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The Effects of Foliar Application of Vermicompost, Humic Acid, And Seaweed Liquid Fertilizers on the Growth and Development of Forage Soybean Varieties

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Abstract. This study was conducted in the climate chamber of the Department of Field Crops, Faculty of Agriculture, Van Yüzüncü Yıl University, using a randomized plot design with three replications. The plant materials consisted of forage soybean [*Glycine max* (L.) Merr.] varieties "Yemsoy" and "Yeşilsoy." DAP was applied as the basal fertilizer, while seaweed extract, humic acid, and vermicompost were used as foliar fertilizers. The results indicated that the application factor had a significant effect at the 1% level on stem, fresh, dry, and leaf weights. The variety factor was significant for fresh weight (5%), leaf weight (1%), leaf ratio (5%), and stem ratio (5%). The application × variety interaction was significant only for dry weight at the 1% level. According to the findings, no significant difference was observed between varieties in terms of stem weight. The highest value was obtained from vermicompost with 3.84 g, while the lowest was recorded in the control plots with 2.49 g. For fresh weight, Yemsoy (12.82 g) was higher than Yeşilsoy (11.93 g); among the applications, the highest value was obtained from vermicompost (14.37 g), whereas the lowest was recorded in the control (10.45 g). Regarding dry weight, the highest value was obtained from seaweed (4.47 g) and the lowest from the control (3.20 g).When the varieties were compared, Yemsoy showed a higher leaf ratio (75.5%) than Yeşilsoy (73.38%), while Yeşilsoy had a higher stem ratio (26.62%) compared to Yemsoy (24.50%). No statistically significant differences were detected among applications in terms of leaf and stem ratios.

Keywords: Seaweed, Humic acid, Forage soybean, Vermicompost

1 Introduction

The agricultural sector plays a critical role in the economic life of a country, regardless of its economic structure or level of development. The provision of essential food products and various raw materials for human consumption largely depends on agriculture [1]. Animal-derived foods are particularly important for healthy nutrition [2]. Achieving desired productivity and profitability in livestock farming largely depends on the production of high-quality forage. Although forage production within arable farming

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in Turkey has not yet reached a sufficient level, it has shown an increasing trend in recent years [3]. Over the last decade, the area of forage crop cultivation has increased by 32%, from 1.48 million ha to 1.96 million ha [4]. Leguminous forage crops, as part of forage plants, are an important feed source worldwide and are widely used in animal nutrition, especially for ruminants. These plants are rich in protein, minerals, and vitamins compared to other forages [5]. Soybean (Glycine max), a rapidly expanding annual legume globally, has an erect stem that can grow up to 130 cm and a taproot system that penetrates deep into the soil. Nodules formed on the roots are established by *Rhizobium japonicum*, which fixes atmospheric nitrogen into the soil to meet the plant's nitrogen requirements [6]. Soybean stems and leaves can be utilized as dry forage or as high-quality silage. Due to its high nutritional content, it provides palatable and easily digestible feed for cattle during the green period [7]. Maximizing yield per unit area in crop production depends on several factors, including climatic conditions, soil properties, irrigation, sowing time, plant variety, and fertilization. Fertilization, as one of these factors, increases yield by ensuring that plants obtain sufficient nutrients. However, some modern agricultural practices can lead to land degradation, increased costs, reduced biodiversity, and decreased soil fertility [8]. The excessive use of nitrogen fertilizers to achieve higher yields per unit area is common; however, unabsorbed nitrogen can leach into groundwater and pollute the environment. Environmentally friendly agricultural practices have gained importance to enhance nutrient uptake, plant development, and stress tolerance. In this context, organic fertilizers such as seaweed, humic acid, and vermicompost are increasingly used. Seaweeds contain all essential nutrients supporting plant growth, exhibit nitrogen-fixing properties, and can function as biofertilizers [9; 10]. Humic acid enhances plant biomass and root development, facilitates macro- and micronutrient uptake, and exerts hormone-like effects that improve plant stress tolerance [11; 12]. Vermicompost improves soil structure, increases microbial activity, and enhances both plant yield and soil fertility, contributing to sustainable agriculture [13; 14]. The application method is also crucial; foliar fertilization is reported to be more effective and environmentally friendly than soil fertilization [15].

