Growth and Flowering Response of Lagurus (*Lagurus ovatus* L.) to *Ascophyllum nodosum* Extract Based Biostimulant and Gibberellic Acid (GA_3) Application

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Research Article

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Abstract

Lagurus (*Lagurus ovatus* L.) is an important ornamental annual grass with fluffy flower heads which are in high demand in dry flower industry. The stems of lagurus are frequently used in floral arrangements and dried flower crafts. The utility of this flower in the dry flower industry cannot be underrated. Despite the huge demand for this flower, the economic returns obtained from its sale are comparatively low which is mainly due to the production of short stems and smaller heads that fetch low prices in the market. Therefore, the present investigation was undertaken with the key objectives of assessing the influence of different levels of seaweed extract containing *Ascophyllum nodosum* (control, 2ml L^{-1} and 4ml L^{-1}) and GA_3 (control, 150 ppm, 250 ppm, 350 ppm and 450 ppm) on the growth and flowering of gurus. The seaweed extract was applied as drench and was applied as foliar spray. A higher dose (4ml L^{-1}) of seaweed extract performed superior in terms of plant spread, number of leaves, flag leaf length, flag leaf width, leaf area, chlorophyll content at 30,60 and 90 days after transplanting, days taken to flower bud initiation, days to flowering, number of inflorescences per plant, flower head length, weight of root, weight of shoot and root: shoot ratio and root length. On the contrary highest plant height and stem length was recorded without any seaweed extract and 450 ppm GA_3 produced maximum plant height, plant spread, number of leaves, flag leaf length, leaf area, chlorophyll content at 30,60 and 90 days after transplanting, days to first flower bud initiation and days to flowering, number of inflorescences per plant, flower head length, stem length, fresh and dry weight of shoot and root length. However, GA_3 application of @ 350 ppm resulted in the highest root dry weight and root: shoot ratio while maximum flag leaf width (1.21 cm), root fresh weight was found with GA_3@ 250 ppm. An increase in GA_3 dose resulted in a linear increase in growth and flowering parameters.

Introduction

Lagurus (*Lagurus ovatus* L.) commonly known as hare's tail grass or bunny tail grass is an ornamental winter season annual grass belonging to the Poaceae family (https://plants.ces.ncsu.edu/plants/lagurus-ovatus/). Lagurus possesses a diploid chromosome number of 2n=14 (Spies and van Wyk 1995) and typically attains a modest height ranging from 30 to 50 cm (Chelariu et al. 2018). Lagurus prefers soils having PH ranging between 6.6 to 7.5 and sunny locations for better growth (Brickell and Cathey 2004; Ondono et al. 2016). Lagurus is a hardy clump forming grass (Tomaskin and Tomaskinova 2020) oftenly grown in gardens in mixed borders for exquisite looks due to flower panicles displaying narrow soft leaf blades and sheaths covered with fine hairs. It is easily propagated through seeds (Chelariu et al. 2018). It is preferably used in the dry flower industry to create value-added products like flower bouquets, arrangements, wall pictures, hangers and other decorative items (Kashyap et al. 2016). In India its production is limited to certain regions only to meet out the demand of dry flowers for domestic purposes and for export. Despite the huge demand of this flower, the economic returns obtained from its sale are comparatively low which is mainly due to the production of short stems and smaller heads that fetch less price in the market. However, very scanty research has been

carried out in this crop so far. The scientific data specifically related to its growth and flowering is scarce.

Seaweed and its derived products are commonly utilized in crop production due to the presence of several plant growth-stimulating compounds (Khan et al.2009). Seaweed is alternative to synthetic fertilizers and are used to improve crop yields (Fleurence 2022). Seaweeds stimulates plant growth and root elongation due to the presence of growth hormones like auxins or auxin like compounds, cytokinins, giberellins and betaine (Fleurence 2022; Nedumaran 2017; Patel and Mukherjee 2021). Moreover, Mohy El-Din (2015) concluded that seaweed liquid fertilizers are effective and low cost fertilizers that can be produced as eco-friendly biofertilizers.

It was reported earlier that seaweeds are source of plant growth regulators, organic osmolites, amino acids, mineral nutrients, vitamins and vitamin precursor (Sahoo 2000; Khan et al. 2009). As far as the sustainability is concerned, application of seaweed extract for crop production seems to be promising. Seaweeds are also rich in potassium, nitrogen and micronutrients which serve as outstanding fertilizers (Dhargalkar and Pereira 2005).

Seaweeds are valuable component affecting plant physiology and aiding plants in adapting to stressful conditions (Matysiak et al. 2011). They encompass green, brown and red marine macro algae. Extracts of brown seaweeds are extensively utilized in horticultural crops due to their ability to promote plant growth and enhance crop tolerance to abiotic stresses; including salinity, extreme temperatures, nutrient deficiency, and drought (Bhattacharya et al. 2015) and to foster the development and strengthen the quality performance of floricultural crops (Kularathne et al. 2021).

Studies conducted by various workers and co-workers using seaweed extract biostimulants in ornamental crops, grasses and field crops as foliar and drench applications shows positive effects as reported by Harhash et al. (2023) in Dahlia; Al-Karimjassim and Radhi (2019) in freesia; Krajnc et al. (2012) in pelargonium; dos Santos et al. (2019) in ornamental sunflower; Zhang et al. (2023) in *Agrostis stolonifera*; Muraleedharan et al. (2020) in anthurium; Loconsole et al. (2022) in *Lantana camara* and *Abelia x grandiflora*; Al Hasany et al. (2019), Mohy El-Din (2015) and Matysiak et al. (2011) in wheat; Traversari et al. (2022) and Sumangla et al. (in rose; Li and Mattson (2015) in petunia.The extract from *Ascophyllum nodosum* seaweed is beneficial in improving seedling growth and development and reducing their production expenses. However, to maximize the bio stimulant effects the correct concentration must be used (dos Santos et al. 2019).

Commercial growers of ornamental plants incorporate the use of plant growth regulators in their cultivation practices. Among the growth regulators GA_3 is most widely used. Gibberellic acid, a tetra cyclic diterpenoid compound acts as a plant hormone, promoting growth and development by triggering transitions from juvenile to adult leaf stage, meristem to shoot growth, vegetative to flowering, as well as influencing sex expression and grain development (Gupta and Chakrabarty 2013). Many studies on growth promotion with GA_3 present an insight into its role in floral transition and elongation of stem and

enhancement of flowers size (Hew and Clifford 1993). Gibberellins are also reported to be responsible for regulating a variety of plant development processes including major flowering stages (Kozlowska et al. 2007). Most studies report the effects of GA_3 on various ornamental plants but there is insufficient knowledge on the effect of GA_3 on growth and flowering of lagurus. Exogenous application of GA_3 regulates the physiological activities of flowering crops, ultimately influencing their growth and production in many flowering crops (Girwani et al. 1990; Pal 2019; Pradeep Kumar et al. 2020).

Materials And Methods

Experimental Site and Location

The study was conducted at the Experimental Farm of the Division of Floriculture and Landscaping, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India during the year 2023-2024. The experimental site is situated at an elevation of 296 meters above mean sea level (MSL) and at a latitude of 33°55' North and longitude of 74°58' East. The area experiences subtropical climate with hot dry summer, hot and humid rainy season, and cold winter. Meteorological data recorded during the cropping period shows that average rainfall ranges between 0.24 mm to 3.23 mm and minimum and maximum temperature ranges between 5.95^{o}C to 31.99^{o}C. Relative humidity during the period ranges from 42.13 to 91.97 percent.

Nursery Preparation

Nursery bed measuring 1.25 m × 3 m was prepared, with thorough hoeing and weeding. The bed was elevated 15 cm above the ground level to facilitate proper drainage of excess water. Well composted farmyard manure was incorporated into the bed and seeds were sown in the mid of October month by line sowing method. The seeds were sown in rows 5 cm apart and at a depth of 2-3 cm. The opened rows were filled with a mixture of farmyard manure, soil, and sand in a 2:1:1 ratio. Nursery beds were mulched with straw and then watered using a fine rose can. Once the seed sprouted, the mulch was removed.

Field Preparation, Transplanting and Aftercare

The experimental field was conditioned to a fine tilth by ploughing 2 to 3 times using a tractor equipped with a rotavator. After removing plant residues and weeds, the field was levelled. Subsequently, beds of the necessary dimensions were made as per the layout plan.

Healthy seedlings having fully expanded 4 leaves were transplanted in the experimental plots at a spacing of 30 cm x 30 cm, accommodating 9 seedlings per bed of dimensions 1m x 1m. To minimize transplanting shock, transplanting was carried out during the cooler evening hours. Immediately after transplanting, light irrigation was given. To ensure full plant population, mortality if any in the transplanted seedlings was replaced with fresh seedlings during the first ten days after transplanting. After the establishment of transplanted seedlings, standard intercultural operations were followed.

