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ALLOMETRIC DEVIATION IN BIOMASS AND BIOCHEMICALS OF SUNFLOWER (*HELIANTHUS ANNUUS*) PLANTS AMPLIFIED BY LEMONGRASS (*CYMBOPOGON CITRATUS*) FOLIAR EXTRACT

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Abstract

Growth of crops is recently studied in terms of allometry that explains the growth attainment pattern of plant components. Current study describes the effect of lemongrass foliar extract on sunflower plants and the investigations focus the intense response of sunflower vegetative parts. For this purpose, biomass along with major metabolites i.e. carbohydrates, proteins and chlorophyll (a and b) contents have been extracted and evaluated. In this study, different concentrations of lemongrass applied to sunflower plants that showed 1% concentration to be the best adapted application for growth promotion in treated plants. Highest fresh weight, Average Growth Rate and Relative Growth Rate (12.1±0.4 mg, 1.9±0.09 mg/week and 0.9±0.04 mg/week respectively) attained by 1% samples. Among leaves, shoots and roots, leaves showed highest adaptive capability by synthesizing greater amount of chlorophyll a and carbohydrates in 1% treated plants. Whilst control samples showed higher activity in producing greater amount of carbohydrates (1.04±0.3 mg/ml) in roots. In shoots, carbohydrates (3.02±1.0 mg/ml) and proteins (2.04±0.2 mg/ml) were also found in greater amount in 1% samples. Two-way ANOVA produced a highly significant (p<0.001) relationship among metabolites of leaves, roots and shoots. Overall, the study produced comprehensive outcomes hence supports the utilization of natural bio-stimulants for crop growth.

Key words: Allometry; Biochemicals; Foliar extract; Lemongrass; Sunflower.

Introduction

Plants characteristics are the reflectors of their specific functional traits. The characteristics undergo gradual changes upon exposure to different environmental complexes. Plants being phototrophs broadly dependent on the range of available primary resources *i.e.,* light, moisture, nutrients and other resources hence this resource availability programs the plant response against environmental flux or stress. The response may provide alteration in regular growth pattern, statiometric fluctuation or may be the changes in sizes of plant parts (Khan, 2018). Co-variant growth relationships of plant attributes produce allometric or isometric formulation in plants (Anfodillo *et al*., 2016). In natural and stressed conditions, plant traits have been examined in the literature as their traits involve co-variance in growth consuming processes (Weiner, 2004; Westoby & Wright, 2006). This unbalanced relationship of plants parts has manifested by the limiting factors acting upon them. Stem growth dimension, wood density, stem mechanical strength can be compared to leaf growth, photosynthetic efficiency or with root enlargement and propagation as the parameters to fill the knowledge gap for allometric studies in plants (Sterck *et al*., 2006a & b; Rosell *et al*., 2012; Castorena *et al*., 2015; Reich *et al*., 1997). Area and mass scaling of stems and leaves, determination of relationships among species in a habitat and development of co-variant properties in plant parts have debated in some studies like Cannell & Dewar, 1994; Zhang *et al*., 2016. The allometries seem to be an initiative tool towards phyllogenetic characterization of a species under certain conditions (Niklas, 1994; West *et al*., 1999; Niklas & Enquist, 2001). It has been seen that stress is a consequence in most of the cases for an evolutionary character; a least contradictory combination occurs when the change enters to a genome that produces evolutionary character in the organism (Niklas & Enquist, 2001). Physical and biochemical imbalance in the natural growth and metabolic phenomenon can lead to evolutionary mechanism. Therefore, in current study, variabilities have been pointed in the growth scaling of plant parts with the differences in biochemical synthesis during growth attainment process. The investigations will also detect whether the foliar extract devastated the yield of crop or enhanced the crop quality. For this study, sunflower is used to examine growth and lemongrass extract is used as an influencer.

Sunflower (*Helianthus annuus*), a native North American crop in 16th century that later on introduced to Europe and from 19th century the crop originally and hybrid forms successfully cultivated all over the world (Fernandez *et al*., 2019). The highest demand of the crop is due to the production of oil from sunflower seeds that made it the fourth economically rich crop worldwide (Oilworld, 2016). Pakistan cultivates the crop for its oil production as a major oil crop (Hussain, 2018) as well as utilizes its high biodegradability for the production of other materials like paints and plastics prepared from substances (lignins, resins, wood, extracts, manure) present in different parts of the plant (Fernandez *et al*., 2019).