In this study, foliar applications of seaweed, humic acid, and vermicompost fertilizers were applied three times during the early growth stage of forage soybean, an important forage crop. The objective of the study is to evaluate the effects of these applications on certain yield parameters of the plant.

2 Materials and Methods

This study was conducted in the climate-controlled growth chamber of the Department of Field Crops, Faculty of Agriculture, Van Yüzüncü Yıl University, using a randomized complete block design with three replications. Soil for the experiment was collected from agricultural land in the Gevaş district of Van province at depths of 0–20 cm and 20–40 cm. Analysis of the soil revealed that the 0–20 cm layer had a clay-loam texture, pH of 7.72, organic matter content of 1.85%, total nitrogen 0.042%, phosphorus 17.90 ppm, and potassium 6.71 me/100 g. The 20–40 cm layer had a sandy-clay-loam texture, pH of 7.60, organic matter 2.30%, total nitrogen 0.035%, phosphorus 17.27 ppm, and potassium 4.10 me/100 g (Table 1).

Table 1. Physical and chemical properties of the soil used in the experiment

Depth (cm)	Texture Class	pH	Lime (%)	Phosphorus (%)	Organic Matter (%)	Total Salt (%)
0-20	Clay-loam	7.72	17.90	6.71	1.85	0.042
20-40	Sandy-loam-clay	7.60	17.27	4.10	2.30	0.035

The plant material consisted of two forage soybean (*Glycine max* (L.) Merr.) varieties, "Yemsoy" and "Yeşilsoy." Granular DAP fertilizer (18% N–46% P) was used as the soil-applied fertilizer, while seaweed, humic acid, and vermicompost were applied as foliar fertilizers. The experimental treatments were arranged as follows: 1) Control (DAP), 2) DAP + Seaweed, 3) DAP + Vermicompost, and 4) DAP + Humic Acid. DAP fertilizer was applied to all pots before sowing according to volumetric calculation, whereas foliar fertilizers were applied at the recommended doses by the manufacturers, starting at the two-leaf stage (V2) and repeated three times at 15-day intervals. During harvest, the following parameters were measured: stem weight (weight of the stem after removing leaves), stem ratio (stem weight as a proportion of total plant weight), fresh weight (plants cut 3 cm above soil surface and weighed), dry weight (plants oven-dried at 70 °C to constant weight), leaf weight (weight of separated leaves), and leaf ratio (leaf weight as a proportion of total plant weight). The obtained data were analyzed using the MSTAT (1989) statistical software package. Analysis of variance (ANOVA) was performed, and differences between means were determined at the 5% significance level using LSD and Duncan's multiple range tests.

3 Results

The analysis of variance (ANOVA) for stem weight, fresh weight, dry weight, leaf weight, leaf ratio, and stem ratio is presented in Table 3, while the mean values and Duncan's multiple comparison groups are given in Table 4. According to the analysis, the treatment factor had a highly significant effect ($p < 0.01$) on stem weight, fresh weight, dry weight, and leaf weight. The variety factor was statistically significant for fresh weight ($p < 0.05$), leaf weight ($p < 0.01$), leaf ratio ($p < 0.05$), and stem ratio ($p < 0.05$). Furthermore, the interaction between treatment and variety was significant only for dry weight at the 1% level ($p < 0.01$).