Experimental Design

The experiment was laid out in Factorial Randomized Complete Block Design with two factors and three replications. Treatments comprised of three levels of seaweed extract soil drenches (untreated control, 2ml L^{-1} and 4ml L^{-1}) and five levels of foliar sprays of Gibberellic Acid (untreated control, 150 ppm, 250 ppm, 350 ppm and 450 ppm).

Administration of Treatments

The commercial seaweed extract BIOVITA® (PI Industries Ltd., Gujarat, India) was used for the experiment. The commercial formulation of brown algae *Ascophyllum nodosum* which contains 200 ppm Sulphur, 500 ppm Magnesium, 500 ppm Calcium, 5000 ppm Sodium, 20 ppm Boron, 20 ppm Iron, 1 ppm Manganese, 1 ppm Copper, 5 ppm Zinc and traces of cytokinins, auxins, proteins and amino acids. Seaweed extract was prepared in three concentrations of 0, 2 and 4 ml L^{-1} by diluting the commercial formulation with water. Seaweed extract was given as soil drench at 30, 60 and 90 days after transplanting. Control plants were drenched with water.

For administration of gibberellic acid, commercial formulation of gibberellic acid (CDH® Pvt. Ltd., New Delhi, India) was used. Gibberellic acid was prepared in five concentrations of 0, 150, 250, 350, 450 ppm. The plants were sprayed with gibberellic acid at 30, 60 and 90 days after transplanting. Control plants were sprayed with water. All the plants received thorough spray from the top to the ground level till runoff.

Measurement of Growth and Flowering Parameters

The data on various morpho-floral parameters were recorded for each treatment by randomly selecting five plants per treatment per replication. Plant height and plant spread were measured at peak flowering stage. The length and width of uppermost leaf was measured as flag leaf length and width respectively. Leaf area was determined by using a Leaf area meter 211 (SYSTRONICS® India Ltd.) during peak flowering stage. The sampling of leaf was done from the top, middle and bottom of the plant and the average was worked out. The chlorophyll content of leaf was recorded at 30, 60, and 90 days after transplanting with the help of the SPAD - 502 chlorophyll meter (Minolta Corporation Ltd., Osaka, Japan) on three newly expanded leaves and three fully matured leaves separately and averaged at each group.

At full maturity, the representative plants were uprooted for destructive sampling. Plant parts were separated into roots and shoots. Fresh weight of each part was determined immediately after harvest and the plant parts were dried in a hot air oven at 52^{o}C for 24 hours until a constant weight was obtained. After drying, shoot and root weight was calculated. The root: shoot ratio on fresh and dry weight basis was derived to denote the ratio of water-absorbing area (root) and the transpiration area (shoot) of a plant and was calculated as outlined by Racey (1985).

Statistical Analysis

The data pertaining to the growth and flowering parameters were analyzed using analysis of variance (ANOVA) to test the significance in the data recorded. The means were compared with Duncan's Multiple Range Test at 5% probability where ANOVA indicated significant differences. The analysis was conducted using SPSS analytical package (IBM SPSS Statistics 27.0.1). Correlation and principal component analysis for various parameters were worked out using R-software package for data analysis.

Results

Growth Traits

The results indicate that both seaweed extract and GA_3 treatments significantly affected growth attributes (refer to Tables 1, 2, 3, 4, 5, 6 and Fig. 1). The plants drenched three times with seaweed extract at 4 ml L^{-1} produced substantially higher plant spread (44.39 cm), number of leaves (296.69), flag leaf length (6.92 cm), flag leaf width (1.22 cm), leaf area (5.46 cm^2) and reduced plant height, with the control treatment exhibiting the tallest plants of 56.12 cm. The plant sprayed three times with 450 ppm GA_3 steadily increased plant height (65.45 cm), plant spread (46.49 cm), number of leaves (314.78), flag leaf length (7.57 cm) and leaf area (5.88 cm^2). Similarly, 250 ppm GA_3 resulted in a maximum flag leaf width (1.21 cm). Among the various combinations of treatments, the maximum plant height recorded was 69.13 cm with the application of 0 ml L^{-1} seaweed extract and 450 ppm GA_3. Furthermore, the combination of 4 ml L^{-1} seaweed extract combined with 450 ppm GA_3 resulted in notable increase in plant spread (49.20 cm) and leaf number (320.67). However, the effects on flag leaf length, flag leaf width, and leaf area did not show any significant results.

Chlorophyll Contents

The findings indicate that both seaweed extract and GA_3 significantly influenced chlorophyll levels (see Tables 7, 8 and 9). Plants that received a seaweed extract treatment of 4 ml L^{-1} exhibited notably elevated chlorophyll content measured at 30, 60, and 90 days after transplanting, yielding SPAD values of 29.00, 39.44, and 42.73, respectively. Similarly, the foliar application of 450 ppm GA_3 resulted in a consistent increase in chlorophyll content at 30, 60, and 90 days after transplanting, with SPAD values recorded at 27.73, 38.91, and 43.09, respectively. Among the various treatment combinations, the highest chlorophyll content at all measured intervals (30, 60, and 90 days after transplanting) was observed with the conjoint application of 4 ml L^{-1} seaweed extract plus 0 ppm GA_3, producing SPAD values of 30.97, 41.82, and 45.04, respectively.

Flowering Traits

The different concentrations of seaweed extract and GA_3 had a notable impact on flowering characteristics (see Tables 10, 11, 12, 13,14 and Fig. 2 and 3). The application of 4 ml L^{-1} of seaweed extract significantly reduced the time required for the first flower head initiation (97.86 days) and the overall time to flowering (104.77 days). Furthermore, it led to an increased number of inflorescences per plant (172.76) and longer flower head length (4.25 cm), while also resulting in shorter stem lengths, with the control group displaying the tallest stem at 52.22 cm. Similarly, plants treated with foliar application of 450 ppm GA_3 exhibited a consistent decrease in the number of days until the first flower head initiation (95.90 days) and flowering (101.27 days), while simultaneously increasing the number of inflorescences per plant (177.89), flower head length (4.64 cm) and stem length (62.92 cm). Of all the treatment combinations, 0 ml L^{-1} seaweed extract + 450 ppm GA_3 resulted in the longest stem length observed at 67.32 cm. Additionally, combination of 4 ml L^{-1} seaweed extract + 450 ppm GA_3 reduced the number of days to first flower head initiation (95.00 days) and flowering (100.13 days) while increasing the inflorescences per plant to 188.27. However, the interaction on the size of the flower heads was non-significant.

Root and Shoot Traits

The characteristics of both roots and shoots were significantly influenced by the seaweed extract and GA_3 (as shown in Tables 15, 16, 17, 18, 19, 20, and 21). The application of 4ml L^{-1} seaweed extract resulted in the most remarkable measurements, including the highest fresh root weight of 20.68 g, fresh shoot weight of 104.96 g, root dry weight of 9.99 g, shoot dry weight of 49.55 g and a root-to-shoot ratio of 0.23 (on fresh weight basis) and 0.22 (on dry weight basis), along with a root length measuring 12.50 cm. For plants treated with GA_3, foliar application of 450 ppm demonstrated significant results, achieving a maximum fresh shoot weight of 103.11 g, a dry shoot weight of 50.69 g and a root length of 12.37 cm. Moreover, the maximum fresh weight of shoots (104.96 g), root dry weight (9.80 g), and root-to-shoot ratio of 0.26 (on fresh weight basis) and 0.22 (on dry weight basis) were recorded with 350 ppm GA_3. Although, 250 ppm GA_3 noted the highest fresh root weight of 23.18 g. Among the various combinations, the best results for shoot fresh weight (108.85 g) and dry weight (52.07 g) were observed with treatment combination of 4 ml L^{-1} seaweed extract plus 450 ppm GA_3. Additionally, highest fresh root weight of 26.87 g was found with 2 ml L^{-1} seaweed extract plus 250 ppm GA_3. The treatment combination 4 ml L^{-1} seaweed extract plus 350 ppm GA_3 produced dry root weight of 11.53 g and a root-to-shoot ratio of 0.24 on a dry weight basis. However, the interaction effects on the fresh root-to-shoot ratio and root length were found to be non-significant.

Correlation Analysis

The correlation plot provides an in-depth look at how different plant traits interact with each other, revealing both positive and negative relationships (Fig. 4). The plant height exhibit strong positive correlations with plant spread (r= 0.56, p=0.74), number of leaves (r=0.74, p=0.74), number of inflorescence (r=0.62, p=0.05) and dry weight of shoot (r=0.65, p=0.01). Length of flower head was found

to be positively correlated with plant spread (r=0.75, p=0.01) and stem length (r=0.63, p=0.05). Stem length was also positively correlated with plant spread (r=0.60, p=0.05), number of leaves (r=0.75, p=0.01) and fresh weight of shoot (r=0.54, p=0.05). This means that plants with greater height tend to increase plant spread, greater number of leaves and inflorescences. As plant height increases, so does the number of leaves and inflorescences, which are also indicators of overall plant vigor and health.