Lemongrass (*Cymbopogon citratus*), a fast growing herb in Pakistan, native to South eastern region in Asia. An herb of various health benefits and used in ethnobotany to cure a number of diseases mainly stomach problems, skin problems, heart and vascular diseases (Leite *et al*., 1986; Borrelli & Izzo, 2000). This paper demonstrates the use of two economically and medicinally important crops of Pakistan that examines the possibilities of producing a better quality crop. The investigations involve amplification of lemongrass foliar extract and its effects on biosynthesis and allometry of sunflower plants growth. This will focus the physiological

anomalies develop during growth stages of sunflower plants enriched by lemongrass extract and to highlight the productive or inhibitory events.

Materials and Methods

Extract preparation: Lemongrass foliar extract was prepared from fresh leaves planted in the greenhouse of Department of Botany, Federal Urdu University, Karachi. The extract was prepared in different concentrations that were 0.5%, 1%, 2% and 3% in distilled water, filtered after 24 hours and preserved for further treatments.

Experimental design: Sunflower seeds were sterilized and five sets (+ replicates) of treatments were prepared by soaking in water, 0.5%, 1%, 2% and 3% lemongrass extract respectively in petriplates. After germination of seeds, the established seedlings were transplanted to their respective pots, each pot consisted of five replicates. The experiment took place for 16 weeks after seedling establishment, the growth attributes were measured after 10, 20, 30 and 40 spray exposure to the plants at 7 days interval to each treatment.

Germination% and Vigor were achieved in a maximum of 72 hours period and were calculated by using following formulae:

$$\text{Germination percentage (GP)} = \frac{\text{Total number of germinated seeds}}{\text{Total number of seeds}} \times 100 \text{ (Khan \& Ungar, 1997)}$$

$Vigor = [N1/2+N2/2+N3/3+Nn/n] \times 100$ (Khandakar & Bradbeer, 1983)

Biomass estimation (Paine *et al*., 2011):

$$AGR = M_2 - M_1/t_2 - t_1$$
$$RGR = ln\ (M_2 - M_1/t_2 - t_1)$$

where, AGR = Average growth rate, RGR = Relative growth rate, M_2 and M_1 = dry weight of plant final and initial respectively. t2 – t1 = final and initial time respectively. Ln (M_2) – ln (M_1) = natural log of dry weight of plants final and initial respectively.

Biochemical analysis: Chlorophyll content: 0.1gm of fresh leaf sample was homogenized in pistin and mortar with 0.5ml of 80% acetone, centrifuged at 1000rpm for 05 minutes. Supernatent was collected in another test tube and debris was centrifuged again by adding 80% acetone. Obtained supernatent was collected and final volume was adjusted to 10 ml. The absorbance was measured at 480, 510, 645 and 663 nm by using JENWAY 6305 spectrophotometer. The chlorophyll a and b estimations followed Arnon., (1949).

$$\text{Total chlorophyll (mg/g)} = \frac{20.2(D645)+8.02(D663)\times V}{1000 \times W}$$

where:
V = Final volume (10ml) of chlorophyll extract in 80% acetone
W = Fresh weight (0.1g) of leaves used for chlorophyll extraction

Carbohydrates: 0.1gm of fresh leaf sample of each treatment was homogenized in 5ml ethanol then boiled in water bath for 10-15minutes. After cooling at room temperature, the samples were centrifuged at 3000rpm twice. The supernatents were collected in other test tube and final volume was adjusted with ethanol upto 10ml. 1ml of extract in 5ml of freshly prepared Anthrone reagent was boiled for 30 minutes. The absorbance was measured by using the JENWAY 6305 spectrophotometer at 620nm against reagent blank. Amount of carbohydrates was calculated from the standard curve prepared from D-glucose Yemm & Willis (1954).

Proteins: 0.1g of leaf samples were macerated in four ml of chilled sodium phosphate buffer (7pH). The samples were centrifuged twice at 1000rpm for five minutes. Final volume of the supernatent was made up to 10ml with sodium phosphate buffer (7pH). In 0.1ml or 100µl extract was added in 5 ml of diluted assay reagent (1:4). The sample was kept at room temperature for 30 minutes. The absorbance of each treatment was measured at 595nm by JENWAY 6305 spectrophotometer. The protein content in the tissue was calculated from the standard curve of BSA (bovine serum albumin) as mg/g fresh wt (Bradford, 1976).

