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RESEARCH ARTICLE

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Assessment of Leaf Area Index and its Relationship with Growth and Yield of Fodder Cowpea as Influenced by Sources of Irrigation and Nutrients

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ABSTRACT

Background: Fodder cowpea is an important leguminous, short duration, warm season crop widely cultivated. Though India ranks first in livestock population, the productivity is found lesser than the world average due to deficiency in availability of green fodders. As fresh water application usage is increasing for the cultivation of field crops and high value crops, fodder crops are found negligible crops but responds well to water and nutrients. Leaf area index is one of the determinative parameters for the increased yield, an attempt was made to determine the relationship between the growth and yield of fodder cowpea with the application of domestic sewage water and nutrients.

Methods: studies were conducted during 2019 and 2020 to study the relationship between different sources of irrigation water and nutrients on the growth and yield of fodder cowpea. Treatments in main plot consists of irrigation with water using well water (I_1), domestic sewage water (I_2) and well water and domestic sewage water alternatively (I_3). Treatments in sub plot consists of no nutrient (N_1), Farm Yard manure alone (N_2), Farm Yard manure + NPK ((N_3) and NPK alone (N_4), in split plot design and replicated thrice. The leaf constant was determined graphically plotted in regression and used for calculation of leaf area. The relationship between leaf area index and the growth and yield parameters of fodder cowpea were determined.

Result: Our investigation concluded that the application of domestic sewage water along with farmyard manure + NPK significantly increased plant height, number of leaves per plant, leaf length, leaf width, leaf area and leaf area index of fodder cowpea. The data also reveals that leaf area index correlated positively with plant height, number of leaves per plant, biomass per plant and yield of fodder cowpea.

Key words: Domestic sewage water, Fodder cowpea, Nutrients, Relationship of leaf area index, Vegetative fodder crop.

INTRODUCTION

Cowpea (*Vigna unguiculata*) is a largely cultivated legume food and fodder in Asia, Africa, South and Central America. It is an annual herb and suitable for cultivation as a warm season crop globally (Benin Firmin *et al*., 2021). Cowpea contains large amount of carbohydrates, proteins, vitamins, dietary fibres and essential minerals. It contains low amounts of lipids and anti-nutritional factors and so can be harvested at any stage of crop harvest (Carvalho *et al*., 2017). The green leaves and haulms are used as a fodder for livestock, rich in nutrients (Gondwe *et al*., 2019). It is a short duration crop and a good fodder source, hence, making it as a valuable source in crop-livestock integration (Singh *et al*., 2003). India occupies 2.29% land area, supports world's 17% of the human population and 10.5% of livestock. Though India is the largest milk producer of the world but the average is found less compared to the world's average. The productivity of livestock is low in Indian condition and the major reasons for decreased productivity are deficiency of feed and fodder, health, breed and improper management. Almost 80% of the livestock are reared in marginal, small and medium holdings (Roy and Singh, 2013).

The main attribute for lower productivity of livestock is the malnutrition or the deficiency in availability of fodder. The deficiency of green fodder is estimated as 11.24%, dry fodder as 23.4% and concentrate as 28.9% (Roy *et al*., 2019). The deficiency in available fodder is due to shortage of land area for cultivation, diversion of available resources for cultivation of field and high value crops (Vennila and Ananthi, 2023).

Fodder crops are found as the negligible crops and often deprived of with the water and nutrients. Water is one of the important limiting factor for fodder crops cultivation. Due to limited water resources an alternative for fresh water is essential. Hence, an alternate for use of fresh water in agriculture and to improve the availability of green fodders is with the use of domestic sewage water. Though the use of domestic sewage water in agriculture is an age old

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practice, it has not gained momentum in use in agriculture extensively due to the facts such as non-acceptance of the produces, handling *etc* (Farshid Shoushtarian and Masoud Negahban-Azar, 2020). This is the time where waste water can be utilised for crop production as the fresh water availability is decreasing day by day. The reuse of waste water poses a potential benefit as its nutrient content can be extensively harvested for improving crop productivity and soil fertility, but at the same time reaps out the negative effect on human and ecology due to the presence of toxic elements, microorganisms and that needs to be addressed **(**Helmecke *et al*., 2020).

Previous studies have shown that different water sources and application levels, influences the crop growth, yield and availability of nutrients. The water availability and efficiency is found significant with the type of crops cultivated, cultivars, sources of water for irrigation and other agronomical parameters (Jerry and Christian Dold, 2019). In India, the water scarcity is acute, contributing to 25 to 30 percent of water use efficiency. With adoption of specialised irrigation techniques such as drip irrigation, sprinkler irrigation *etc*, the use efficiency can be improved. But as the installation cost is huge, the adoption level is low and hence the viable option is use of domestic sewage water. It is highly important to improve the resource use efficiency through application of water.

