125% RDF along with enriched FYM and humic acid @ 20 kg ha^{-1} which was incorporated in the soil before sowing and foliar treatment of 1.0% Urea + 0.5% $CaCl_2$ (T_8) and the minimum height was observed in control treatments (T_{12}) at all stages of crop. The plant height has increased with the crop duration and with the response of fertilizer application. Similarly, the average number of green leaves per plant was found to be higher in T_8 at 30 DAS (7.2), 45 DAS (10.3) and harvest stage (16.3) of maize crop. This also leads to increase in the total dry matter production per plant and the maximum DMP at 30 DAS (17.0 g), 45 DAS (36.0 g) and harvest stage (71.4 g) also was produced in T_8 when compared with other treatments.

In case of fodder cowpea, growth parameters were measured on 30, 45 DAS and harvesting of crop respectively. The maximum plant height at 30 DAS (58.9 cm), 45 DAS (100.2 cm) and at harvest stages (181.4 cm) were observed by the application of 125% RDF along with enriched FYM and HA @ 20 kg ha^{-1} and foliar treatment of 1.0% Urea + 0.5% $CaCl_2$ (T_8) and the average number of branches per plant was found to be higher in T_8 at 30 DAS (6.5), 45 DAS (14.33) and harvest stage (23.3) of fodder cowpea. The maximum dry matter production per plant was obtained at 30 DAS (13.7g), 45 DAS (35.8g) and harvest stage (47.06g) by the application of 125% RDF along with enriched FYM and HA @ 20 kg ha^{-1} and foliar spray of 1.0% Urea + 0.5% $CaCl_2$ (T_8).

The obtained results concluded that increasing the nitrogen levels had significantly increased the vegetative growth of crop and also increased the internode length which led to an increase in the plant height (Aman and Rab, 2013) [4]. Chen (2004) [7] stated that nitrogen is the main component of chlorophyll and other enzymes responsible for the metabolic process involved in vegetative growth which directly involved in the active cell division and cell elongation process. Humic acid is a bio-stimulant that contains PGR's which directly influenced vegetative growth by increasing the number of green leaves and branches when applied with increasing levels of nitrogen. Humic acid also increased the absorption of nitrogen in the soil by plants and increasing its efficiency.

Intercropping of maize with legumes generally increased the uptake of nitrogen from soil by fixing the atmospheric nitrogen through root nodules (Prasanthi and Venkateswaralu 2014) [19], which also improves the growth of fodder crops. Maximum plant height and more number of leaves per plant also increased the dry matter accumulation due to humic acid application along with N fertilization (Motaghi and Nejad 2014; Sharif *et al.,* 2002) [18, 22].

Leaf parameters

In fodder maize, application of 125% RDF along with enriched FYM and humic acid @ 20 kg ha^{-1} and foliar treatment of 1.0% Urea + 0.5% $CaCl_2$ (T_8) has considerably influenced the leaf length and breadth, thereby increasing the leaf area index at different stages 5.99 (30 DAS), 12.52 (45 DAS), 18.47 (harvest stage). Leaf to stem ratio is very important for green fodder for cattle consumption. In this experiment, fodder maize had decreased the leaf : stem ratio was observed due to the increased stem weight and crop maturity. The maximum leaf : stem ratio (0.70) was produced by the application of 100% RDF (T_{10}) which was on par treatment T_8 imposing the application of 125% RDF along with enriched FYM and humic acid @ 20 kg ha^{-1} and foliar treatment of 1.0% Urea + 0.5% $CaCl_2$ (T_8).

In the case of fodder cowpea, application of 125% RDF along with enriched FYM and humic acid @ 20 kg ha^{-1} and foliar treatment of 1.0% Urea + 0.5% $CaCl_2$ (T_8) also considerably influenced the leaf length and breadth, thereby increasing the leaf area index at different stages 1.75 (30 DAS), 5.63 (45 DAS), 12.40 (harvest stage). The maximum leaf to stem ratio (1.38) was recorded by the application of 125% RDF along with enriched FYM and humic acid @ 20 kg/ha and foliar treatment of 1.0% Urea + 0.5% $CaCl_2$ (T_8) during harvest.