Results

The experimental preparation and environmental details were determined in Table 1. Sunflower seeds were sown in the month of August, seeds started germination after 12 hours of sowing which was completed in 72 hours. Germination % and vigor were monitored at an interval of 12 hours found highest in Control samples i.e., 37±8 and 5±2 with a highest dry weight achieved at the final harvest on 16th week i.e., 3.8±0.15mg (Table 2). Among treated samples, 1% plants superseded by attaining fresh weight, AGR and RGR (12.1±0.4mg, 1.9±0.09mg/week and 0.9±0.04mg/week respectively). 0.5% samples gained highest leaf area (25±8cm) at 16th week harvest (Table 2). Fig. 1 presented Normal (Gaussian) probability model illustrating the fits of correlation coefficients as a function of response (AGR) and predictor (RGR). Control, 0.5% and 2% lie significantly normally and show a strong linear pattern with some slight deviations. While 1% provided a long tailed departure that indicates some outliers in the results, lie in the normally distributed medium with weakly positive correlation in normal fit. 3% also produced a negatively long tailed departure with weak correlation with the normal fit hence indicating some abnormalities in the data.

Table 1. Environmental (mean) details covering experimental span.

Time duration	November 2018 – February 2019 (16 weeks)
Temperature	16ºC - 27ºC
Relative Humidity	58% - 60%
Precipitation	10mm - 15mm
Wind	0.8 – 0.9 m/s
Soil pH	6.8
Soil texture	sandy-clay

Table 2. Sunflower plants germination and growth summary under treatment with different lemongrass extract concentrations.

Samples	Germination %	Vigor/12 hr	Plant fresh wt (gm)	Plant dry wt (gm)	Leaf area (cm)	Biomass(mg) AGR v/s RGR	
Control	37 ± 8*	5 ± 2*	9.8 ± 0.3	3.8 ± 0.15*	25.8 ± 3	Slope	0.034
0.5%	30 ± 5	3 ± 1	6.5 ± 0.4	1.73 ± 0.23	28 ± 8*	Intercept	1.31
1%	32 ± 6	4 ± 1	12.1 ± 0.4*	3.01 ± 0.23	21.14 ± 3	R^2	98%
2%	33 ± 6	3 ± 1	6.6 ± 0.22	2 ± 0.03	10 ± 3	Adj-R^2	97%
3%	28 ± 3	3 ± 1	3.22 ± 0.14	1.35 ± 0.073	6.4 ± 1.2	Significance	p<0.01

Table 3. Biochemical synthesis (Carbohydrates, proteins, chlorophyll a and b) in leaves of sunflower plants in accordance to spray period.

	Carbohydrates	Proteins	Chlorophyll a	Chlorophyll b
	10th spray			
Control	1.76 ± 0.1	5.49 ± 0.4	2.27 ± 0.2	0.81 ± 0.04
0.5%	1.69 ± 0.3	5.37 ± 0.3	2.05 ± 0.1	0.76 ± 0.05
1%	1.14 ± 0.1	5.87 ± 0.6*	2.98 ± 0.3*	1.08 ± 0.09*
2%	1.17 ± 0.1	5.61 ± 0.5	1.66 ± 0.1	0.34 ± 0.02
3%	1.78 ± 0.1*	5.71 ± 0.6	1.21 ± 0.1	0.52 ± 0.04
	20th spray			
Control	1.49 ± 0.1	4.12 ± 0.8	2.62 ± 0.3	1.17 ± 0.9*
0.5%	2.13 ± 0.5	4.62 ± 1.0*	2.22 ± 0.2	1.12 ± 0.9
1%	2.09 ± 0.5	4.13 ± 0.7	2.72 ± 0.3*	0.93 ± 0.06
2%	2.37 ± 0.6*	4.16 ± 0.8	2.36 ± 0.2	0.79 ± 0.05
3%	2.35 ± 0.5	4.11 ± 0.8	1.7 ± 0.2	0.61 ± 0.06
	30th spray			
Control	6.92 ± 1.4*	3.67 ± 0.6*	0.97 ± 0.03	0.40 ± 0.01
0.5%	4.79 ± 0.9	2.57 ± 0.5	1.29 ± 0.09	0.52 ± 0.02
1%	3.06 ± 0.6	3.25 ± 0.6	1.17 ± 0.08	0.45 ± 0.01
2%	2.91 ± 0.4	2.35 ± 0.4	1.37 ± 0.09*	0.53 ± 0.01*
3%	2.67 ± 0.4	3.03 ± 0.4	1.14 ± 0.09	0.47 ± 0.01
	40th spray			
Control	2.53±0.7	5.34±1.1	1.58±1.3	0.71±0.04*
0.5%	3.54±0.9	5.69±1.2	1.64±1.3	0.66±0.02
1%	4.94±1.0*	5.99±1.2*	1.77±1.0	0.60±0.02
2%	3.02±0.8	5.58±1.1	0.45±0.05	0.59±0.01
3%	4.34±0.8	5.69±1.1	2.01±0.9*	0.37±0.009