Though cowpea is widely cultivated, there has been a limited research on agronomic practices aimed to improve the total fodder biomass produced per plant (Mary and Gopalan, 2006) and on use of domestic sewage water for irrigation. Cowpea has morphological diversity and requires minimal resources for enhanced biomass productivity (Hallauer, 2011).

It has been noticed that the application of nutrients enhances crop yield (Jayne Mugwe and Erick Oduor Otieno, 2021). Leaf area index is the total leaf area per unit ground area, that it's a commonly used parameter to quantify vegetative canopy (Welles and Norman, 1991). It is also identified that leaf area index is largely acted upon by factors such as location, plant density, nutrient and water application and hence, accurate quantification of leaf area index is a must (Tsialtas and Maslaris, 2008) and important to estimate the relationship between the LAI and yield components of cowpea. Hence, with diversified available cultivars and varieties of cowpea, coupled with various external factors, production strategies are need to be formulated where water is the limiting factor. Hence, the present study was performed for two years in two seasons to evaluate the leaf area index with respect to the application of different water sources and nutrients.

MATERIALS AND METHODS

The experiments were conducted during *rabi* season of 2019 and 2020 at the Madras Veterinary College campus, Tamil Nadu Veterinary and Animal Sciences University, Chennai. It is located at 13.0827°N latitude, 80.2707°E longitude and 6.7 m above mean sea level. The experimental field comes under the soil order of alfisols. The soil is red soil with a field capacity of 16.73% and alkaline in soil reaction. Soil available nitrogen content in soil is 165.8 kg ha^{-1}, available phosphorous is 17.6 kg ha^{-1} and available potassium is 238.7 kg ha^{-1} and with organic carbon content of 0.25%. The extractable DTPA Mn, Fe, Zn, Pb, Cd and Cr of soil is 2.16, 196.53, 0.96, 4.93, 0.03 and 0.01 mg kg^{-1} respectively. The domestic sewage water collected near the dairy unit of Madras veterinary college and subjected to determination of extractable DTPA Mn, Fe, Zn, Pb, Cd and Cr using atomic absorption method and the values obtained were 0.07, 0.06, 0.06, 0.03 0.02, 0.01 mg l^{-1} respectively. The pH of the domestic sewage water was 7.1 and EC of 1.82 µS cm^{-1}. The macro nutrients of domestic sewage water i.e nitrogen is 73.8 mg l^{-1}, phosphorous is 6.23 mg l^{-1} and potassium is 10.96 mg l^{-1}.

Field preparation, experimental design and cultural practices

The experimental field was ploughed and cultivator was used to obtain fine tilth of the soil. The experiment was laid out in split plot design with three replications. Main plots consisted of three treatments under different sources of irrigation and sub plots with four treatments under nutrients. Each plot measured 2 × 2 m with 1 m between blocks and plots. Treatments in main plot consists of irrigation with water using well water (I_1), domestic sewage water (I_2) and ground water and domestic sewage water alternatively (I_3). Treatments in sub plot consists of no nutrient (N_1), Farm Yard manure alone (N_2), Farm Yard manure + NPK ((N_3) and NPK alone (N_4).

The variety Co 9 of cowpea obtained from Tamil Nadu Agricultural University was used for sowing under two years of study. Sowing was done adopting a spacing of 30 × 10 cm. Gap filling and thinning was done within two weeks of sowing to have two seedlings per hill and in order to maintain 100% plant population. Weeding was done 20 days after sowing. The recommended dose of nutrients for cowpea is 25: 40: 20 kg NPK ha^{-1} and the nutrients were applied in the form of urea, single super phosphate and murate of potash. The quantity of farm yard manure applied was 12.5 t ha^{-1}. As per the treatment schedule, half the dose of urea, full the dose of single super phosphate and murate of potash were applied basally and remaining half the dose of urea was top dressed. The entire quantity of required farmyard manure was applied basally.

Data collection and analysis

Leaf length and leaf width were measured for calculation of leaf area of cowpea during the first year of study (2019). Plant height, number of leaves per plant, leaf length, leaf width, biomass per plant were measured during both the years of the study. Plant height was measured from the base of the plant to the tip of the plant. Leaf length and leaf width were measured from the fully expanded central leaflet collected from the seventh node of the main stem (Peksen *et al*., 2005). The widest distance of the central leaflet was measured for leaf width and distance from the node to the tip was measured for leaf length. The yield per plot was calculated and extrapolated for hectare yield at the time of harvest by harvesting the entire shoot leaving about 15 cm from the ground level using sickle. The data on vegetative and yield parameters were subjected to ANOVA using the R–Project statistical software and differences between treatments were considered statistically significant at probability level of 5% using the least significant difference (LSD) test.