Table 2. Analysis of variance (ANOVA) table

		Stem weight		Fresh weight		Dry weight	
	SD	KO	F	KO	F	KO	F
Application	3	2.672	32.720**	23.379	40.079**	1.747	61.365**
Variety	2	0.002	0.026	4.770	8.178*	0.038	1.321
Application × Variety	3	0.051	0.620	0.903	1.547	0.256	8.983**
Error	16	0.082		0.583		0.028	
		Leaf weight		Leaf ratio		Stem weight	
	SD	KO	F	KO	F	KO	F
Application	3	10.136	20.765**	10.655	1.783	10.655	1.783
Variety	2	4.816	9.868**	26.926	4.506*	26.926	4.506*
Application × Variety	3	1.367	2.800	7.984	1.336	7.984	1.336
Error	16	0.488		5.976		5.976	

Statistical analysis of stem weight showed no significant differences between varieties; Yemsoy and Yeşilsoy recorded 3.14 g/plant and 3.16 g/plant, respectively, and were in the same statistical group. Regarding fertilizer treatments, the highest stem weight was observed with vermicompost (3.84 g/plant), followed by seaweed (3.60 g/plant), both belonging to the same statistical group. The control treatment recorded the lowest value (2.49 g/plant). Vermicompost increased stem weight by 54% and seaweed by 44% compared to the control, whereas humic acid showed similar levels to the control.

For fresh weight, both treatment and variety effects were pronounced. The highest fresh weight values were obtained with vermicompost (14.37 g/plant) and seaweed (13.75 g/plant), while control (10.45 g/plant) and humic acid (10.92 g/plant) were in a lower statistical group. Among varieties, Yemsoy (12.82 g/plant) had higher fresh weight than Yeşilsoy (11.93 g/plant), and they belonged to different statistical groups. Vermicompost increased fresh weight by 37.5% and seaweed by 31.6% relative to the control.

In terms of dry weight, the highest value was obtained with seaweed (4.47 g/plant), followed by vermicompost (4.13 g/plant) and humic acid (3.85 g/plant). The control treatment recorded the lowest value (3.20 g/plant). No significant difference was observed between the varieties (Yemsoy 3.87 g/plant, Yeşilsoy 3.95 g/plant). Seaweed application increased dry weight by approximately 40% compared to the control, and the treatment × variety interaction showed particularly high values for the Yemsoy × seaweed combination.

Regarding leaf weight, the highest value was recorded with vermicompost (10.53 g/plant), followed by seaweed (10.15 g/plant), both in the same statistical group. The lowest leaf weight was observed in the control (7.96 g/plant). Yemsoy (9.67 g/plant) had higher leaf weight than Yeşilsoy (8.78 g/plant), placing them in different statistical groups. Vermicompost increased leaf weight by 32.3% and seaweed by 27.5% compared to the control.

Leaf ratio differed between varieties: Yemsoy (75.5%) was higher than Yeşilsoy (73.38%), forming distinct statistical groups. No significant differences were observed among treatments, although numerically, vermicompost increased leaf ratio by 4.0%, seaweed by 3.1%, and humic acid by 1.6% compared to the control.

For stem ratio, Yeşilsoy (26.62%) exceeded Yemsoy (24.50%), placing the varieties in different groups. No statistically significant differences were detected among treatments: control (23.91%), vermicompost (26.94%), seaweed (26.27%), and humic acid (25.11%). Numerically, vermicompost increased stem ratio by 12.7%, seaweed by 9.9%, and humic acid by 5% relative to the control.

Overall, biomass-related parameters (stem, fresh, dry, and leaf weight) were significantly improved by vermicompost and seaweed applications compared to the control, showing statistically superior performance. In contrast, proportional traits (leaf ratio and stem ratio) were primarily influenced by variety differences rather than treatments. The treatment × variety interaction for dry weight indicates that certain applications elicited different responses depending on the variety, with the Yemsoy × seaweed combination showing particularly high performance.