The increased leaf area index at closer spacing was due to the production of the number of leaves per unit area which consequently increased the biomass production (Sibhatu *et al.,* 2015) [23]. In paired row system, the higher density planting increased the photosynthetic efficiency with the increase in the number of leaves per unit area (Javanmard *et al.,* 2009) [14]. The combined application of humic acid with nitrogen enhanced the cell division which increased the length, width and number of leaves (Kumar and Narmadha 2018; Iqbal *et al.*, 2006) [17, 13]. The rate of LAI decreased at the harvest stage because of the loss of leaves by senescence. Higher LAI also directly influenced dry matter production. The findings of Atarzadeh *et al*., (2013) [5] revealed that application of humic acid increased the leaf area index of cowpea. Leaf to stem ratio is very important for green fodder for cattle consumption and in case of fodder maize, the decrement in the leaf to stem ratio was observed due to the increased stem weight and crop maturity. Higher the leaf to stem ratio, more will be the feed use efficiency. The higher ratio indicates that the green foliage yield of the crop and decreases with the crop maturity (Ram and Singh 2003). It is concluded that by increasing the optimum dose of nitrogen level led to accumulation in the stem and increased the stem weight at the harvest stage (Kumar *et al.*, 2016) [15].

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

Treatments	Plant height (cm)			Number of leaves			DMP (g plant^{-1})			Leaf Area Index			Leaf: Stem ratio		
	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	65 DAS	30 DAS	45 DAS	65 DAS
T_1	70.6	148.4	195.3	6.5	8.2	11.2	13.3	30.3	58.8	3.74	8.02	13.12	1.39	1.12	0.44
T_2	70.3	152.4	205.4	6.6	8.9	11.7	12.2	33.1	60.9	4.40	7.36	11.75	1.34	1.37	0.46
T_3	70.5	158.7	210.8	6.5	8.7	12.3	12.8	27.8	61.8	4.70	8.78	13.30	1.23	0.96	0.43
T_4	75.1	164.1	218.0	6.8	9.2	13.8	13.6	30.7	65.7	4.56	11.11	14.42	1.35	1.05	0.48
T_5	78.3	167.5	225.2	7.0	9.5	14.7	15.3	34.1	67.8	5.82	10.13	16.79	1.42	1.15	0.50
T_6	72.2	160.5	212.3	7.0	9.7	13.0	12.1	28.3	62.5	4.99	10.00	14.29	1.26	0.85	0.50
T_7	75.5	168.7	228.4	7.1	10.1	15.0	13.8	32.1	67.4	4.47	10.42	17.28	1.38	0.90	0.55
T_8	80.8	175.5	237.4	7.2	10.3	16.3	17.0	36.0	71.4	5.99	12.52	18.47	1.43	0.95	0.68
T_9	69.4	146.3	182.1	6.4	8.4	10.3	10.9	26.0	57.1	3.37	7.77	10.63	1.12	0.85	0.65
T_{10}	75.3	159.8	192.8	6.8	8.8	12.2	11.7	28.5	60.3	4.69	9.66	13.35	1.22	0.93	0.70
T_{11}	78.5	164.3	208.8	7.0	9.3	13.0	12.1	33.6	66.1	3.60	10.29	15.59	1.36	0.98	0.46
T_{12}	66.3	121.8	165.2	5.2	7.4	9.7	9.8	25.5	49.1	2.55	5.97	10.37	1.07	0.95	0.57
SEd	1.41	2.61	4.21	0.13	0.21	0.31	0.32	0.54	1.22	0.11	0.16	0.31	0.02	0.02	0.01
CD (p=0.05)	2.93	5.41	8.75	0.27	0.44	0.64	0.66	1.12	2.54	0.24	0.32	0.65	0.05	0.04	0.03

(T_1 – 100% RDF + Foliar spraying of 1.0% MAP + 0.5% $CaCl_2$; T_2 - 100% RDF + Enriched FYM + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_3 - 75% RDF + Enriched FYM + HA @ 10 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_4 - 100% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_5 - 125% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_6 - 75% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_7 - 100% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_8 - 125% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_9 - 75% RDF; T_{10} - 100% RDF; T_{11}- 125% RDF; T_{12}- absolute control.)