Determination of leaf area index

Method adopted by Addai and Scott (2011) was used for determination of leaf constant. Around 36 leaf samples were collected for the treatments with irrigation with well water, domestic sewage water and alternation of well and domestic sewage water along with the application of farm yard manure+25: 40: 20 kg NPK ha^{-1} (recommended dose of nutrients) during the year 2019. Leaf length and leaf width obtained for the 36 leaves were used for calculating the measured leaf area. True leaf area for 36 leaves were calculated by outlining the leaves on a graph sheet to measure the leaf area. With the measured and true leaf area, coefficient of regression lines was obtained by plotting the values of measured and true leaf area. The leaf area constants for the irrigation water treatments with recommended dose of nutrients were obtained. The leaf constant obtained was used to calculate the leaf area by multiplying with leaf length and leaf width. The same leaf constants obtained during 2019 were used to calculate the leaf area for the year 2020. The leaf area was divided by the spacing adopted to get the leaf area indices.

RESULTS AND DISCUSSION

Leaf area

The leaf area constant obtained were 0.6047, 0.6899 and 0.6466 for the fodder cowpea treated with well water, domestic sewage water and well water and domestic sewage water alternately for irrigation respectively (Fig 1, 2 and 3). These leaf constants obtained were used for calculation of leaf area of fodder cowpea experimentation during 2019 and 2020. The leaf constants are essential for calculation of leaf area. Accurate calculation of leaf area index is dependent on leaf area. This method of quantification of leaf area facilitates calculation of leaf area though without the use of leaf area meters. This is in line with the findings of Addai and Alimiyawo (2015). Leaf area index quantification which is an important parameter for validation of growth and development of the crop is based on the leaf area. Leaf area differs with the application of different sources of irrigation water which implies that the domestic sewage water with nutrients such as nitrogen, phosphorous and potassium could have benefited the leaf area (Kaizzi *et al*., 2007 and Therese *et al*., 2019).

Vegetative growth of fodder cowpea

Fodder cowpea behaved differently in terms of plant growth depending on the application of different sources of irrigation water and nutrients (Table 1). The number of leaves per plant, leaf length and leaf width of fodder cowpea was found influenced by the application of different sources of irrigation water and nutrients (Table 1). Application of different sources of irrigation water had not influenced the plant height, number of branches per plant and leaf stem ratio of fodder cowpea. However, application of farmyard manure + NPK (inorganic nutrients) (N_3) had influenced the plant height (84.4 cm), number of branches per plant (4.23) and leaf stem ratio (0.947) of fodder cowpea. Application of domestic sewage water (I_3) had shown significant improvement in number of leaves per plant (14.8), leaf length (19.2 cm) and leaf width (14.80 cm) of fodder cowpea followed by the application of well water and domestic sewage water alternately.

Application of farmyard manure along + NPK (N_3) had significantly influenced the vegetative growth of fodder cowpea in terms of number of leaves per plant (20.73), leaf

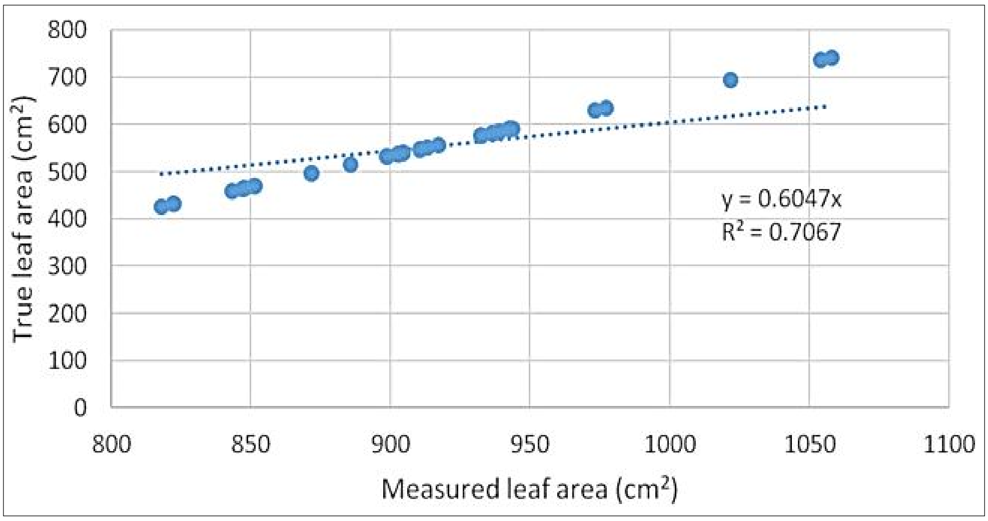

Fig 1: Determination of leaf area constant for fodder cowpea with well water irrigation.