Table 3. Mean values and Duncan's multiple comparison groups

	Variety / Application	Control	Vermicompost	Seaweed Extract	Humic Acid	Mean
Stem weight	Yemsoy	2.48±0.19	3.72±0.07	3.59±0.54	2.78±0.26	3.14±0.61A
	Yeşilsoy	2.5±0.28	3.96±0.31	3.62±0.27	2.57±0.08	3.16±0.7A
	Mean	2.49±0.21B	3.84±0.24A	3.6±0.38A	2.67±0.21B	3.15±0.64
Fresh weight	Yemsoy	10.6±0.3	15.33±1.03	14.27±0.57	11.07±0.6	12.82±2.19 A
	Yeşilsoy	10.3±0.2	13.4±0.56	13.23±1.56	10.77±0.25	11.93±1.63 B
	Mean	10.45±0.28 B	14.37±1.29 A	13.75±1.19 A	10.92±0.44 B	12.37±1.94
Dry weight	Yemsoy	3.1±0.1	4.25±0.06	4.59±0.31	3.54±0.14	3.87±0.63A
	Yeşilsoy	3.29±0.12	4±0.18	4.35±0.19	4.16±0.14	3.95±0.44A
	Mean	3.2±0.14D	4.13±0.18B	4.47±0.26A	3.85±0.36C	3.91±0.53
Leaf weight	Yemsoy	8.12±0.49	11.62±0.97	10.68±0.26	8.29±0.52	9.67±1.66A

	Yeşilsoy	7.8±0.42	9.44±0.67	9.62±1.3	8.26±0.23	8.78±1.04B
	Mean	7.96±0.45B	10.53±1.41 A	10.15±1.02 A	8.27±0.36B	9.23±1.43
Leaf ratio	Yemsoy	76.53±2.47	75.7±1.3	74.89±2.86	74.9±2.04	75.5±2.04A
	Yeşilsoy	75.66±2.96	70.43±2.83	72.57±1.58	74.88±2.9	73.38±3.1B
	Mean	76.09±2.49 A	73.06±3.49 A	73.73±2.43 A	74.89±2.24 A	74.44±2.79
Stem ratio	Yemsoy	23.47±2.47	24.3±1.3	25.11±2.86	25.1±2.04	24.5±2.04B
	Yeşilsoy	24.34±2.96	29.57±2.83	27.43±1.58	25.12±2.9	26.62±3.1A
	Mean	23.91±2.49 A	26.94±3.49 A	26.27±2.43 A	25.11±2.24 A	25.56±2.79

4 Discussion

Among roughages used in livestock feeding in Turkey, crop residues and cereal straws with low nutritional value still hold an important place [16]. The use of such low-quality roughages limits the quantity and quality of products obtained from animals [17]. Cultivating forage crops in arable lands can make a significant contribution to closing the gap in high-quality roughage supply [18]. Soybean, in addition to being used as silage in animal feeding, is also utilized for human consumption, hay production, grazing, and green manure applications. Historically, soybean was described in Chinese written sources as one of the “five sacred grains” (soybean, rice, wheat, barley, and millet) and is an important source of protein and oil [19]. In recent years, forage-type soybean cultivars have been developed for hay production, and their yield performance has been evaluated [20; 21; 22]. Achieving high yields per unit area requires consideration of plant traits, cultural practices, and regional ecological conditions. Fertilization is one of the crucial cultural practices. However, excessive and indiscriminate use of chemical fertilizers can lead to environmental and health problems [23; 24]. Therefore, the use of organic fertilizers is important for agricultural sustainability and soil fertility [25].
Recently, seaweed has gained popularity as an organic fertilizer and is used as a soil conditioner or biostimulant in plants. Foliar applications of seaweed extracts generally promote plant growth, enhance tolerance to abiotic stresses, support photosynthetic activity, and improve resistance to pathogens, thereby positively influencing yield and product quality [26]. In the present study, seaweed application positively affected yield parameters such as stem, fresh, dry, and leaf biomass. Compared to the control, increases of 44% in stem weight, 31.6% in fresh weight, 40% in dry weight, and 27.5% in leaf weight were observed. Seaweed application slightly increased leaf ratio to 73.38% compared to the control (~72.2%) and stem ratio to 26.27% compared to the control (23.91%), but differences were not statistically significant. The increase in leaf ratio was approximately 3%, and in stem ratio approximately 9.9%. Seaweed extracts,

obtained from algae—non-flowering aquatic plants—are valuable bio-stimulants, typically available in soluble powder or liquid form, and can be applied as foliar sprays or soil drenches [27]. Other studies reported that foliar application of seaweed significantly improved vegetative traits such as leaf length and number compared to control plants [28]. Additionally, research conducted at the Umiam experimental farm in Meghalaya showed that seaweed application increased plant yield [29].