On the other hand, traits associated with early flowering, such as the first flower head initiation and days to flowering, show strong negative correlations with traits like plant height, plant spread, number of leaves, chlorophyll content, number of inflorescences and root length. This suggests that plants that flower earlier tend to have lower plant height, lower plant spread, fewer leaves and lower chlorophyll content, which might reflect a trade-off where energy is allocated more towards reproductive processes at the expense of vegetative growth.

Yield attributes parameter i.e. number of inflorescences shows a significant positive correlation with parameters *viz.*, stem length (r=0.63, p=0.05), dry weight of root (r=0.59, p=0.05) and root: shoot ratio on dry weight basis (r=0.65, p=0.01).

The goal of our experiment is to increase stem length, and length of flower head. The correlation of stem length and length of flower head was highly significant. Understanding these relationships allows to make more informed decisions about which traits to prioritize for improving overall plant performance.

Principal Component Analysis

The best treatment for enhancing growth, flowering and yield of lagurus was evaluated using principal component analysis where insignificant relationship between growth and flowering attributes due to different treatments *viz.*, seaweed extract drenches and GA_3 foliar dose applications were analyzed.

Growth and flowering parameters from 15 treatment combinations were subjected to PCA for analysis of compositional variations. The correlation coefficients of different variables in PCA were evaluated by the cosine of the angle between their vectors (Thakur and Kumar, 2020).

Principal component analysis indicated that three components (PC1, PC2 and PC3) with eigen value more than one accounted for about 90.11 % of the total variation among 21 characters of *Lagurus ovatus.* The principal component PC1, PC2 and PC3 contributed about 64.58%, 17.08% and 8.45% respectively to the total variation (Table 22, 23 and Fig. 5).

The association among the different variables in PC-1 and PC-2 with factor loadings is presented in Fig. 6 and 7. Biplot depicts the variation contribution of parameter with respect to first two principal components. X-axis represents PC-1 and Y-axis represents PC-2. From the biplot it can be seen that highest amount of contribution among the traits is observed in plant height, stem length and length of flower head.

Almost all the variables are positively contributing. The analysis revealed that the treatment combinations *viz*., 2ml L^{-1} seaweed extract + 250 ppm GA_3, 4ml L^{-1}seaweed extract + 150 ppm GA_3, 4ml L^{-1} seaweed extract + 250 ppm GA_3 and 4ml L^{-1} seaweed extract + 350 ppm GA_3 were located on the positive side of PC1 in the upper right quadrant resulting in plants with higher flag leaf width, root shoot ratio on fresh weight and dry weight basis, root length, fresh weight and dry weight of shoot and chlorophyll content at 60 and 90 days after transplanting. Parameters like days to first flower head initiation and days to flowering are located in the upper left quadrant of the biplot.

Discussion

In the present experiment, the results of the experimental study on impact of seaweed extract and GA_3 on the growth and flowering characteristics of lagurus have been discussed below.

Growth Traits

Treatments with seaweed extract and GA_3 significantly impacted all growth attributes, including plant height, plant spread, number of leaves, flag leaf length, flag leaf width, and leaf area. Plants that received three drenches of seaweed extract at a concentration of 4 ml L^{-1} displayed markedly enhanced vegetative characteristics, except plant height. The seaweed extract is rich in various phyto hormones, vitamins, organic compounds, and certain macro and micronutrients at varying concentrations, which collectively promote vegetative growth and significantly affect the flowering traits (Crouch et al. 1992; Dawczynski et al. 2007). The increase in leaf length and width can be attributed to the auxins and cytokinins present in the seaweed extract (Abbas et al. 2020). These findings are supported by studies conducted by Khadim et al. (2019) in carnation; El-Hady (2020) in tuberose and Alhasan et al. (2021) in gerbera. Furthermore, it was observed that plant height decreased with higher concentrations of seaweed extract, which may result from water-soluble growth inhibitors extracted from *Ascophyllum nodosum* that was earlier reported to inhibit lettuce growth significantly (Hussain and Boney 1973). Bioassay, thin-layer, and gas-liquid chromatography analyses revealed that one such compound was abscisic acid (ABA), which has been documented by Kingman and Moore (1982) in *Ascophyllum nodosum*. Additionally, plants that received three foliar sprays of 450 ppm GA_3 exhibited significantly improved vegetative characteristics. This notable improvement is likely due to the stimulation of both cell division and elongation, leading to increased internodal distance attributed to the foliar application of GA_3 (Sajid et al. 2016). The promotive effect of GA_3, combined with its efficient mobilization capacity, may have further enhanced vegetative growth (Singh et al. 2018). These observations align with previous findings by Tyagi et al. (2008) in calendula, Girisha et al. (2012) in daisy, Patra et al. (2015) in gerbera, and Kumar et al. (2015) in China aster.

Chlorophyll Content

Seaweed extract and GA_3 treatments significantly influenced the chlorophyll content at 30, 60 and 90 DAT. Plants that received three drenches of seaweed extract at a concentration of 4 ml L^{-1} exhibited

markedly higher chlorophyll content at all three measurement intervals. The increase in SPAD values may be attributed to the presence of betaines in the seaweed extract, which are known to enhance chlorophyll levels in the plant (Whapham et al.1993). Additionally, plants that were sprayed three times with 450 ppm GA_3 showed significantly higher chlorophyll content. GA_3 plays a stimulating role by reducing the activity of the enzyme chlorophyllase, which subsequently decreases chlorophyll degradation. This process contributes to an improved rate of photosynthesis and increases leaf surface area (Jacob-Wilk et al.1999). An enhancement in leaf chlorophyll content due to GA_3 application was also noted by Gad et al. (2016) in *Ixora coccinea* and Yaghoubi et al. (2013) in *Bellis perennis*.

Flowering Traits

Treatments with seaweed extract and GA_3 had a significant impact on all flowering parameters, including the days to the first flower head initiation and flowering, the number of inflorescences per plant, the length of the flower head, and stem length. Plants that received three drenches of seaweed extract at a concentration of 4 ml L^{-1} exhibited significantly improved flowering characteristics, although stem length remained unaffected. The early production of florigen and other flower-inducing compounds in plants treated with seaweed extract may account for the quicker appearance of flower buds (Pandya and Mehta 2023). These findings align with the results reported by Al-Hatem et al. (2023) in Chrysanthemum. Al-Hamazawi (2019) noted that the positive outcomes could be attributed to the beneficial properties of seaweed extract, which contains vitamins, macronutrients, and micronutrients, that enhance vegetative growth and subsequently result in an increased number of flowers. However, the seaweed extract did not significantly affect stem length, a result that corresponds with Velasco et al. (2020) in *E. grandiflorum* var. Florida and *E. grandiflorum* var. Rosie. Plants that received three foliar sprays of 450 ppm GA_3 demonstrated significantly superior flowering characteristics. According to Singh and Srivastav (2009), the improved flower production resulting from GA_3 treatment can be attributed to its role in promoting the induction of flower bud break, leading to the differentiation of floral primordia in the apical growth zone. The increase in leaf size and abundance in the GA_3 treatment group may have enhanced their photosynthetic capacity, allowing for greater energy allocation to the sink, which in turn resulted in a higher flower count and larger flowers (Sharifuzzaman et al. 2011; Sajid et al. 2016). Additionally, GA_3 facilitated stem elongation by promoting cell division, thereby increasing stem length (Al Khassawaneh et al. 2006).

Root and Shoot Ratio

Treatments with seaweed extract and GA_3 had a significant impact on all root and shoot characteristics, including fresh weight of both root and shoot, root-to-shoot ratio based on fresh and dry weight, and root length. Plants that received three drenches of seaweed extract at a concentration of 4 ml L^{-1} displayed significantly greater root and shoot biomass. This enhancement can be attributed to the presence of various growth regulators, as well as macro and micronutrients in the seaweed extract, which positively influence the vegetative growth characteristics of the plants, such as shoot number and flower stalk

length (Ordog et al.2004). Additionally, it was earlier reported that the application of seaweed extract improved both the root-to-shoot ratios and biomass accumulation in tomato seedlings by promoting root growth (Crouch and van Staden 1992). Plants that received three foliar sprays of 350 ppm and 450 ppm GA_3 exhibited significantly increased root and shoot biomass. The enhanced movement of water and nutrients likely facilitated the production of more photosynthetic products, which were subsequently distributed throughout the different parts of the plant. This process contributed to the overall growth and development of the seedlings, resulting in greater dry weight (Brain et al. 1959; Shenmugavelu 1966). These results are consistent with the findings of Abdullah and Abdurrahman (2017) regarding the fresh and dry weight of roots in turf grasses.