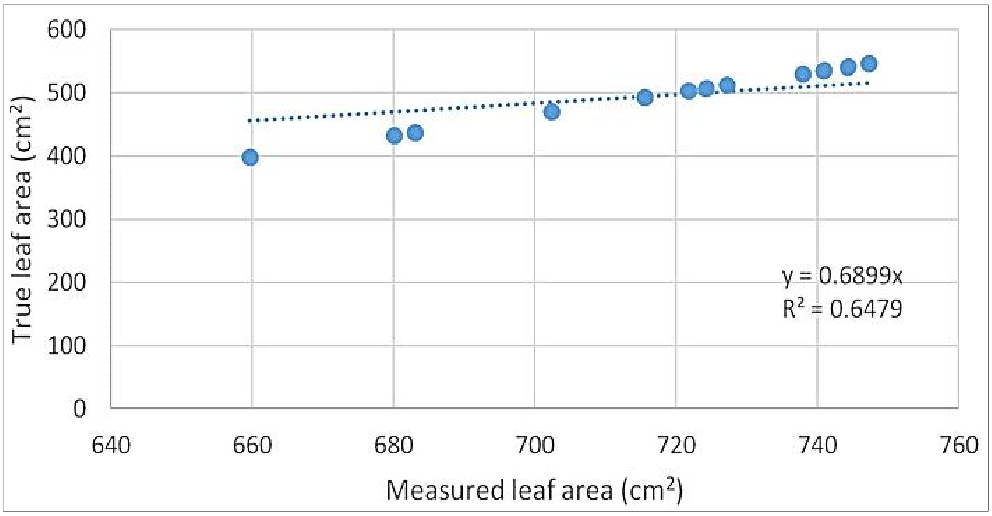

Fig 2: Determination of leaf area constant of fodder cowpea with domestic sewage water irrigation.

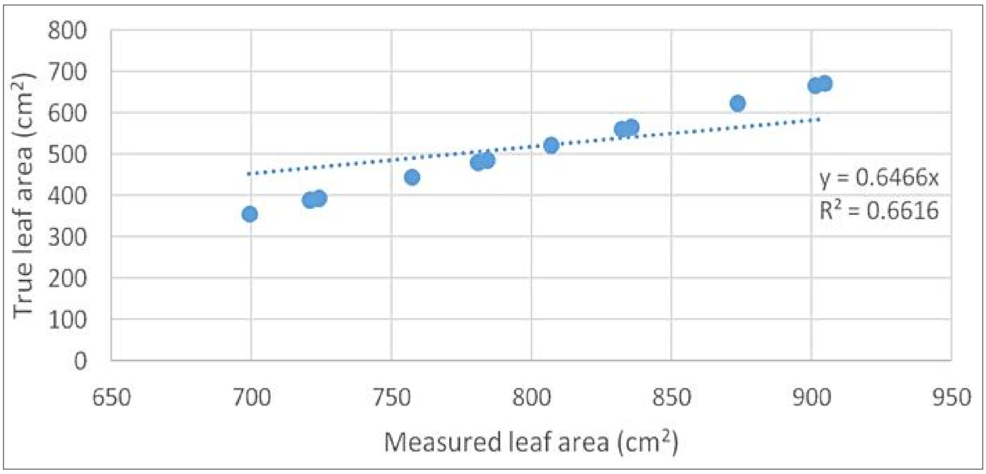

FIg 3: Determination of leaf area constant for fodder cowpea with well water and domestic sewage water irrigation alternately.

Table 1: Effect of treatments on the vegetative growth parameters of fodder cowpea.

Treatments	Plant height (cm)	No. of branches per plant	Leaves per plant	Leaf length (cm)	Leaf width (cm)	LS ratio
Irrigation sources						
I_1	77.4±1.45a	3.95±0.08a	13.375±1.21c	17.78±1.27c	13.38±1.21c	0.876±0.016a
I_2	80.1±1.79a	4.09±0.07a	16.45±1.58a	20.85±1.62a	16.45±1.58a	0.903±0.021a
I_3	78.5±1.43a	4.01±0.07a	14.8±1.16b	19.20±1.22b	14.80±1.16b	0.903±0.017a
CD (p=0.05)	NS	NS	0.583	1.381	0.583	NS
CV	2.7	3.3	2.4	4.4	2.4	3.5
Nutrients						
N_1	72.6±0.94c	3.68±0.05b	8.93±0.41d	13.33±0.56d	8.93±0.41d	0.838±0.013b
N_2	77.2±0.88bc	4.01±0.04a	13.5±0.23c	17.90±0.45c	13.5±3.90c	0.87±0.013ab
N_3	84.4±1.17a	4.23±0.04a	20.73±0.83a	25.13±0.89a	20.73±5.98a	0.947±0.015a
N_4	80.0±0.91 ab	4.15±0.04a	16.30±0.34b	20.73±0.52b	16.33±4.71b	0.921±0.015a
CD (p=0.05)	5.43	0.23	1.13	2.69	1.13	0.08
CV	5	4.1	5.4	9.9	5.4	6.6
Irrigation × Nutrients						
LSD	12.85	0.542	2.66	6.31	2.66	NS

