RESEARCH ARTICLE

The Macronutrient and Humic Acid Connection: Boosting Growth in Cereal-Pulse Intercropping

P. Dhamodharan[1*], V. M. Sankaran[2], D. Rajakumar[3], S. Somasundaram[4]

[1*]Department of Agronomy, AC&RI, TNAU, Killikulam-628252
[2]Department of Agronomy, Madras Veterinary College, Chennai
[3]Department of Agronomy, HRS, Pechiparai
[4]Cotton Research Station, Veppanthattai

Received: 17 Apr 2024
Revised: 30 Apr 2024
Accepted: 15 May 2024

ABSTRACT

The research study detailing the effect of the 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 contain 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, Macronutrients, Growth*

INTRODUCTION

Globally, forage grasslands are commonly chosen for livestock feed, constituting around 26% of land area and 70% of agricultural space (FAO, 2010). Forage crops can be directly fed to cattle through partial drying or pre-digestion processing. Bulky feeds, also known as fodder derived from grasses, cereals, and legumes, constitute the feed consumed in larger proportions and are accessible through grazing or processed forms like hay or dry biomass. On the other hand, concentrates are nutrient-rich supplements given in smaller amounts, typically byproducts of processed cereals, oilseeds, legume seeds, agricultural molasses, and animal byproducts.

Livestock management proves to be a feasible and lucrative occupation, generating a significant annual cash revenue. Feed accounts for approximately two-thirds of the overall expense of raising animals. According to Ghosh *et al*. (2016), the current feed deficiency is approximately 35.6% for green fodder, 10.95% for dry fodders and residues, and 44% for concentrate feed ingredients. Challenges arise from the difficulty of transporting fodder over long distances, contributing to seasonal and regional scarcities. Ensuring high-quality feed, essential nutrients, and proper medical care can keep cattle healthier and more productive.

Intercropping fodder legumes with cereal fodder improves fodder quality and boosts land productivity. Maize, being a versatile cereal crop, adapts to various agroclimatic conditions and is widely used for grain and feed due to its rapid growth, crop duration, succulent quality, and palatability. *Rhizobium leguminasorum*, a bacterium, aids legumes in fixing atmospheric nitrogen, enhancing production and intercrop yield. Incorporating organic materials like enriched farmyard manure (FYM) and humic acid (HA) further increases crop output (Albayrak and Camas, 2005; Akman, 2004).

111|4-6|22

*Corresponding author's e-mail: dhambala199@gmail.com

Therefore, a forage-based diet for livestock, either alone or supplemented with concentrate, is a viable option. Concentrate feed supplements address nutritional deficiencies, improve livestock performance, and are crucial during sensitive stages, such as calving. Given that forage is used for almost all livestock, this review focuses on forages, not concentrates (Erb *et al.,* 2012). Cultivating various forages under mixed farming offers dietary and environmental advantages. Nutritional quality can be enhanced by providing livestock with different fodder mixtures. For instance, growing alfalfa as a sole crop or intercropping it with various grass species can maximize yield and protein productivity per unit area compared to other forage legumes. To meet the increasing demand for fodder crops, efforts should focus on increasing productivity, expanding cultivable areas, and adopting various technologies like multi-cropping, intercropping, intensive cropping, and relay cropping (Kumar *et al.,* 2010). Providing high-quality nutritional fodder is also crucial (Singh *et al*., 2010).

MATERIAL AND METHODS

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 were 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 a paired row system (2:2) with an 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 the 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), were applied to the treatment plots. Half the dose of N and the full dose of P and K were applied as basal doses, and the remaining dose of N, the full dose of P and K, were applied as basal doses, and the remaining dose of N was given at 30 DAS. Foliar spraying of 1.0% MAP, 1.0% urea, and 0.5% CaCl2 were applied on 30 and 45 DAS, respectively. Fodder cowpea was harvested at 55 DAS, whereas fodder maize was 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.

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

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

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

Statistical Analysis

Statistical Analysis Data were statistically analysed following the procedure given by Gomez and Gomez (2010). Data pertaining to weeds were transformed to square root scale whenever significant variation existed, critical difference was assembled at a five per cent probability level. Such of those treatments where the difference is not significant are denoted as NS.