Biochemical analysis of sunflower plants produced highest protein content, chlorophyll content including chlorophylla and chlorophyll b in 1% plants at 10th spray i.e. 5.87±0.6 mg/ml, 2.98±0.3 mg/ml and 1.08±0.09 mg/ml respectively (Table 3). The major biochemicals in the leaves of sample plants were found in a discrete distribution pattern at 20th and 30th spray as all the samples bear some highest degree of biochemical synthesis at certain level. The treatment ended up at 40th spray with highest carbohydrates (4.94±1.0 mg/ml) and proteins (5.99±1.2 mg/ml) in 1% samples, chlorophyll a was highest (2.01±0.9 mg/ml) in 3% samples while chlorophyll b was highest (0.71±0.04mg/ml) in Control samples.

Roots and shoots of sunflower plants after being dominated by Control samples at 10th and 30th spray and 2% at 20th spray, 40th spray produced highest carbohydrates (3.02±1.0 mg/ml) and proteins (2.04±0.2 mg/ml) in shoots and 1.99±0.02 mg/ml of highest proteins in roots in 1% samples (Table 4). Control plants synthesized 1.04±0.3mg/ml carbohydrates as the highest amount among other treated plants in their roots (Table 4).

Analysis of Variance (ANOVA) two way method produced highly significant (p<0.001) relationship among carbohydrates, proteins, chlorophyll a and chlorophyll b in the leaves of sample plants (Fig. 2) with F-value = 22.08. Two-way ANOVA among carbohydrates and proteins of shoots and roots was also highly significantly (p<0.001) correlated with each other with F = 39.77 (Fig. 3). Residuals of leaves, roots and shoots were closely fitted with the normal probability model (Figs. 4 and 5). Although, there were some deviations in root-shoot assimilated products that showed some fluctuations occurred in the regular streamline of biosynthesis at some levels in roots that wasn't corresponded to shoots or vice versa.

Upon correlating the biochemicals and their relative effectiveness on production under foliar extract of lemongrass herb, it was observed that majority of the biochemicals behaved independently. Correlations among leaves of treated samples provided strong correlation (p<0.001) between chlorophyll a and b while a strongly negative correlation (p<0.001) was estimated between chlorophyll a and carbohydrates in the leaves (Fig. 6). Shoots and roots samples showed a positive correlation (p<0.01) between carbohydrates of roots and shoots while weakly positive correlation (p<0.05) proteins of roots and shoots (Fig. 7). However, there was no correlation observed between carbohydrates and proteins of roots and shoots.

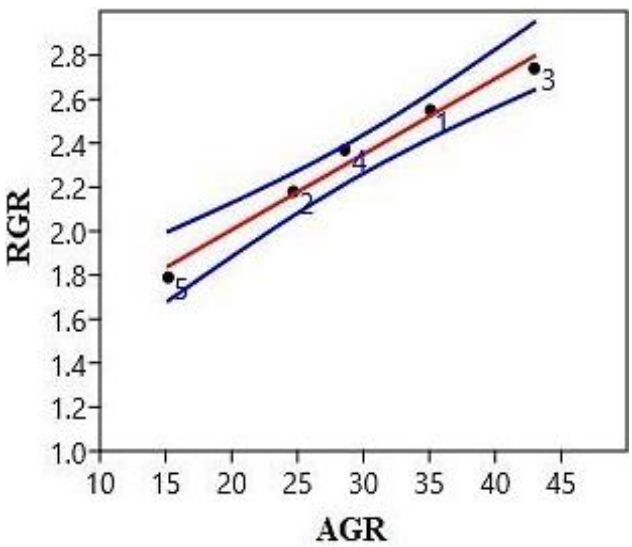

Fig. 1. Normal probability distribution model for sunflower plants biomass: AGR and RGR at different concentrations of lemongrass extract.