length (25.13 cm) and leaf width (20.73) followed by application of NPK alone (N_4). Domestic sewage water can be used as a fertilizer or soil amendment which in turn has the ability to improve growth rate of crops (Ojobor and Tobih 2015). The present study had the similar findings and may corroborated to the fact that the availability of nutrients in domestic sewage water would have enhanced the nutrients available in the soil and hence the availability of nutrients to the plants to improve growth parameters. This is in line with the findings of Naddafi *et al.* (2005).

The interaction effect of irrigation water and nutrients were significant, indicating a positive relationship between sources of water and nutrients. Application of domestic sewage water along with farm yard manure + NPK (I_3N_3) recorded significant growth attributes. The nutrients available with the domestic sewage water and the application of nutrients could influence the availability of nutrients in soil with their synergistic effect and thereby resulting in enhanced growth parameters of fodder cowpea which is in line with the findings of Vennila and Ananthi (2023).

Table 2: Effect of treatments on biomass (g per plant) of cowpea.

Treatments	I_1	I_2	I_3
N_1	80.35±0.44	93.84±0.51	90.17±0.49
N_2	98.75±0.54	102.15±0.56	99.99±0.55
N_3	138.06±0.75	142.66±0.78	139.61±0.76
N_4	107.37±0.59	125.77±0.69	111.04±0.61
	Irrigation	**Nutrient**	**Irrigation * Nutrient**
CD (p=0.05)	3.81	3.04	7.19

Table 3: Effect of treatments on dry matter yield (t ha^{-1}) of cowpea.

Treatments	I_1	I_2	I_3
N_1	2.77±0.16	3.23±0.02	3.10±0.26
N_2	3.40±0.02	3.52±0.06	3.44±0.19
N_3	4.75±0.26	4.92±0.26	4.80±0.03
N_4	3.70±0.20	4.33±0.23	3.82±0.02
	Irrigation	**Nutrient**	**Irrigation * Nutrient**
CD (p=0.05)	0.087	0.111	0.263

Table 4: Effect of treatments on green fodder yield (t ha^{-1}) of cowpea.

Treatments	I_1	I_2	I_3
N_1	17.86±0.10	20.85±0.11	20.04±0.11
N_2	21.94±0.12	22.70±0.12	22.22±0.12
N_3	30.68±0.17	31.70±0.17	31.02±0.17
N_4	23.86±0.13	27.95±0.15	24.68±0.14
	Irrigation	**NutrientIrrigation**	*** Nutrient**
CD (p=0.05)	0.33	0.74	1.76

Biomass yield

For leaf area per plant, biomass per plant, dry matter yield and green fodder yield of fodder cowpea is significantly influenced by application of different sources of irrigation water and nutrients (Table 2, 3, 4 and Fig 4, 5). The biomass per plant (g per plant), dry matter yield (t ha^{-1}) and green fodder yield (t ha^{-1}) was found higher with the application of domestic sewage water (I_2) with respect to nutrients application of farm yard manure + NPK (N_3). The interaction between different sources of irrigation water and nutrients were found significant in terms of yield parameters and yield of fodder cowpea. Application of well water and unfertilised plot had significantly lesser biomass per plant and yield of fodder cowpea (I_1N_1). Application of domestic sewage water and farmyard manure + NPK (I_2N_3) had the highest biomass per plant (142.66 g per plant), dry matter yield (4.92 g per plant) and green fodder yield (31.70 t ha^{-1}) of fodder cowpea. The biomass per plant and yield are the results of increase in leaf area per plant. An increase in leaf area increases the leaf area index and thus the yield of the plant. As green fodder yield is the vegetative biomass, it is determined by the growth parameters. In this study, as the application of domestic sewage water and farmyard manure+NPK had significantly influenced the growth parameters of fodder cowpea, in turn resulted in the yield of fodder cowpea.