RESULTS AND DISCUSSION

Growth parameters

The non-destructive observations of plant growth parameters include plant height, the total number of leaves, and total dry matter production (DMP) of the fodder maize under intercropping with fodder cowpea were 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 an 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). Chen (2004) 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 (Ayub *et al.,* 2009). 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), which also improves the growth of fodder crops. Maximum plant height and the 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).

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).

T8 - Application 125 % RDF + Enriched FYM + 20 kg ha^{-1} HA + Foliar application of 1.0% Urea + 0.5% $CaCl_2$

T12 - Absolute control treatment

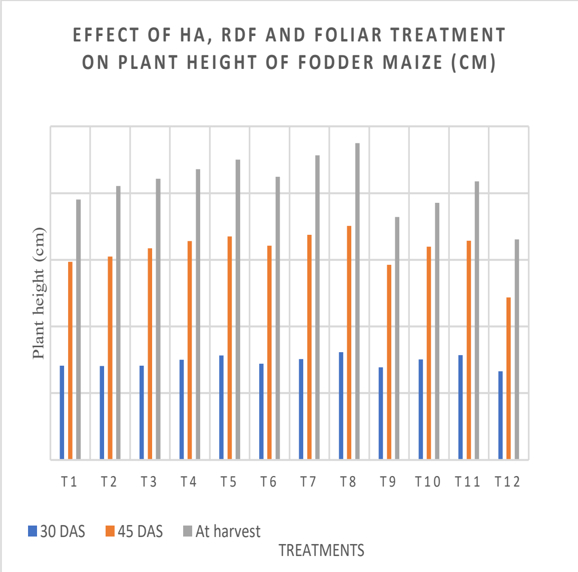

Fig . 1. Effect of HA, RDF and foliar treatment on Plant height of fodder maize (cm)

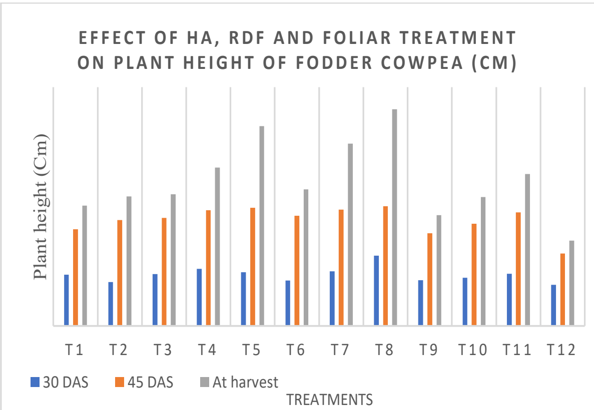

Fig. 2. Effect of HA, RDF and foliar treatment on Plant height of fodder cowpea (cm)

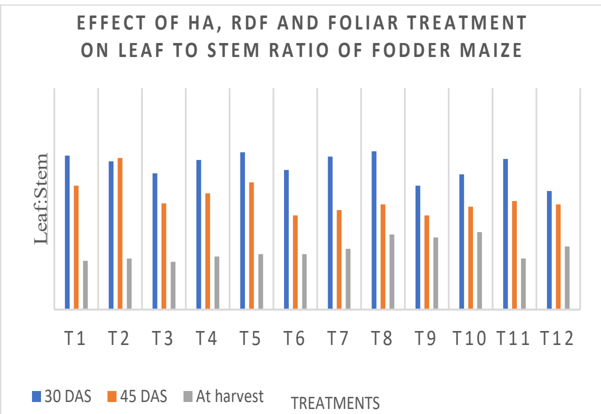

Fig. 3. Effect of HA, RDF and foliar treatment on Leaf to Stem ratio of fodder maize