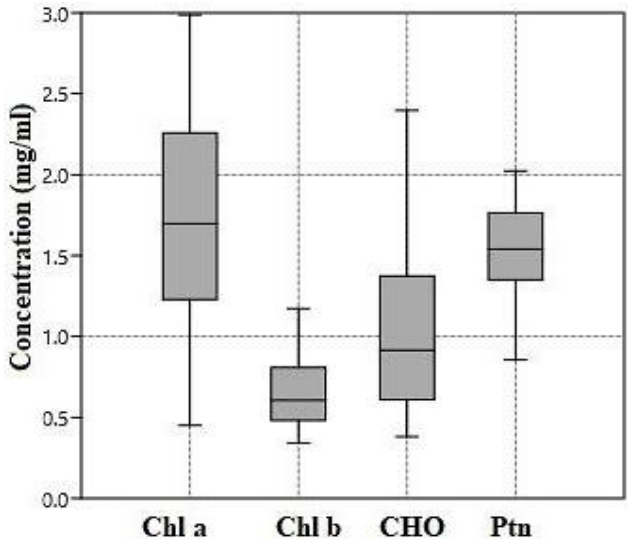

Fig. 2. Variance in biochemical synthesis (chlorophyll a, chlorophyll b, carbohydrates, proteins) in leaves.

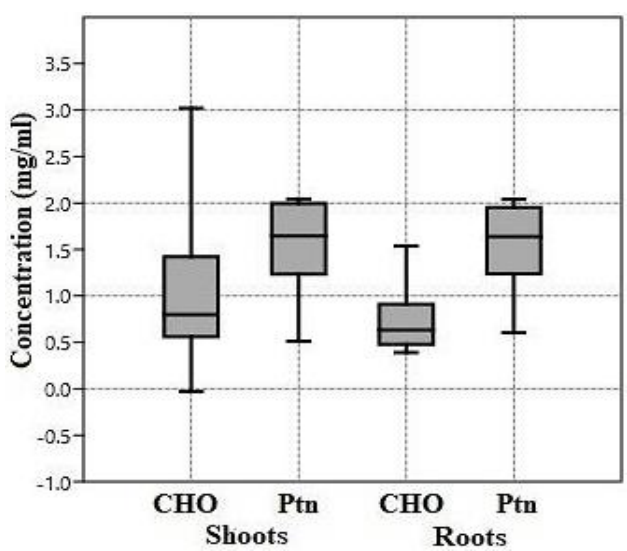

Fig. 3. Variance in biochemical synthesis (carbohydrates, proteins) in shoots and roots.

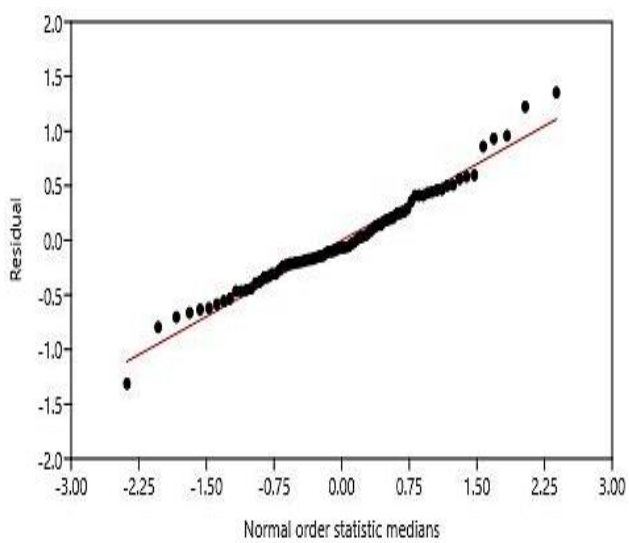

Fig. 4. Normality of residuals for biochemical production in leaves.