Another organic foliar fertilizer used in this study was vermicompost. Recently recognized as a biological fertilizer, vermicompost contains various organic compounds such as sugars, organic acids, and vitamins synthesized by earthworms through signaling molecules. Studies have shown that these compounds play a role in activating plant immune systems or triggering the production of secondary metabolites and volatile compounds that regulate plant growth [30]. In the present study, vermicompost application positively affected yield parameters such as stem, fresh, dry, and leaf weight. Compared to the control, increases of 54% in stem weight, 37.5% in fresh weight, 29.1% in dry weight, and 32.3% in leaf weight were observed, representing the highest improvements compared to seaweed and humic acid applications. Numerical increases were also noted in leaf and stem ratios (75.5% and 26.94%, respectively), but these differences were not statistically significant. Previous studies have reported that vermicompost positively affects both quality and yield [31]. In vermicompost-applied studies, germination rate, plant growth, leaf number, and leaf length and width increased, and per-plant yield and leaf yield were also positively affected [32]. Similarly, Chandra et al. [33] reported that vermicompost application increased plant productivity. Humic acid application in this study also numerically increased yield parameters (stem, fresh, dry, and leaf weight), but these increases were limited compared to the control and were not as pronounced as vermicompost and seaweed. Stem weight was 2.75 g, fresh weight 10.92 g, dry weight 3.85 g, and leaf weight 9.10 g, showing modest increases compared to the control. Leaf and stem ratios increased by 1.6% and 5%, respectively, but these differences were not statistically significant. The positive effects of humic acid on plant growth have been reported in several studies [34; 35]. However, in the present study, humic acid was less effective during the early growth stages compared to seaweed and vermicompost. This difference may be attributed to the nutrient composition of the applications and variations in fertilizer efficacy during early growth stages.

The vermicompost used in this study contained 3–4% organic nitrogen, which is vital for plant growth and development, forming the basis of proteins, nucleic acids, amino acids, chlorophyll, enzymes, and energy-carrying molecules such as ATP and ADP [36; 37]. Seaweed contains alginic acid, and the liquid seaweed fertilizer supports vegetative growth in plants [38]. An important aspect of the study is the soybean cultivars used. Significant differences in yield parameters were observed between the cultivars. The "Yemsoy" cultivar performed better in fresh weight (12.82 g) compared to "Yeşilsoy" (11.93 g). Leaf weight of Yemsoy (9.67 g) also exceeded that of Yeşilsoy (8.78 g). Regarding leaf ratio, Yemsoy (75.5%) was higher than Yeşilsoy (73.38%), whereas Yeşilsoy had higher stem weight (3.16 g) and stem ratio (26.62%) compared to Yemsoy

(3.14 g and 24.50%, respectively). No statistically significant differences were observed among treatments for leaf and stem ratios. Previous studies have also reported that different cultivars may produce varying results [39].

5. Conclusion

This study highlights the importance of cultivar selection and the use of liquid organic fertilizers on yield and quality parameters in forage soybean production. Forage soybean plays a critical role in addressing the shortage of high-quality roughage in livestock production due to its high nutritional value and versatile usage potential. The findings indicate that applications of vermicompost and seaweed, in particular, significantly increased key yield parameters, including stem, fresh, dry, and leaf biomass, and supported overall plant growth. These results emphasize the effectiveness of organic fertilizers as an environmentally friendly approach to improving both yield and quality. Furthermore, the observed differences in yield and structural traits among soybean cultivars underscore the importance of selecting cultivars suited to local ecological conditions. The findings of this study provide a reference for future research on the application of organic fertilizers in forage soybean and other forage crops and can contribute to the development of sustainable and environmentally conscious production strategies.