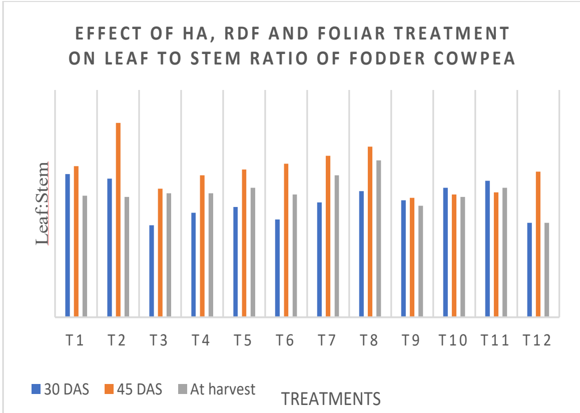

Fig. 4. Effect of HA, RDF and foliar treatment on Leaf to Stem ratio of fodder cowpea

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). In the 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; Darapuneni *et al.,* 2018). The combined application of humic acid with nitrogen enhanced the cell division which increased the length, width and number of leaves (Dhamodharan *et al*., 2023; Iqbal *et al.,* 2006). 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 (Darapuneni, 2018). The findings of Atarzadeh *et al.,* (2013) 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 (Darapuneni, 2018; Kumar *et al.,* 2016; Jadav *et al.,* 2018).

CONCLUSION

The benefit of intercropping fodder maize with fodder cowpea increased productivity with increased plant population under paired row method and 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.

Funding and Acknowledgment

No funding

Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Originality and plagiarism

We ensure that we have written and submitted only entirely original works, and if we have used the work

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.)

and/or words of others, that has been appropriately cited.

Consent for publication

All the authors agreed to publish the content.

Competing interests

There were no conflict of interest in the publication of this content

Data availability

All the data of this manuscript are included in the MS.

REFERENCES

Acikgoz, E, Mehmet Sincik, A Karasu, O Tongel, G Wietgrefe, Uğur Bilgili, Mehmet Oz, S Albayrak, Zm Turan, and At Goksoy. Forage soybean production for seed in mediterranean environments. *Field Crops Research* 2009; **110 (3):**213-218. https://doi.org/10.1016/j.fcr.2008.08.006

Akman, Zekeriya. 2004. “Effects of humic acid-added foliar fertilizer on ear yield and agronomic characters of sweet corn (Zea mays saccharata).” *Indian journal of agricultural science* **74 (1):**38-39. DOI: 10.9734/JALSI/2020/v23i1130196

Albayrak, Sebahattin, and Necdet Camas. 2005. “Effects of different levels and application times of humic acid on root and leaf yield and yield components of forage turnip (Brassica rapa L.).” *Journal of Agronomy*. DOI: 10.3923/ja.2005.130.133

Aman, Sher, and Abdur Rab. 2013. “Response of tomato to nitrogen levels with or without humic acid.” *Sarhad Journal of Agriculture* **29 (2):**181-186.

https://link.gale.com/apps/doc/A336158939/AONE?u=anon~a6d86a2c&sid=googleScholar&xid=a8b51d09

Atarzadeh, Sh, M Mojaddam, and T Saki Nejad. 2013. "The interactive effects humic acid application and several of nitrogen fertilizer on remobilization star wheat." *International Journal of Biosciences* **3 (8):**116-123. doi: http://dx.doi.org/10.12692/ijb/3.8.115-123

Ayub, M, Ma Choudhry, A Tanveer, and B Ahmad. Effect of different levels of nitrogen and seeding density on growth, yield and quality of maize fodder. *Andhra Agricultural Journal (India)* 2001. https://epubs.icar.org.in/index.php/IJAgS/article/view/41122

Chen, Y, Ce Clapp, and H Magen. 2004. "Mechanisms of plant growth stimulation by humic substances: The role of organo-iron complexes." *Soil Science and Plant Nutrition* **50 (7):**1089-1095. https://doi.org/10.1080/00380768.2004.10408579

Dhamodharan, P., M. Raguramakrishnan, and N. Arivukkumar. "Humic Acid as Combined with Different Levels of NPK Fertilizer and Farmyard Manure to Enhance a Fodder Maize-Cowpea Intercropping System." Journal of Experimental Agriculture International 45, no. 11 (2023): 1-8. DOI: 10.9734/jeai/2023/v45i112229

Eyheraguibel, Boris, Jérôme Silvestre, and Philippe Morard. 2008. "Effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of maize." *Bioresource technology* **99 (10):**4206-4212. http://dx.doi.org/10.1016/j.biortech.2007.08.082

Erb, Karl-Heinz, Andreas Mayer, Thomas Kastner, Kristine-Elena Sallet, and Helmut Haberl. "The impact of industrial grain fed livestock production on food security: an extended literature review." Alpen Adria University Klagenfurt-Vienna-Graz, Austria.(Retrieved 19 June 2013 from http://goo.gl/6smPcP) (2012).