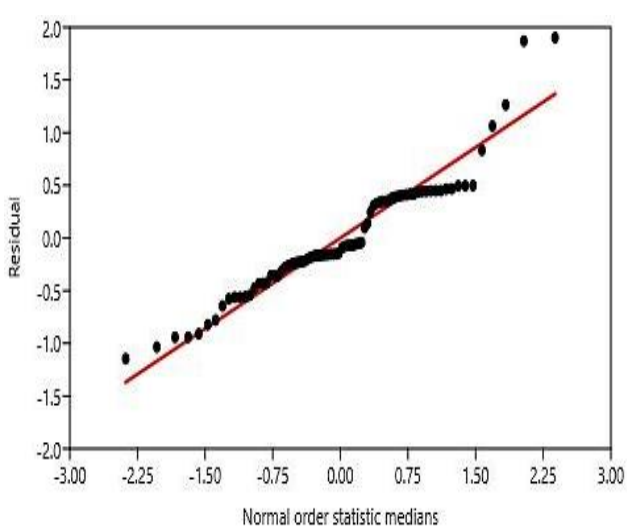

Fig. 5. Normality of residuals for biochemical production in shoots and roots.

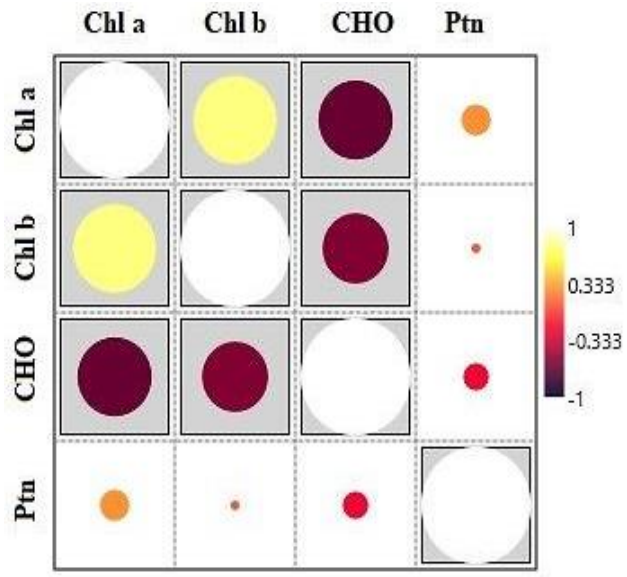

Fig. 6. Correlation map of leaves biochemicals (chlorophyll a, chlorophyll b, carbohydrates, proteins).

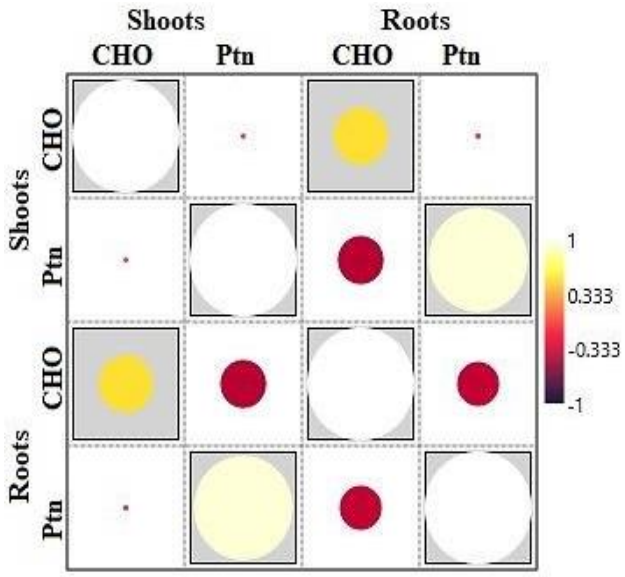

Fig. 7. Correlation illustration of carbohydrates and proteins in shoots and roots respectively.

Table 4. Biochemical synthesis (Carbohydrates and proteins) in stem and roots of sunflower plants in accordance to spray period.