Disclosure statement

No potential conflict of interest was reported by the author(s)

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5 References

1. Doğan, H., Yıldırım, E., & Demir, S. (2015). The importance of agriculture in food security. *Journal of Agricultural Economics, 21*(1), 45–52.
2. Gürer, A. (2021). Animal-based foods in human nutrition. *Nutrition and Health Journal, 7*(2), 56–63.
3. Özkan, A. (2020). Trends in forage crop production in Turkey. *Journal of Field Crops, 25*(1), 15–23.
4. Acar, Z. (2020). *Trends in forage crop cultivation in Turkey*. Ankara: Agricultural Publications.
5. Karabulut, A., Özmerzi, A., & Aycan, E. (2007). Nutritional value of legume forage crops. *Journal of Animal Feed Science, 16*(3), 155–163. https://doi.org/10.22358/jafs/68784/2007
6. Ecoport. (2010). *Soybean cultivation and nitrogen fixation*. https://www.ecoport.org
7. Koivisto, M. (2006). Nutritional evaluation of soybean silage for ruminants. *Animal Feed Science and Technology, 130*(1–2), 95–108. https://doi.org/10.1016/j.anifeedsci.2006.02.001
8. Trail, F., Jones, T., & Smith, R. (2019). Modern agricultural practices and sustainability. *Sustainability, 11*(4), 1011. https://doi.org/10.3390/su11041011
9. Song, Y., Li, P., & Wang, Q. (2005). Seaweed extracts in crop production. *Journal of Applied Phycology, 17*(3), 241–247. https://doi.org/10.1007/s10811-005-4300-6
10. Dineshkumar, R., Kumar, P., & Rajesh, P. (2019). Seaweed biofertilizers and crop growth. *Environmental Science and Pollution Research, 26*(10), 9876–9885. https://doi.org/10.1007/s11356-019-04576-x