FAO (2010). Challenges and Opportunities for Carbon Sequestration in Grassland Systems: A Technical Report on Grassland Management and Climate Mitigation. (Rome: Food and Agriculture Organization of the United Nations).

Ghosh, Pk, Dr Palsaniya, and R Srinivasan. Forage research in India: Issues and strategies. *Agricultural Research Journal* 2016; **53 (1):**1-12. DOI: 10.5958/2395-146X.2016.00001.6

Gomez K.A, Gomez A.A. 2010. Statistical Procedures for Agricultural Research. Wiley India Pvt. Ltd, New Delhi

Iqbal, A, M Ayub, H Zaman, and R Ahmad. 2006. "Impact of nutrient management and legume association on agro-qualitative traits of maize forage." *Pakistan Journal of Botany* **38 (4)**:1079. https://www.pakbs.org/pjbot/abstracts/38(4)/20.

Javanmard, Abdollah, Ad Mohammadi Nasab, Aziz Javanshir, Mohammad Moghaddam, and Hosein Janmohammadi. 2009. "Forage yield and quality in intercropping of maize with different legumes as double-cropped." *J. Food Agric. Environ* **7 (1):**163-166. https://doi.org/10.1234/4.2009.1459

Kumar, Sachin, Anil Kumar, Jagdev Singh, and Parveen Kumar. 2016. "Growth indices and nutrient uptake of fodder maize (Zea mays L.) as influenced by integrated nutrient management." *Forage Res* **42 (2)**:119-123. http://forageresearch.in/wp-content/uploads/2016 /09/119-123.pdf

Kumar, Kr, and Vb Bhanumurthy. 2001. "Effect of staggered sowing and relative proportion of cowpea on the performance of maize+ cowpea intercropping system." *Forage Res* **27 (2):**105-110. DOI: 10.18805/ag.v37i4.6459

Motaghi, Sahar, and Tayeb Saki Nejad. 2014. "The effect of different levels of humic acid and potassium fertilizer on physiological indices of growth." *International Journal of Biosciences* **5 (2):**99-105. http://dx.doi.org/10.12692/ijb/5.2.99-105

Prasanthi, K, and B Venkateswaralu. Fodder quality in fodder maize-legume intercropping systems. *Journal of Tropical Agriculture* 2014; **52 (1):**86-89. https://jtropag.kau.in/index.php/ojs2/article/view/308

Ram, Sn, and Bhagwan Singh. 2003. "Physiological growth parameters, forage yield and nitrogen uptake of sorghum (Sorghum bicolor) as influenced with legume intercropping, harvesting time and nitrogen level." *Indian Journal of Agronomy* **48 (1):**38-41. https://www.indianjournals.com/ijor.aspx?target=ijor:ija&volume=48&issue=1&article=011

Singh, Mk, Rn Singh, Sp Singh, Mk Yadav, and Vk Singh. 2010. "Integrated nutrient management for higher yield, quality and profitability of baby corn (Zea mays)." *Indian Journal of Agronomy* **55 (2):**100-104. DOI: 10.59797/ija.v55i2.4736

Sharif, M, Riaz A Khattak, and Ms Sarir. 2002. "Effect of different levels of lignitic coal derived humic acid on growth of maize plants." *Communications in soil science and plant analysis* **33 (19-20):**3567-3580. https://doi.org/10.1081/CSS-120015906

Sibhatu, Berhane, Ketema Belete, and Taye Tessema. 2015. "Effect of Cowpea Density and Nitrogen Fertilizer on a Sorghum-Cowpea Intercropping System in Kobo, Northern Ethiopia." *International Journal of Agriculture and Forestry* **5 (6)**:305-317. doi:10.5923/j.ijaf.20150506.02