	Stem		Roots	
	Carbohydrates	**Proteins**	**Carbohydrates**	**Proteins**
	10th spray			
Control	0.55 ± 0.01	2.04 ± 0.1*	0.62 ± 0.02*	1.97 ± 0.04
0.5%	0.55 ± 0.03	2.01 ± 0.1	0.47 ± 0.01	1.97 ± 0.05
1%	0.29 ± 0.01	1.98 ± 0.1	0.46 ± 0.03	2.02 ± 0.09*
2%	0.69 ± 0.01*	1.91 ± 0.1	0.52 ± 0.01	1.69 ± 0.02
3%	0.68 ± 0.01	2.01 ± 0.1	0.39 ± 0.01	1.75 ± 0.04
	20th spray			
Control	0.58 ± 0.03	1.39 ± 0.15*	0.50 ± 0.03	1.32 ± 0.09
0.5%	0.76 ± 0.04	1.37 ± 0.1	0.63 ± 0.03	1.34 ± 0.09
1%	0.87 ± 0.04	1.37 ± 0.07	0.64 ± 0.03	1.37 ± 0.06
2%	0.83 ± 0.04	1.39 ± 0.08*	0.65 ± 0.02*	1.38 ± 0.05*
3%	1.02 ± 0.05*	1.38 ± 0.08	0.48 ± 0.02	1.35 ± 0.06
	30th spray			
Control	2.99 ± 0.4*	1.18 ± 0.6*	1.53 ± 0.03*	1.36 ± 0.15
0.5%	2.38 ± 0.1	0.51 ± 0.02	1.00 ± 0.09	1.46 ± 0.2
1%	0.03 ± 0.01	0.76 ± 0.06	1.11 ± 0.08	1.59 ± 0.2*
2%	0.64 ± 0.04	0.63 ± 0.02	0.66 ± 0.04	1.11 ± 0.1
3%	1.05 ± 0.4	0.98 ± 0.06	0.63 ± 0.05	0.85 ± 0.1
	40th spray			
Control	0.54 ± 0.7	1.89 ± 0.19	1.04 ± 0.3*	1.50 ± 0.02
0.5%	1.47 ± 0.9	1.99 ± 0.25	0.44 ± 0.02	1.75 ± 0.02
1%	3.02 ± 1.0*	2.04 ± 0.2*	0.80 ± 0.18	1.99 ± 0.02*
2%	1.26 ± 0.8	1.98 ± 0.2	0.48 ± 0.02	1.60 ± 0.01
3%	2.18 ± 0.8	1.93 ± 0.2	0.95 ± 0.2	1.76 ± 0.02

Discussion

Research advances in plant growth models and plant part's size related queries have fascinated biologists towards allometric investigations. The scaling phenomenon of plant parts during growth emphasized the mechanistic strategy of different parts in the plant body on exposure to newly introduced environmental factors. A rapid response of effected plant in some cases has convinced the biologists to predict the relative effectiveness of the stress (Qadir *et al*., 2021 & 2020). Moreover, the allometric deviations could also predict the partitioning of constructive mechanism in the plants related to their biomass or other physiological activities (Niklas, 2004). Current study explained the changes in biomass on the basis of biochemical synthesis in plant parts upon endogenous application of lemongrass extract. Nardi *et al*., (2009 and 2016) claimed that plant growth and their macroflora can be affected by bio-stimulants of other plants. Jang & Kuk (2019) studied the effects of Chinese Chive and soybean leaves and shoot extracts on growth of lettuce. They found significant increase in shoot fresh weight while plant height did not produce any visible differentiation in their treatments (1%, 3% and 5%). However, current study provided a similar response from sunflower shoots in their fresh weight and height (length). Our treated roots failed to respond dynamically against the provided extract. The response of leaves in their fresh weight was remarkable than other parameters. Noshad & Khan (2019) concluded positive effects of food industrial residues on *Solanum melongena* growth as their shoots growth and fruit production enhanced at a greater rate. Khan (2018) provided several examples of positive allelopathic effects on crop production and growth yield such as tomato extracts on wheat and rice crops. Our study revealed rapid deviations in roots shoot and leaves growth after 10, 20, 30 and 40 exposures of lemongrass leaf extract. It was clearly visible that as the exposure number increased, a loss in fresh and dry weight of roots consistently occurred in the treated plants whereas in shoots and leaves at some levels, 1% treatments attained highest biomass observed as well as biochemical synthesis. Duke *et al*., (2000) suggested the use of biochemicals from various plants can alter growth dynamics of other plants; the basic requirement is the chemistry of both plants i.e. treatments and applications.