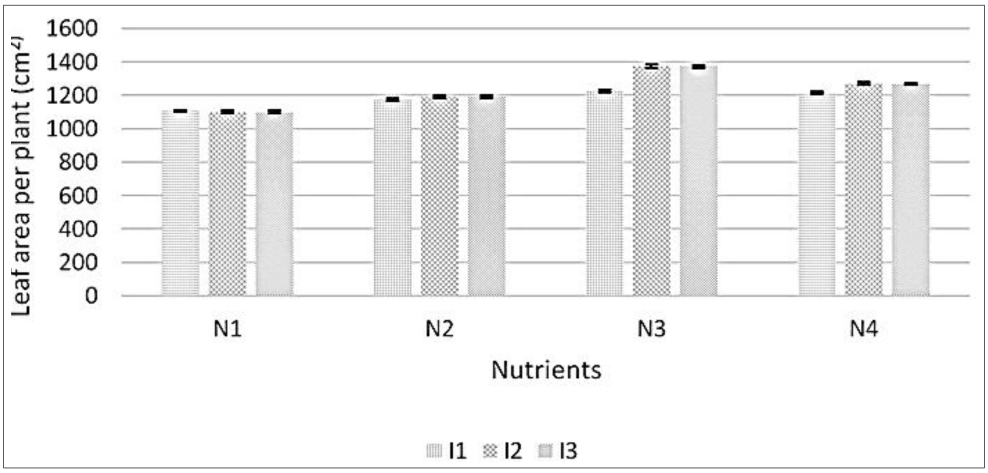

Fig 4: Effect of treatments on leaf area per plant of fodder cowpea.

The increased plant height in domestic sewage water with organic and inorganic nutrients might be due to the continuous availability of nutrients helping increase in plant height, leaf length, leaf width in turn influencing the leaf area of the plants and hence increase in biomass (g) per plant and yield of fodder cowpea (Mousavi and Shahsavari, 2014). The vegetative growth parameters such as number of leaves per plant, leaf width and leaf length helps in more leaf area as a consequence of production of more assimilates in turn relating to the biomass per plant and yield of the crops as concurred by the findings of (Achuba and Oshiokpu, 2019). Galavi *et al*. (2009) also reported that the increase in plant vigour in terms of height, number of functional leaves and their expansion with respect to domestic sewage water and application of full dose of NPK fertilizer along with farmyard manure found to utilise the radiant energy more effectively thereby increased synthesis of carbohydrates, eventually increased the greenness and plant weight of plant resulting in higher yield of crops. Abo-Shady *et al*. (2017) reported that improved growth and yield and the quality of the plants results from the soils amended with organic manure. In this study, the quantity of nutrients such as organic matter, nitrogen, phosphorous, potassium etc, contributed from the domestic sewage water and the applied nutrients had influenced the growth of fodder cowpea and in turn enhanced the crop yield of fodder cowpea. This is in line with the findings of Nelson and Cox (2005).

Relationship between leaf area Index and growth and yield

Regression analysis showed significant effects of leaf area index on plant height, number of leaves per plant, biomass per plant and green fodder yield of fodder cowpea (Fig 6, 7, 8 and 9). Application of domestic sewage water for irrigation, along with the application of farmyard manure + NPK (I_2N_3) resulted in significantly higher, plant height, number of leaves plant, biomass per plant and green fodder yield of fodder cowpea. The leaf area index and the growth and yield parameters of fodder cowpea are directly proportional. As the application of domestic sewage water for irrigation, along with the application of farmyard manure + NPK resulted in higher leaf area index, it had direct influence on the plant

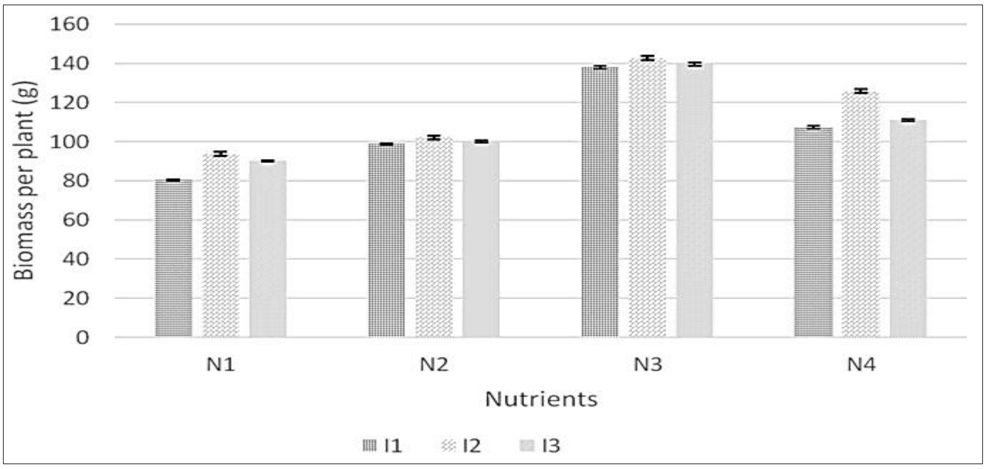

Fig 5: Effect of itreatments on biomass per plant (g) of fodder cowpea.