Correlation and PCA analysis

Correlation studies shows significantly positive correlations among the phenotypic characters of *Lagurus ovatus* where flowering parameters and growth attributes correlate significantly with the application of different doses of seaweed extract and GA_3. Therefore, optimum doses of seaweed extract and GA_3 can be adopted to improve the flowering attributes and to produce higher yield in lagurus. PCA analysis showed that lagurus crop is positively affected by different doses of seaweed extract and GA_3. Miceli et al. (2019) reported that response of plants to GA_3 treatment is species, time and dose- dependent indicating that hormone requirements relative concentrations and responses changes between species.

Declarations

Author Contribution

AS conceived the idea; N.L., R.M., A.S., K.M.G. and S.G. executed the field research, analyzed the data and wrote all parts of the manuscript and whereas N.L., A.S. and V.G. supervised the work.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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Tables

Table1. Influence of seaweed extract and GA_3 on plant height (cm) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	32.84 ± 0.91h	37.61 ± 1.94g	37.45 ± 2.19 g	**35.97 ± 2.80 e**
150 ppm	53.11 ± 4.16ef	49.79 ± 1.82 f	49.24 ± 1.32 f	**50.71 ± 2.98 d**
250 ppm	59.51 ± 2.93cd	56.17 ± 1.93de	55.70 ± 2.48 de	**57.13 ± 2.80 c**
350 ppm	65.98 ± 3.03ab	60.67 ± 0.22c	56.19 ± 1.52de	**60.95 ± 4.57 b**
450 ppm	69.13 ± 2.76 a	63.73 ± 1.79bc	63.57 ± 2.54bc	**65.48 ± 3.44 a**
Mean	**56.12 ± 13.56a**	**53.59 ± 9.76 b**	**52.43 ± 9.17 b**	

Table 2. Influence of seaweed extract and GA_3 on plant spread (cm) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	36.90 ± 2.96 a	40.70 ± 1.31 bc	42.53 ± 1.17b	**40.04 ± 3.03c**
150 ppm	38.52 ± 2.63 cd	40.43 ± 1.50bc	41.90 ± 0.72bc	**40.28 ± 2.14 c**
250 ppm	39.87 ± 2.70 bcd	41.07 ± 0.59bc	42.33 ± 0.85 b	**41.09 ± 1.80 c**
350 ppm	41.80 ± 0.95 bc	41.47 ± 1.60bc	45.97 ± 2.24 a	**43.08 ± 2.61 b**
450 ppm	48.13 ± 0.91a	42.13 ± 1.51 b	49.20 ± 2.67 a	**46.49 ± 3.67a**
Mean	**41.04 ± 4.45 b**	**41.16 ± 1.30 b**	**44.39 ± 3.25 a**	

Table 3. Influence of seaweed extract and GA_3 on the number of leaves per plant of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	202.13 ± 2.01 g	259.00 ± 9.56 ef	290.67 ± 2.72c	**250.60 ± 39.18 e**
150 ppm	252.67 ± 1.36 f	262.07 ± 6.39 e	271.47 ± 6.23 d	**262.07 ± 9.31 d**
250 ppm	278.00 ± 4.23 d	291.47 ± 3.31 c	293.67 ± 5.67c	**287.71 ± 8.32 c**
350 ppm	291.93 ± 2.72c	302.13 ± 3.78 b	307.00 ± 1.97 b	**300.36 ± 7.12 b**
450 ppm	304.33 ± 3.29 b	319.33 ± 2.66a	320.67 ± 2.81 a	**314.78 ± 8.26 a**
Mean	**265.81 ± 37.52 c**	**286.80 ± 24.54 b**	**296.69 ± 17.46 a**	

Table 4. Influence of seaweed extract and GA_3 on flag leaf length (cm) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	4.76 ±0.05 h	5.16 ± 0.24 g	5.56 ± 0.03 ef	**5.16 ± 0.37 e**
150 ppm	5.47 ± 0.02 f	5.77 ± 0.12 e	6.32 ± 0.18d	**5.85 ± 0.39 d**
250 ppm	6.45 ± 0.22d	6.91 ± 0.14c	7.37 ± 0.31b	**6.91 ± 0.45 c**
350 ppm	6.46 ± 0.20 d	7.38 ± 0.21 b	7.46 ±0.18 b	**7.10 ± 0.51 b**
450 ppm	7.28 ± 0.03 b	7.53 ± 0.15 b	7.89 ±0.18 a	**7.57 ± 0.29 a**
Mean	**6.09 ± 0.91 c**	**6.55 ± 0.97 b**	**6.92 ± 0.90 a**	

Table 5. Influence of seaweed extract and GA_3 on flag leaf width (cm) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	1.12 ± 0.01 fg	1.14 ± 0.04 defg	1.18 ±0.02 bcde	**1.15 ± 0.04 d**
150 ppm	1.17 ± 0.01cdef	1.19 ± 0.02 bcde	1.21 ± 0.03 abc	**1.19 ± 0.02 b**
250 ppm	1.19 ± 0.02 bcd	1.20 ± 0.04 abc	1.25 ± 0.06 a	**1.21 ± 0.04 a**
350 ppm	1.14 ± 0.03 efg	1.17 ± 0.03 cdef	1.23 ± 0.02 ab	**1.18 ± 0.04bc**
450 ppm	1.10 ± 0.03 g	1.15 ± 0.02 defg	1.22 ± 0.03 abc	**1.16 ± 0.05 cd**
Mean	**1.14 ± 0.04 c**	**1.17 ± 0.03 b**	**1.22 ± 0.04 a**	

Table 6. Influence of seaweed extract and GA_3 on leaf area (cm^2) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	3.75 ± 0.10 e	4.33 ± 0.27 de	4.62 ± 0.18 d	**4.23 ± 0.42 c**
150 ppm	4.41 ± 0.54 de	4.91 ± 0.40 cd	5.06 ± 0.10 bcd	**4.79 ± 0.45 b**
250 ppm	5.37 ± 0.57 abc	5.63 ± 0.55 abc	5.71 ± 0.62 ab	**5.57 ± 0.52 a**
350 ppm	5.52 ± 0.17 abc	5.79 ± 0.19 ab	5.84 ± 0.73 ab	**5.72 ± 0.41 a**
450 ppm	5.73 ± 0.21 ab	5.86 ± 0.09 a	6.06 ± 0.85 a	**5.88 ± 0.46 a**
Mean	**4.96 ± 0.84 b**	**5.31 ± 0.68 a**	**5.46 ± 0.74 a**	

Table7. Influence of seaweed extract and GA_3 on chlorophyll content (SPAD value) after 30 days of transplanting in *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	18.59 ± 1.85 e	27.29 ± 2.31 bcd	30.97 ± 2.27 a	**25.62 ± 5.81b**
150 ppm	24.31 ± 2.08 d	25.27 ± 1.57 cd	27.79 ± 2.26abc	**25.79 ± 2.32 b**
250 ppm	25.23 ± 0.84 cd	26.00 ± 2.20 bcd	28.28 ± 1.32 abc	**26.50 ± 1.93 ab**
350 ppm	26.02 ± 1.50 bcd	27.03 ± 2.20 bcd	28.97 ± 2.01 ab	**27.34 ± 2.11 ab**
450 ppm	26.10 ± 1.93 bcd	28.10 ± 2.49 abc	29.00 ± 0.64 ab	**27.73 ± 2.06 a**
Mean	**24.05 ± 3.24 c**	**26.74 ± 2.11 b**	**29.00 ± 1.90 a**	

Table 8. Influence of seaweed extract and GA_3 on chlorophyll content (SPAD value) after 60 days of transplanting in *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	23.36 ± 1.34 d	41.66 ± 1.59 a	41.82 ± 5.37 a	**35.61 ± 9.63 c**
150 ppm	35.23 ± 1.74 c	35.99 ± 1.70 bc	37.60 ± 1.71 bc	**36.27 ± 1.82 bc**
250 ppm	36.49 ± 1.22 bc	36.65 ± 1.08 bc	38.13 ± 2.51 abc	**37.09 ± 1.69 abc**
350 ppm	37.20 ± 0.82 bc	37.48 ± 2.57 bc	39.64 ± 1.76 ab	**38.11 ±1.98 ab**
450 ppm	38.26 ± 3.45 abc	38.47 ± 1.65 abc	40.00 ± 2.09 ab	**38.91 ± 2.33 a**
Mean	**34.11 ± 5.89 b**	**38.05 ± 2.55 a**	**39.44 ± 2.98 a**	