Among the plant parts, leaves assumed to be the power house in the plant body for being phototroph due to the presence of chlorophyll. Kamble *et al*., (2015) advocated for lower synthesis of chlorophyll in young plants than in matured ones, they provided inventories that featured a difference in chlorophyll content at younger and mature plant stages. Contradictory to our findings, the young stages synthesized higher amount of chlorophyll at 10^{th} and 20^{th} exposure which decreased on 30^{th} and 40^{th} spray with an increase in carbohydrate content in leaves. This provided evident information of affectiveness of synthesized photosynthetic product in the form of carbohydrates. While protein assimilation was highest in the mature stage at 40^{th} spray. Production of proteins takes three steps to form a polypeptide chain: initiation, elongation and termination, interference of any external molecule may cause interruption in any of the step hence become responsible for inhibition in protein synthesis (El-Hydary & Chung, 2013; Taiz & Zeiger, 1991). Salem (1989) concluded promotion in protein synthesis in Soybean by applying GA_3. Franklin & Riley, 1977; Lemma *et al*., 2009 found increase in nitrogen content in soil at lower concentration of foliar extracts of *Malva parviflora* and *Artemesia ludia* while destroyed at higher concentration. The increase or decrease in nitrogen content leads to alteration in synthesis of proteins as amino acids are the main constituents of proteins. El-Hydary & Chung (2013); Khan *et al*., (2014 and 2018) listed various biological herbicides that are responsible for increase and decrease in nitrogen content of different important crops like wheat, sorghum, soybean etc that inhibited or promoted protein, nucleic acids synthesis as well as altered various cellular activities like cell division, elongation, cell maturation etc. Current study hypothesized the effect of lemon grass on protein synthesis that showed increased production of proteins in leaf, root and shoot at lower concentration i.e., 10^{th} and 20^{th} spray which lowered at 30^{th} spray but eventually it increased at higher concentration more profoundly in leaves and shoots. It may be due to some higher accumulation of nitrogen in the cells that resulted in production of excessive proteins, transported and reserved in shoots. Higher protein synthesis took place in biological bodies due to the presence of nitrogen based compounds in the cells. This could lead to phyllogenetic variation in plants if the exposure persisted and the newly formed nitrogen bases and amino acids will take part in the revised genetic combination of the treated plants. Pedrol *et al*., 2006 contributed studies over stress related changes in plant metabolism claiming a strong possibility of alteration in genes expression to cope stress condition. In cases when stress intensity increased the production of stress protein may occur in response (Bray *et al*., 2000). Ingram & Bartel 1996; Grover, 2000 have isolated a number of genes that have produced as a result of water stressed condition in plants. Hence the genes if altered they would be able to produced phyllogenetic changes.

Therefore, it can be concluded that the extract influenced positively on the growth of sunflower plants as depicted in the predefined results. The consecutive increased exposure of extract observed to be greatly productive at the initial (10^{th} spray) while at the 20^{th} and 30^{th} spray the formed carbohydrates, proteins and chlorophyll a and b gradually undergo into a destructive or abnormal phase at a slower rate. This seems to be logical as any alien endogenous application probably produce constructive effects in the initial stages which upon increase in concentration produce inhibition to the host plants. In the current finding, an unexpected biochemical synthesis preferably proteins in leaves and stems and chlorophyll a in leaves observed at 40^{th} spray while the production of other compounds has decreased gradually at 20^{th} and 30^{th} spray events. This anomaly in greater production of compounds at higher concentration of lemongrass require expansion in the biochemical

investigations of lemongrass contents to fill the knowledge gap regarding lemongrass biochemistry. The highest response was observed from leaves among the other plant parts. Leaves attained rise in physical and physiological activity after exposure to lemongrass extract at various levels among other plant parts (roots and shoots) while 1% extract established the strongest productive effects among other treated plants. Biomass gain was also achieved highest in 1% samples followed by 0.5% samples. The findings showed that lemongrass foliar extract can be used for growth promotion in sunflower plants.

Conclusion

Current study recommends for application of natural bio-stimulants in agriculture for growth promotion in crops rather than applying artificial fertilizers. Utilization of natural herbs is an efficient way to reduce competition as well as for the enhancement of crop yield. Allometric examination provides a clear growth pathway of the plants hence efficiency of plants is important to study relative to their parts. In the light of current study, it can be concluded that not all the herbs reduce growth, they can be productive as a bio-fertilizer but the criteria varies upon species to species.

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