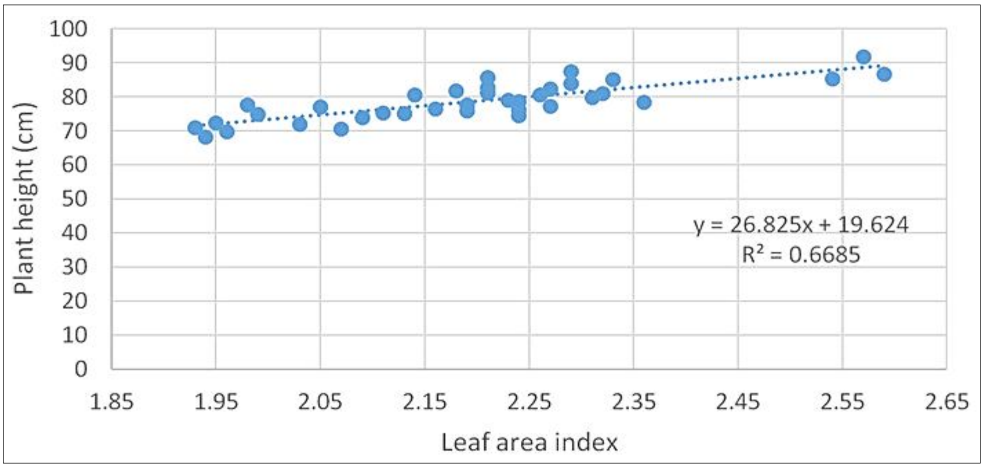

Fig 6: Relationshp between leaf area index and plant height of fodder cowpea.

height, number of leaves plant, biomass per plant and green fodder yield. Leaf area index is important to determine the incoming solar radiation, that affects the phenotypic parameters of the plants (Amanullah *et al*., 2007). The increase in leaf area index is again related to the quantity of nutrients applied. Liu *et al*. (2017) and Mousavi *et al*. (2020)

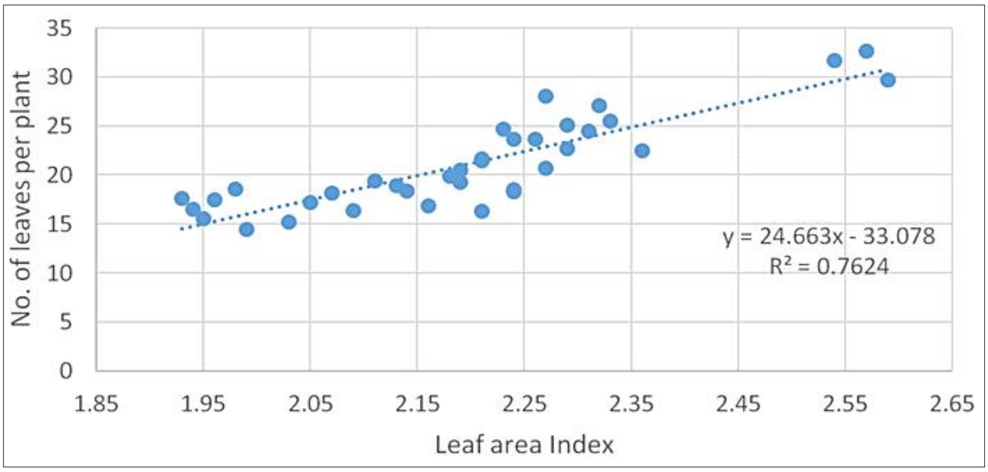

Fig 7: Relationship between leaf area index and no. of leaves per plant of fodder cowpea.