Table 9. Influence of seaweed extract and GA_3 on chlorophyll content (SPAD value) after 90 days of transplanting in *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	33.50 ± 1.42 h	42.08 ± 1.77 cde	45.04 ± 1.81 a	**40.21 ± 5.39 c**
150 ppm	39.76 ± 2.34 g	40.15 ± 1.05 fg	40.97 ± 2.56 efg	**40.29 ± 1.89 c**
250 ppm	40.30 ± 1.37 fg	40.91 ± 0.75 efg	41.35 ± 1.53 def	**40.85 ± 1.19 c**
350 ppm	41.57 ± 1.72 cdef	42.01 ± 2.31 cde	42.53 ± 1.57 bcd	**42.03 ± 1.69 b**
450 ppm	42.67 ± 0.34 bcd	42.84 ± 1.20 bc	43.75 ± 0.59 ab	**43.09 ± 0.85 a**
Mean	**39.56 ± 3.57 c**	**41.60 ± 1.62 b**	**42.73 ± 2.14 a**	

Table 10. Influence of seaweed extract and GA_3 on days to first flower head initiation of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans

Multiple Range Test (DMRT) test.The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	105.50 ± 0.30 a	103.10 ± 0.90 b	101.80 ± 0.40 c	**103.47 ± 1.71 a**
150 ppm	99.20 ± 0.20 d	98.90 ± 0.70 d	99.30 ± 0.10 d	**99.13 ± 0.41 b**
250 ppm	98.50 ± 0.50 de	97.50 ± 0.30 efg	97.00 ± 1.20 fg	**97.67 ± 0.94 c**
350 ppm	97.60 ± 0.20ef	96.50 ± 0.30 fgh	96.20 ± 1.80 ghi	**96.77± 1.12 d**
450 ppm	97.10 ± 0.10 fg	95.60 ± 0.40 hi	95.00 ± 0.40 i	**95.90 ± 0.98 e**
Mean	**99.58 ± 3.16 a**	**98.32 ± 2.76 b**	**97.86 ± 2.64 b**	

Table 11. Influence of seaweed extract and GA_3 on days to flowering of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test.The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	114.20 ± 0.53 a	111.80 ± 0.20 b	110.80 ± 0.40 b	**112.27 ± 1.55 a**
150 ppm	108.13 ± 0.50 c	106.80 ± 0.60 cd	106.60 ± 1.93 d	**107.18 ± 1.27 b**
250 ppm	105.20 ± 0.69 e	104.73 ± 1.29 e	104.60 ± 0.69 e	**104.85 ± 0.85 c**
350 ppm	102.93 ± 0.76 fg	103.80 ± 0.20 ef	101.73 ± 0.50 gh	**102.82 ± 1.01 d**
450 ppm	102.33 ± 1.10gh	101.33 ± 0.23 hi	100.13 ± 0.31i	**101.27 ± 1.12 e**
Mean	**106.56 ± 4.53 a**	**105.69 ± 3.69 b**	**104.77 ± 3.97 c**	

Table 12. Influence of seaweed extract and $GA_{3\ on}$ the number of inflorescences per plant of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	110.67 ± 2.61 i	140.87 ± 1.10 g	160.80 ± 1.06 de	**137.44 ± 21.91 e**
150 ppm	134.47 ± 11.66 h	145.13 ± 3.72 g	163.07 ± 1.79 de	**147.56 ± 13.96 d**
250 ppm	145.53 ± 4.47 g	158.73 ± 1.97 e	172.87 ± 4.11 c	**159.04 ± 12.26 c**
350 ppm	152.60 ± 2.55 f	166.33 ± 0.99 d	178.80 ± 1.51 bc	**165.91 ± 11.46 b**
450 ppm	165.40 ± 2.82 d	180.00 ± 2.50 b	188.27 ± 1.75 a	**177.89 ± 10.24 a**
Mean	**141.73 ± 19.80 c**	**158.21 ± 14.86 b**	**172.76 ± 10.67 a**	

Table 13. Influence of seaweed extract and GA_3 on length of flower head (cm) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	3.58 ± 0.04 h	3.70 ± 0.11 gh	3.76 ± 0.06 g	**3.68 ± 0.10 e**
150 ppm	3.96 ± 0.09 f	3.99 ± 0.08 f	4.08 ± 0.13 ef	**4.01± 0.10 d**
250 ppm	4.05 ± 0.07 ef	4.11± 0.11 ef	4.22 ± 0.09 de	**4.13 ± 0.11 c**
350 ppm	4.34 ± 0.03 cd	4.43 ± 0.17 c	4.43 ± 0.18 c	**4.40 ± 0.13 b**
450 ppm	4.51 ± 0.08 bc	4.62 ± 0.05 ab	4.78 ± 0.05 a	**4.64 ± 0.13 a**
Mean	**4.09 ± 0.34 c**	**4.17 ± 0.35 b**	**4.25 ± 0.37 a**	

Table 14. Influence of seaweed extract and GA_3 on stem length (cm)of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test.The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	30.00 ± 1.18 f	35.35 ± 1.18 e	35.14 ± 0.88 e	**33.50 ± 2.79 e**
150 ppm	51.46 ± 3.07 c	45.58 ± 3.08 d	45.03 ± 2.24 d	**47.35 ± 3.94 d**
250 ppm	53.71 ± 4.17 c	52.75 ± 4.70 c	52.66 ± 3.45 c	**53.04 ± 3.62 c**
350 ppm	60.13 ± 3.14 b	54.14 ± 4.07 c	53.32 ± 4.50 c	**55.86 ± 4.70 b**
450 ppm	67.32 ± 1.63 a	61.03 ± 1.18 b	60.42 ± 1.26 b	**62.92 ± 3.52 a**
Mean	**52.52 ± 13.21 a**	**49.77 ± 9.42 b**	**49.31 ± 9.21 b**	

Table 15. Influence of seaweed extract and GA_3 onthefresh weight of root (g/plant)of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	10.07 ± 1.22 h	19.67 ± 2.05 de	20.67 ± 1.60 cd	**16.80 ± 5.27 c**
150 ppm	14.73 ± 1.75 g	19.73 ± 1.33 de	18.27 ± 0.50 def	**17.58 ± 2.49 c**
250 ppm	19.53 ± 3.00 de	26.87 ± 4.11 a	23.13 ± 1.85 bc	**23.18 ± 4.17 a**
350 ppm	23.80 ± 2.60 b	15.20 ± 1.91 fg	24.00 ± 1.97 b	**21.00 ± 4.74 b**
450 ppm	15.53 ± 1.42 fg	15.27± 0.81 fg	17.33 ± 1.67 efg	**16.04 ± 1.52 c**
Mean	**16.73 ± 5.12 c**	**19.35 ± 4.83 b**	**20.68 ± 3.02 a**	

Table 16. Influence of seaweed extract and GA_3 on the fresh weight of shoot (g/plant) of *Lagurus ovatus* L. Different letters shows significant differences at (P≤0.05) using Duncans Multiple Range Test (DMRT) test.The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	76.37 ± 2.90 f	99.20 ± 1.54 b	107.80 ± 1.60 a	**94.46 ± 14.18 c**
150 ppm	81.48 ± 2.53 e	88.93 ± 2.47 d	99.58 ± 2.25 b	**90.00 ± 8.15 d**
250 ppm	89.06 ± 3.28 d	90.99 ± 7.51 cd	101.74 ± 2.49 b	**93.93 ± 7.30 c**
350 ppm	93.87 ± 2.55 c	97.89 ± 3.07 b	106.82 ± 3.21 a	**99.52 ± 6.29 b**
450 ppm	99.31 ± 0.78 b	101.16 ± 1.35 b	108.85 ± 2.57 a	**103.11 ± 4.63 a**
Mean	**88.02 ± 8.82 c**	**95.63 ± 5.96 b**	**104.96 ± 4.30 a**	

Table17. Influence of seaweed extract and GA_3 on the dry weight of root (g/plant) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	4.33 ± 0.50 f	8.80 ± 0.20 bcde	9.87 ± 0.61 abcd	**7.67 ± 2.57 c**
150 ppm	7.20 ± 0.87 e	8.93 ± 0.12 bcde	9.00 ± 1.74 bcde	**8.38 ± 1.32 bc**
250 ppm	7.73 ± 1.36 de	10.27 ± 0.83 ab	10.07 ± 1.33 abc	**9.36 ± 1.60 ab**
350 ppm	10.80 ± 1.59 ab	7.07 ± 1.51 e	11.53 ± 0.58 a	**9.80 ± 2.36 a**
450 ppm	7.00 ± 2.12 e	7.93 ± 0.42 cde	9.47 ± 0.70 abcd	**8.13 ± 1.57 c**
Mean	**7.41 ± 2.44 c**	**8.60 ± 1.30 b**	**9.99 ± 1.28 a**	

Table 18. Influence of seaweed extract and GA_3 on the dry weight of shoot (g/plant) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	37.13 ± 2.89 h	45.00 ± 1.64 fg	48.33 ± 2.19 bcde	**43.49 ± 5.36 d**
150 ppm	43.67 ± 1.10 g	46.10 ± 1.42 defg	48.20 ± 1.00 bcde	**45.99 ± 2.22 c**
250 ppm	45.40 ± 1.31 efg	48.13 ± 1.53 bcde	49.07 ± 1.72 abcd	**47.53 ± 2.12 bc**
350 ppm	47.07 ± 2.34 cdef	49.60 ± 1.51 abc	50.07 ± 1.92 abc	**48.91 ± 2.19 b**
450 ppm	49.00 ± 1.31 bcd	51.00 ± 1.44 ab	52.07 ± 1.92 a	**50.69 ± 1.92 a**
Mean	**44.45 ± 4.51 c**	**47.97 ± 2.61 b**	**49.55 ± 2.12 a**	