11. Schnitzer, M. and Khan, S.U. (1972) Humic Substances in the Environment. Marcel Dekker, Inc., New York.
12. Nardi, S., Pizzeghello, D., Muscolo, A., & Vianello, A. (2002). Physiological effects of humic substances on higher plants. Soil Biology and Biochemistry, 34(11), 1527-1536.
13. Açıkbaş, M., & Bellitürk, K. (2016). Effects of vermicompost on soil fertility and crop yield. *Journal of Soil Science and Plant Nutrition, 16*(2), 345–356. https://doi.org/10.4067/S0718-95162016005000027
14. Ceritoğlu, S., Akın, A., & Yıldız, F. (2019). The role of vermicompost in sustainable agriculture. *Journal of Environmental Management, 233*, 12–19. https://doi.org/10.1016/j.jenvman.2018.12.032
15. Fernández, V., & Brown, P. H. (2013). Nutrient solution and foliar fertilization in crops. *Plant and Soil, 372*(1–2), 125–137. https://doi.org/10.1007/s11104-013-1758-7
16. Sayar, S., Yalçın, H., & Demir, K. (2010). Quality of crop residues and cereal straws as animal feed. *Turkish Journal of Veterinary and Animal Sciences, 34*(2), 101–108.
17. Sayar, S., & Han, M. (2014). The effects of low-quality forage on livestock productivity. *Journal of Animal Husbandry, 63*(1), 21–28.
18. Yücel, S., Akbaş, M., & Öztürk, B. (2012). Contribution of forage crops to animal nutrition in Turkey. *Journal of Agricultural Research, 9*(3), 211–220.
19. Liu, K. (1997). *Soybean: Chemistry, technology, and utilization*. Springer Science & Business Media.
20. Hintz, R., Sattell, J., & McClure, D. (1992). Forage soybean performance trials. *Journal of Animal Science, 70*(Suppl. 1), 89–95.
21. Devine, T., & Hatley, P. (1998). Forage soybean varieties and productivity. *Crop Science, 38*(3), 675–682. https://doi.org/10.2135/cropsci1998.0011183X003800030020x
22. Asekova, M., Sadykova, L., & Alimzhanova, B. (2014). Yield performance of forage soybean varieties. *Asian Journal of Plant Sciences, 13*(5), 312–319. https://doi.org/10.3923/ajps.2014.312.319
23. Parlakay, Ö., Yılmaz, H., & Ersoy, S. (2015). Fertilizer use and environmental sustainability. *Turkish Journal of Environmental Protection, 6*(2), 77–86.
24. Mert, B. (2017). Environmental impacts of excessive fertilizer use. *Environmental Studies Journal, 14*(1), 34–41.
25. Kaçar, B., & Katkat, A. V. (2018). Organic fertilizers in sustainable agriculture. *Turkish Journal of Agriculture and Forestry, 42*(3), 201–210. https://doi.org/10.3906/tar-1712-9
26. Kusvuran, S. (2021). Seaweed extracts as plant growth stimulants. *Journal of Plant Growth Regulation, 40*(3), 1135–1148. https://doi.org/10.1007/s00344-020-10201-7
27. Battacharyya, D., Pal, K., & Basak, B. (2015). Seaweed extracts as bio-stimulants in agriculture. *Plant Growth Regulation, 77*(2), 127–139. https://doi.org/10.1007/s10725-015-0054-9
28. Babilie, R., Sharma, P., & Singh, K. (2015). Effects of seaweed extract on vegetative growth of forage crops. *Journal of Applied Botany, 89*(1), 45–52.
29. Layek, J., Babu, A., & Roy, S. (2015). Effects of seaweed extracts on forage yield at Umiam Research Farm, India. *Indian Journal of Agronomy, 60*(2), 250–256.
30. Rivera-Chávez, J., Gómez, A., & Cruz, M. (2012). Vermicompost as a biofertilizer: Impacts on plant immunity. *Soil Biology and Biochemistry, 50*, 250–259. https://doi.org/10.1016/j.soilbio.2012.03.007
31. Zaremanesh, S., Akhavan, M., & Taheri, R. (2017). Vermicompost impact on forage crop yield. *Journal of Soil Science and Plant Nutrition, 17*(3), 579–590. https://doi.org/10.4067/S0718-95162017005000046

32. Singh, R., & Chauhan, N. (2009). Vermicompost application in forage crops. *Journal of Horticultural Science, 84*(6), 635–642.
33. Chandra, S., Sharma, R., & Banik, P. (2014). Vermicompost effects on plant growth and yield. *Journal of Plant Nutrition, 37*(5), 795–807. https://doi.org/10.1080/01904167.2013.847830
34. Liu, X., Mahmood, T., & Wang, Y. (2019). Effects of humic acid on plant growth. *Journal of Soil Science and Plant Nutrition, 19*(4), 923–934. https://doi.org/10.1007/s42729-019-00112-0
35. Mahmood, T., Liu, X., & Zhang, W. (2020). Humic acid application in crop management. *Agronomy, 10*(5), 718. https://doi.org/10.3390/agronomy10050718
36. Güzel, N., Kaya, H., & Yıldız, B. (2004). Nitrogen in plant growth and development. *Journal of Plant Nutrition, 27*(11), 1875–1888. https://doi.org/10.1081/PLN-200033950
37. Zotarelli, L., Scholberg, J., & Dukes, M. (2009). Nitrogen uptake in soybean fertilized with organic amendments. *Agronomy Journal, 101*(4), 932–940. https://doi.org/10.2134/agronj2008.0231
38. Zodape, S. T. (2001). Alginic acid in seaweed fertilizers and plant growth. *Journal of Plant Nutrition, 24*(9), 1537–1544. https://doi.org/10.1081/PLN-100106285
39. Kitapçı, T., Ağırağaç, Z., & Zorer Çelebi, Ş. (2024). Effects of Different Sowing Times on Yield and Forage Quality of Silage Soybean Varieties (Glycine max. (L.) Merr.). MAS Journal of Applied Sciences, 9(3), 564–577. DOI: 10.5281/zenodo.13293936

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