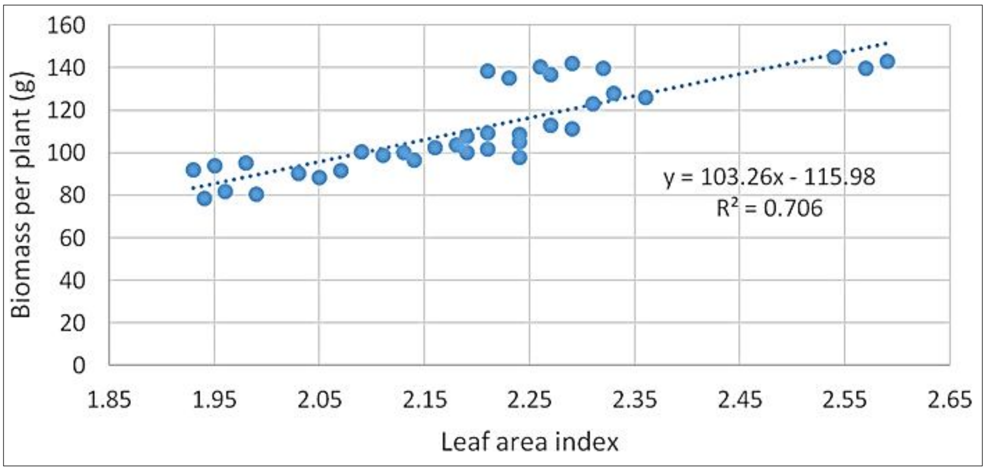

FIg 8: Relationship between leaf area index and biomass per plant of fodder cowpea.

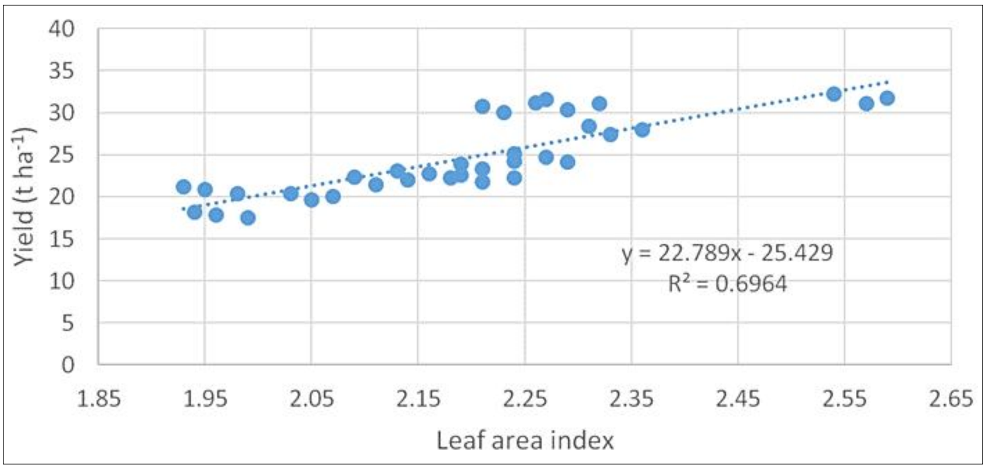

Fig 9: Relationship between leaf area index and yield of fodder cowpea.

Table 5: Correlation between leaf area index and yield components.

Parameters	LAI	Plant height (cm)	Biomass per plant (g $plant^{-1}$)	Green fodder yield (t ha^{-1})
LAI	1			
Plant height (cm)	0.818	1		
Biomass per plant (g $plant^{-1}$)	0.840	0.813	1	
Green fodder yield (t ha^{-1})	0.834	0.772	0.991	1

also reported the positive effect of nutrient application on the leaf area index of maize. The maximum leaf area index occurs at the time of flowering, the plants capture more quantity of solar radiation and thereby increases the photosynthetic rate and thereby enhances the vegetative parameters and yield of the crop. This is in line with the findings of Feng *et al.* (2021).

Correlation between leaf area index and yield components

Correlation analysis (Table 5) showed that there was positive correlation between leaf area index and plant height (0.817), biomass per plant (0.840) and green fodder yield (0.834) of fodder cowpea. Leaf area index and the plant growth and yield parameters are positively correlated. This study indicates that the application of domestic sewage water and nutrients enhanced the availability of nutrients to the plants from the soil and thereby contributing to the rise in green area of the plant and determining the photosynthetic area of the plant. This in accordance with the findings of Mi *et al.* (2018). The study confirms that the leaf area index offers a positive relationship for enhanced growth and yield of vegetative biomass producing crops.

CONCLUSION

The results derived from this study revealed that the application of domestic sewage water along with farmyard manure + NPK significantly increased plant height, number of leaves per plant, leaf length, leaf width, leaf area and leaf area index of fodder cowpea. The data also reveals that leaf area index correlated positively with plant height, number of leaves per plant, biomass per plant and yield of fodder cowpea. This concludes that leaf area index is improved with the application of nutrients and thereby enhances the vegetative yield of fodder cowpea and this crop responds well for the application of domestic sewage water along with the recommended doses of nutrients with organic and inorganic sources.

Conflict of interest

All authors declare that they have no conflicts of interest.

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