Table 19. Influence of seaweed extract and GA_3 on root: shoot ratio on fresh weight basis of *Lagurus ovatus* L. Different letters shows significant differences at (P≤0.05) using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	0.13 ± 0.02i	0.20 ± 0.03 defg	0.21 ± 0.03 def	**0.18 ± 0.04 d**
150 ppm	0.18 ± 0.03fgh	0.22 ± 0.02 cde	0.23 ± 0.02bcd	**0.21 ± 0.03 c**
250 ppm	0.22 ± 0.04 bcd	0.23 ± 0.02 bcd	0.25 ± 0.02abc	**0.23 ± 0.03 b**
350 ppm	0.25 ± 0.03 abc	0.26 ± 0.02 ab	0.28 ± 0.05 a	**0.26 ± 0.03 a**
450 ppm	0.16 ± 0.02 hi	0.17 ± 0.01 gh	0.19 ± 0.02 efgh	**0.17 ± 0.02 d**
Mean	**0.19 ± 0.05 c**	**0.21 ± 0.03 b**	**0.23 ± 0.04 a**	

Table 20. Influence of seaweed extract and GA_3 on root: shoot ratio on dry weight basis of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	0.12 ± 0.01 j	0.19 ± 0.01 efg	0.20 ± 0.02 cdef	**0.17 ± 0.04 d**
150 ppm	0.14 ± 0.01 ij	0.20 ± 0.02 cde	0.22 ± 0.01abc	**0.19 ± 0.04 c**
250 ppm	0.17 ± 0.02 gh	0.21 ± 0.02 cde	0.23 ± 0.01 ab	**0.20 ± 0.03 b**
350 ppm	0.21 ± 0.01 bcd	0.22 ± 0.01 abc	0.24 ± 0.01 a	**0.22 ± 0.01 a**
450 ppm	0.16 ± 0.01 hi	0.18 ± 0.02 fgh	0.19 ± 0.01 defg	**0.18 ± 0.02 cd**
Mean	**0.16 ± 0.03 c**	**0.20 ± 0.02 b**	**0.22 ± 0.02 a**	

Table 21. Influence of seaweed extract and GA_3 on root length (cm) of *Lagurus ovatus* L. Different letters indicate significant differences (P≤0.05) between treatments using Duncans Multiple Range Test (DMRT) test. The results represented the mean and standard deviations (S.D.) of three replicates

Gibberellic acid foliar spray	Seaweed extract (SWE) drench			
	Untreated control	2ml L^{-1}	4ml L^{-1}	Mean
Untreated control	9.91 ± 0.35 f	11.89 ± 0.08 bcd	12.44 ± 0.45 ab	**11.41 ± 1.19 c**
150 ppm	11.08 ± 0.22 e	12.24 ± 0.75 abcd	12.26 ± 0.24 abcd	**11.86 ± 0.71 b**
250 ppm	11.55 ± 0.15 de	12.30 ± 1.00 abcd	12.35 ± 0.32 abcd	**12.07 ± 0.66 ab**
350 ppm	11.59 ± 0.08 cde	12.42 ± 0.75 abc	12.51 ± 0.31 ab	**12.17 ± 0.60 ab**
450 ppm	11.73 ± 0.12 bcde	12.45 ± 0.02 ab	12.92 ± 0.89 a	**12.37 ± 0.68 a**
Mean	**11.17 ± 0.71 b**	**12.26 ± 0.59 a**	**12.50 ± 0.48a**	

Table 22: Eigen values and percentage of variance corresponding to each principal component

	Eigen value	Percentage of variance	Cumulative percentage of variance
Comp 1	13.56	64.58	64.58
Comp 2	3.59	17.08	81.66
Comp3	1.77	8.45	90.11
Comp 4	0.79	3.77	93.88
Comp 5	0.44	2.09	95.97
Comp 6	0.36	1.70	97.68
Comp 7	0.18	0.87	98.55
Comp 8	0.11	0.51	99.07
Comp 9	0.10	0.47	99.54
Comp 10	0.04	0.20	99.74
Comp 11	0.03	0.14	99.88
Comp 12	0.02	0.07	99.96
Comp 13	0.01	0.03	99.99
Comp 14	0.00	0.01	100.00

Table 23: Contribution of each parameter towards variance of principal components

	PC1	PC2	PC3	PC4	PC5
PLH	3.71	1.04	2.95	6.64	9.53
PS	4.40	1.12	6.64	4.96	4.13
NoL	6.89	4.54	0.94	5.65	7.87
FLL	5.77	3.63	0.93	4.80	1.27
FLW	1.81	5.97	9.14	3.17	8.03
LA	6.23	2.51	2.09	1.40	9.05
30	5.02	5.01	6.32	2.49	2.17
60	4.40	3.97	7.14	8.52	4.21
90	5.09	1.50	10.27	5.68	2.83
FHI	5.78	3.60	2.97	1.24	2.08
DTF	5.58	5.31	2.23	4.17	2.47
NOI	6.80	3.85	1.09	5.31	1.48
LFH	5.05	7.79	0.03	1.02	1.27
SL	3.73	1.10	1.47	6.75	6.31
FWR	2.02	9.07	10.17	1.57	1.28
FWS	4.93	2.25	10.17	2.29	2.49
DWR	3.59	8.83	2.79	6.01	1.40
DWS	7.05	1.66	1.28	3.80	1.66
RSF	2.42	7.07	15.67	3.16	8.13
RSD	3.85	8.05	4.61	6.76	1.67
RL	5.87	2.36	1.09	2.82	3.43

Figures

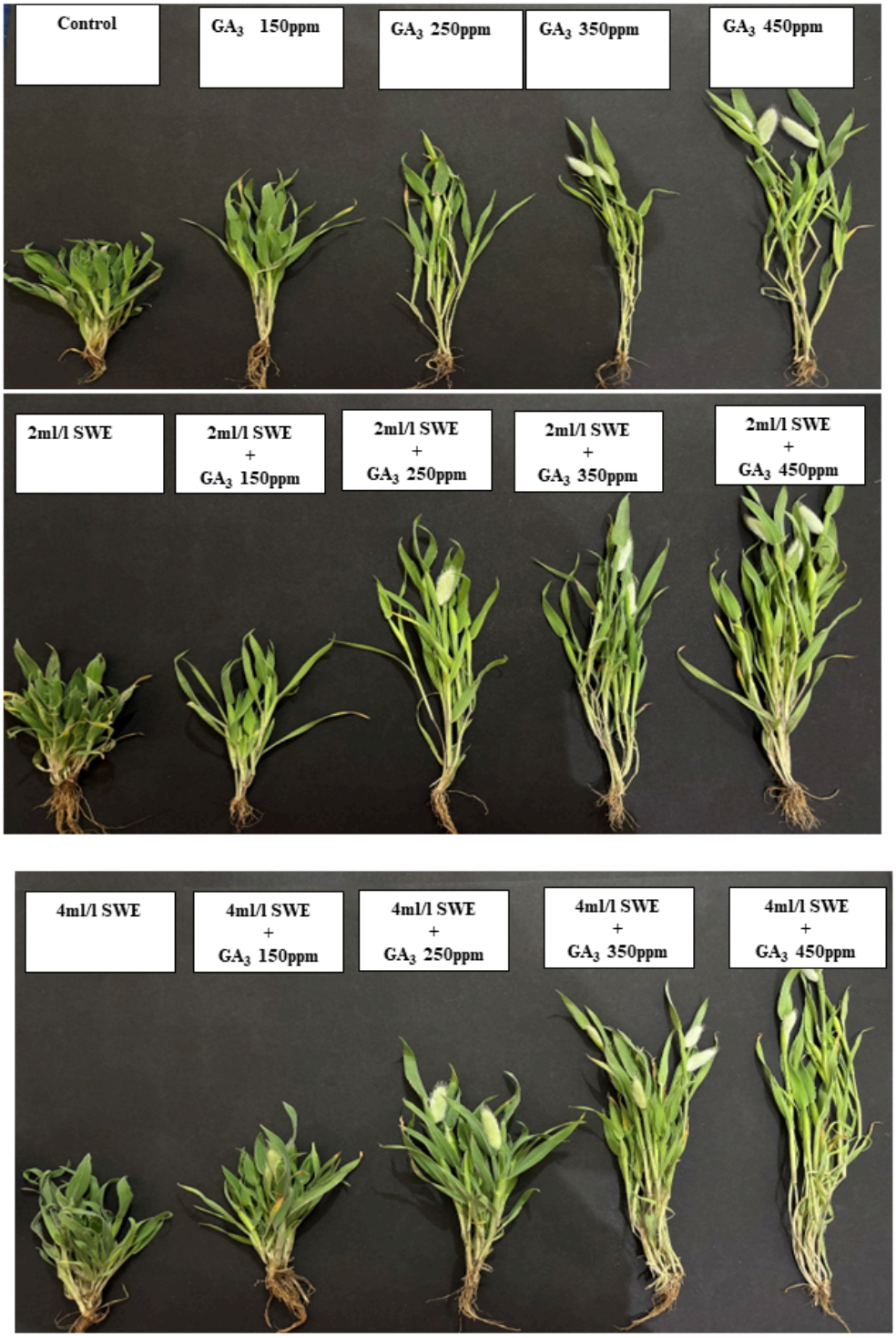

Figure 1

Vegetative stage of *Lagurus ovatus* L. influenced by various seaweed extract and gibberellic acid doses