Table 2: Effect of humic acid, fertilizer levels and foliar treatments on fodder cowpea under intercropping with fodder maize

Treatments	Plant height (cm)			Number of branches/plant			DMP (g plant-1)			LAI			Leaf: Stem ratio		
	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	55 DAS	30 DAS	45 DAS	55 DAS
T_1	42.9	81.0	100.8	4.8	8.8	14.0	10.8	27.95	36.39	1.11	2.70	6.08	1.26	1.33	1.07
T_2	36.8	88.7	108.4	4.9	9.4	16.8	9.2	27.29	39.16	0.99	3.24	7.35	1.22	1.71	1.06
T_3	43.40	90.6	110.2	5.1	9.5	18.3	10.2	26.14	37.95	1.41	3.02	7.77	0.81	1.13	1.09
T_4	47.9	96.9	132.6	5.5	10.2	20.3	12.1	31.46	43.23	1.61	4.15	8.91	0.92	1.25	1.09
T_5	45.1	98.9	167.3	6.0	11.8	22.0	13.5	34.56	44.14	1.62	5.08	10.85	0.97	1.30	1.14
T_6	38.2	92.4	114.4	5.8	10.7	19.7	11.7	29.83	41.89	1.26	3.03	8.78	0.86	1.35	1.08
T_7	45.9	97.3	152.6	6.0	12.1	21.7	13.2	32.43	44.11	1.56	4.92	10.74	1.01	1.42	1.25
T_8	58.9	100.2	181.4	6.5	14.3	23.3	13.7	35.8	47.06	1.75	5.63	12.40	1.11	1.50	1.38
T_9	38.4	77.6	92.8	5.2	9.4	15.7	9.5	25.45	36.70	1.02	2.98	6.29	1.03	1.05	0.98
T_{10}	40.5	85.6	107.9	5.4	10.8	18.3	11.2	27.22	39.02	1.36	4.31	7.93	1.14	1.08	1.06
T_{11}	43.7	95.2	127.1	5.8	12.3	20.3	12.4	31.40	40.09	1.55	5.40	9.74	1.20	1.10	1.14
T_{12}	34.6	60.6	71.6	4.0	8.4	12.0	6.3	22.23	35.56	0.77	2.51	3.78	0.83	1.28	0.83
SEd	0.99	1.89	2.51	0.12	0.22	0.34	0.22	0.54	0.83	0.018	0.09	0.19	0.02	0.02	0.02
CD (p=0.05)	2.06	3.92	5.20	0.26	0.45	0.70	0.46	1.12	1.73	0.04	0.18	0.40	0.05	0.05	0.05

(T_1 – 100% RDF + Foliar spraying of 1.0% MAP + 0.5% $CaCl_2$; T_2 - 100% RDF + Enriched FYM + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_3 - 75% RDF + Enriched FYM + HA @ 10 kg ha^{-1} + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_4 - 100% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_5 - 125% RDF + Enriched FYM + 10 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_6 - 75% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_7 - 100% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_8 - 125% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar spraying of 1.0% Urea + 0.5% $CaCl_2$; T_9 - 75% RDF; T_{10} - 100% RDF; T_{11}- 125% RDF; T_{12}- absolute control.)

T8 - Application 125% RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% CaCl2

T_{12} - Absolute control treatment

Conclusion

The benefit of intercropping of fodder maize with fodder cowpea increased the productivity with increased plant population under paired row method was influenced by the application of humic acid, as well as the increased fertilizer level and enriched farmyard manure. According to the results of the aforementioned study, it is advised to apply soil incorporation of humic acid at a rate of 20 kg ha^{-1} along with 125% RDF and foliar application of 1.0% urea + 0.5% $CaCl_2$ (T_8) to increase the plant height (237 cm & 181 cm), number of leaves (16) and branches (23), dry matter production (71 & 47 g/plant), leaf area index (18 & 12), and leaf: stem ratio (0.68 & 1.38) of fodder maize and fodder cowpea respectively.

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