Figure 2

Flowering of *Lagurus ovatus* L. influenced by various seaweed extract and gibberellic acid doses

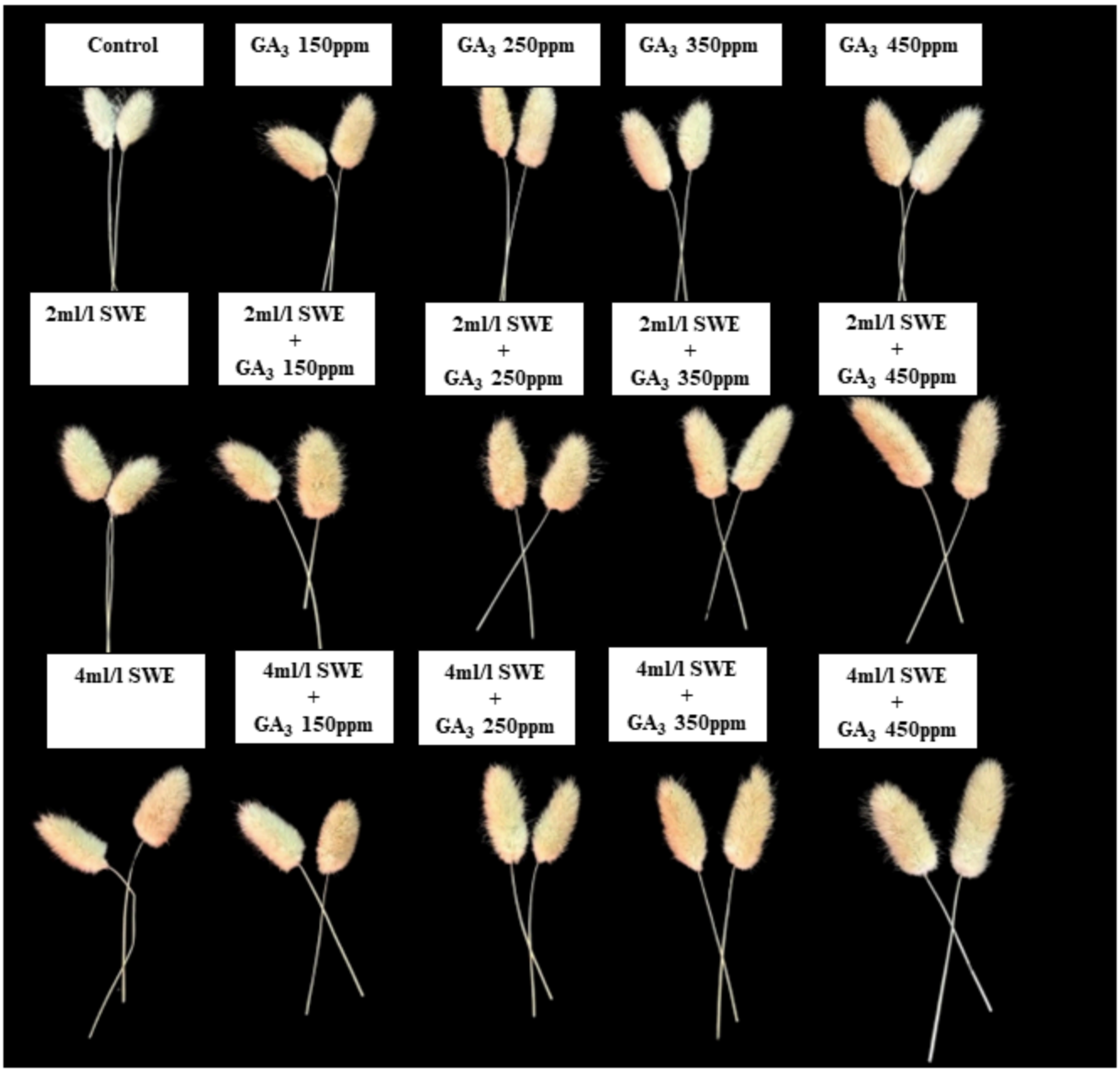

Figure 3

Flower head size of *Lagurus ovatus* L. influenced by various seaweed extract and gibberellic acid doses

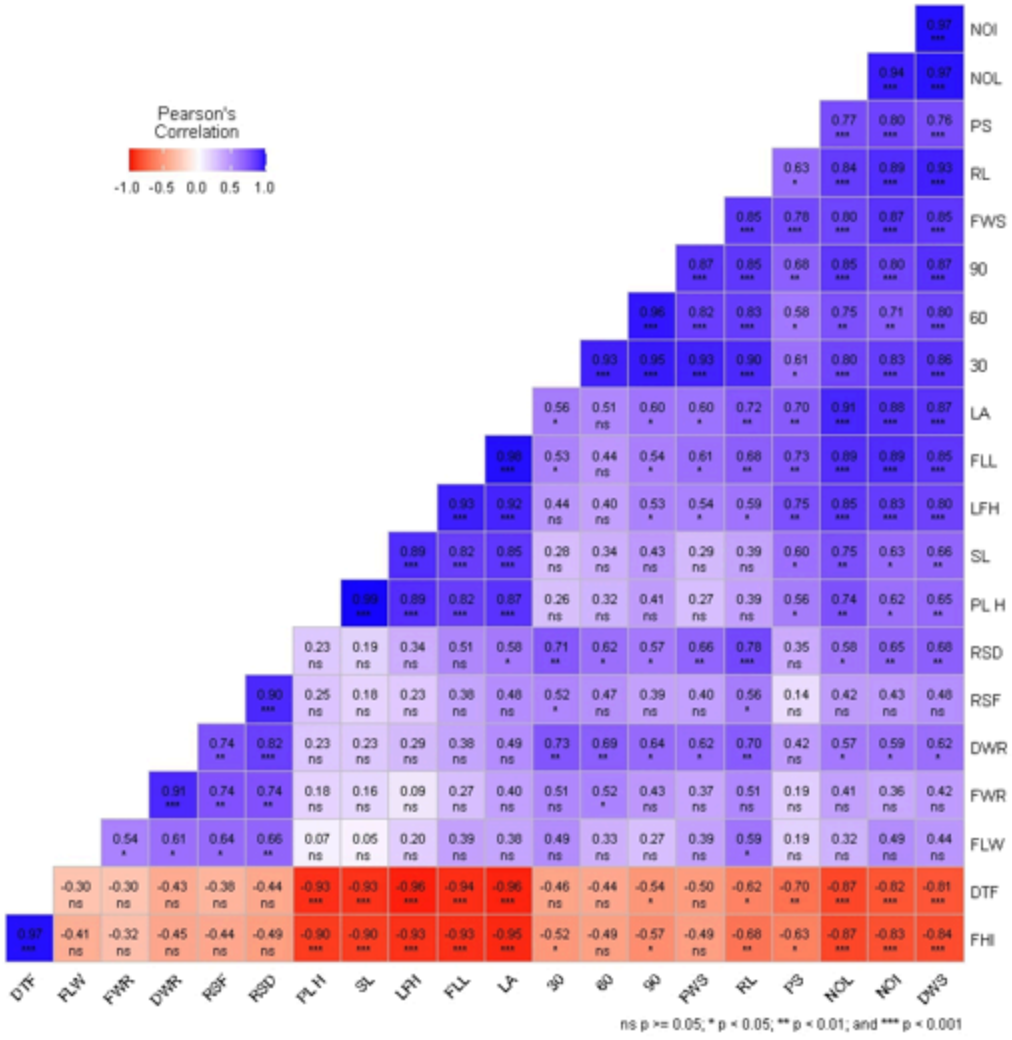

Figure 4

Pearson's correlation matrix of various growth and flowering parameters of *Lagurus ovatus* L. in response to seaweed extract drench and foliar GA_3 applications. PLH- plant height; PS-plant spread; NOL-number of leaves; FLL-flag leaf length; FLW- flag leaf width; LA-leaf area;30-chorophyll content (SPAD value) at 30 days after transplanting; 60-chorophyll content (SPAD value) at 60 days after transplanting; 90-chorophyll content (SPAD value) at 90 days after transplanting; FHI-days to first flower head initiation; DTF- days to flowering; NOI-number of inflorescence; LFH-length of flower head;; SL-stem length; FWR- fresh weight of root; FWS-fresh weight of shoot; DWR- dry weight of root; DWS-dry weight of shoot; RSF-root-shoot ratio on fresh basis; RSD- root shoot ratio on dry basis; RL-root length

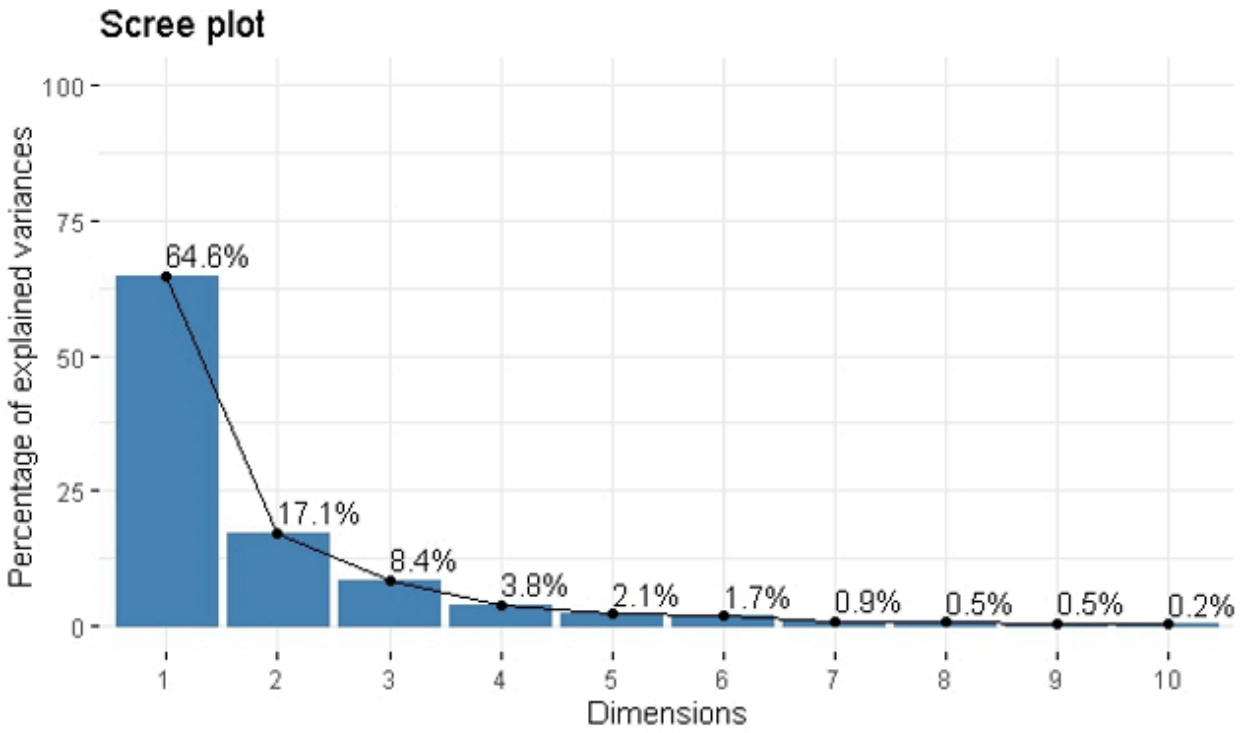

Figure 5

Scree plot of the PCA components for the *Lagurus ovatus* parameters in response of application of seaweed extract and GA_3.

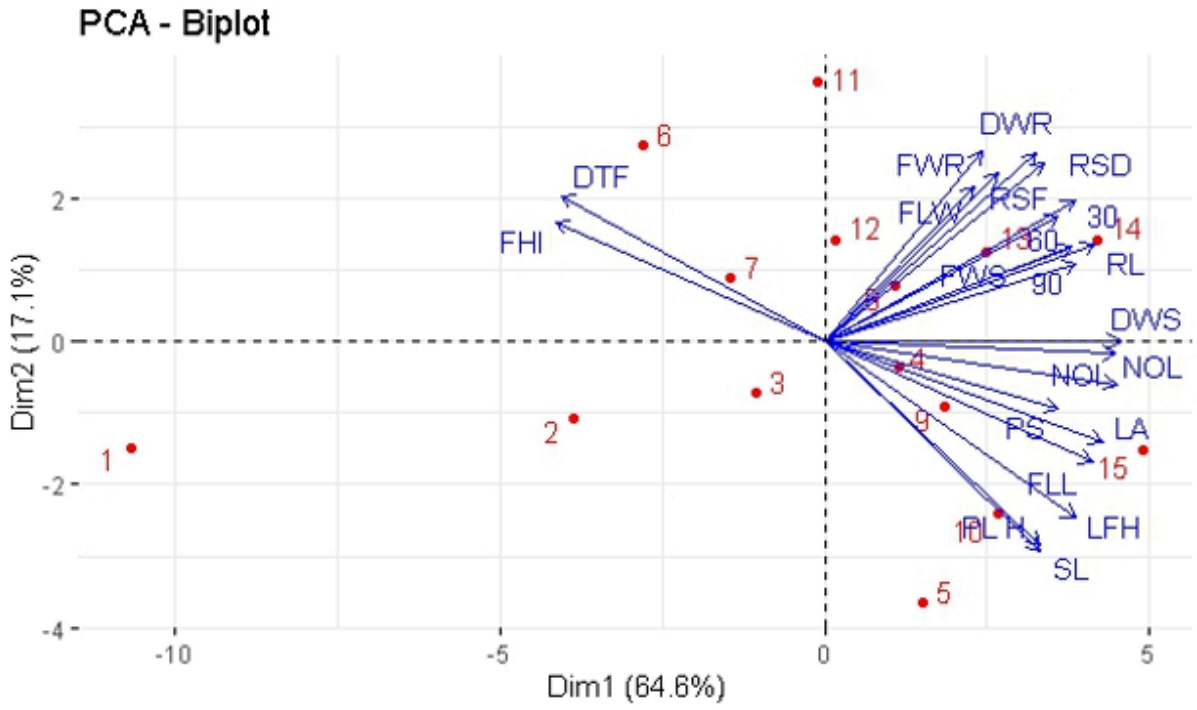

Figure 6

PCA Biplot representing different treatments of seaweed extract and GA_3 along with various parameters of *Lagurus ovatus*.

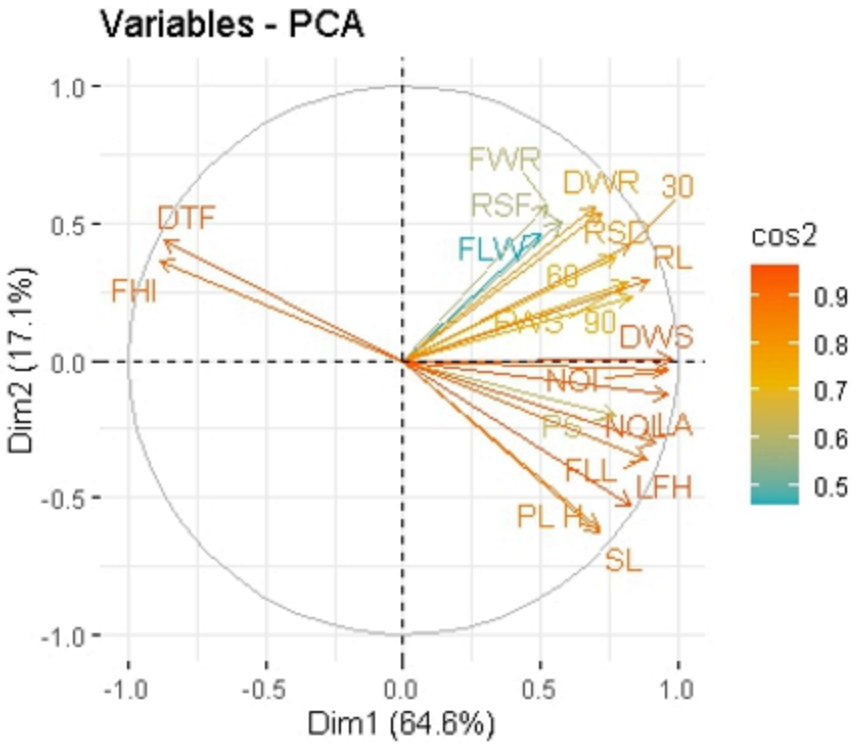

Figure 7

PCA Biplot representing different treatments of seaweed extract and GA_3 along with various parameters of *Lagurus ovatus*.