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Research paper

The Effect of Light Intensity and Watering Interval on Growth and Development of Three Legume Tree Species Seedlings

Dalia, A. Arabi[1], Medani I. Adlan[1], Osman A. Mohamed and kouther, M.Alkheder[1]

Hudieba Research Station ,Agricultural Research Corporation ,Ed Damer, Sudan
Corresponding author: daliaarabi22@gmail.com

Abstract

The cultivation of tree seedlings in a controlled nursery environment is essential for successful aforestation in the semi-desert region of Sudan. Light intensity and water availability are the key factor for the growth and development processes of legume tree seedlings. The objective of this study was to examine the effect of light intensity and watering interval on the growth and development of three nitrogen fixing tree seedlings (*Sesbania formosa, Leuceana leucocephala and Sesbania sesban*). The experiment was carried out at the nursery of Hudieba Research Station, northern Sudan in April 2020. The treatments tested were arranged in a Split-Plot design with three replicates. The studied factors were light intensity (50%, and 100%) and watering interval (3, 6 and 9 days). The measurements were taken after three months successively and different growth parameters were evaluated. Seedlings survival percentage for the three tree species in 50% light intensity under the different watering intervals ranging between (90-100%), Leucaena seedlings exhibit sensitivity to 100% light intensity during germination and growth. The results showed significant interaction effects of the two factors on stem length and nodules, root and shoot dry weight, of the three tree species. The results proved that the best combination of these factors that resulted in the recommended plant able seedling size was; 50% light intensity, watering every 3 days for L. leucocephala; 100% light intensity, watering every 3 days for S. formosa and S. sesban.

Keywords*: N-Fixing trees, light intensity, watering intervals and nodules.*

تأثير شدة الإضاءة وفترات الري على نمو وتطور شتلات ثلاثة أنواع من الأشجار البقولية

داليا عبد الحفيظ أحمد عريبي ,مدني ابراهيم عدلان, عثمان عبد القادر محمد وكوثر محمد الخضر

السودان ،الدامر، هيئة البحوث الزراعية ، محطة بحوث الحديبة

ممثل المؤلفين: daliaarabi22@gmail.com

المستخلص

تُعتبر زراعة شتول الأشجار في بيئة مشاتل مناسبة أمرًا أساسيًا لنجاح نظم التشجير المختلفة في المناطق شبه الصحراوية في السودان. أُجريت الدراسة بمحطة بحوث الحديبة شمال السودان في أبريل 2020 بهدف دراسة تأثير شدة الإضاءة وفترات الري على نمو وتطور شتلات ثلاثة أنواع شجرية مثبتة للنيتروجين و هي شجرة السيسبان, الليوسينا و الفورموزا (*Sesbania formosa*، *Leucaena leucocephala* و *Sesbania sesban.*) تم ترتيب المعاملات وفق تصميم القطاعات المنشقة بثلاث مكررات. المعاملات التي تمت دراستها تضمنت الكثافة الضوئية (50% و100%) وفترات الري (كل 3، 6 و9 أيام). تم أخذ القياسات بعد الشهر الثالث من البذر.وجد ان نسبة بقاء شتلات الثلاث شجرات حية أعلي (90-100%) في نسبة أضاءة 50%، كما أظهرت الدراسة أن شتول شجرة الليوسينا حساسة للنمو والانبات في ضوء الشمس المباشر. أظهرت النتائج وجود اثر معنوي للمعاملات على طول الساق، عدد العقد البكتيرية، الوزن الجاف للعقد البكتيرية ,الجذور والمجموع الخضري (الساق والأوراق) للثلاث أشجار. أثبتت النتائج أن أفضل تركيبة من هذه العوامل أدت إلى حجم شتلات مناسب للزراعة كانت: شدة إضاءة 50% مع ري كل 3أيام لـ*L. leucocephala* ؛ وشدة إضاءة 100% مع ري كل 3 أيام لـ*S. formosa* و*S. Sesban*.

الكلمات المفتاحية: *الأشجار المثبتة للنيتروجين، شدة الإضاءة، فترات الري والعقد البكتيرية.*

Introduction

The semi-desert region of Sudan is particularly prone to desertification, coupled with harsh climatic conditions: i.e. hot and dry summers and scarce rainfall. Generally, tree seedlings are quite sensitive to environmental stresses especially water which is considered as the main limiting factor for successful plantation. Previous studies have reported that drought is a factor negatively influencing seedling survival and establishment (Bouda *et al*., 2013; Claudia *et al*., 2004).

Growing seedlings under such harsh conditions produces weak seedlings Therefore; the production of suitable seedlings necessitates protecting of the juvenile seedlings from the harsh conditions. Germination of many species requires specific light requirements, with species responding to slight variations in the light spectra associated with the season or shaded habitat, triggering or inhibiting germination (Fenner and Thompson 2005). Legume- fixing trees and shrubs play a crucial role in biodiversity dynamics. Also, they play a vital role in agroforestry system because of their multipurpose nature they provide a high quality fodder, nutrient rich mulch for crops, timber and fuel wood, human food and improving the microenvironment and their introduction in cropping systems may contribute to reducing the use of chemical fertilizers and the improved productivity of different soils and to ecosystems stability. The tree legumes most commonly used in agroforestry systems involve Acacia spp., Albizia spp., Calliandra calothyrsus, Faidherbia albida, Flemingia spp., Erythrina spp., Inga spp., Leuceana spp., Gliricidia spp., and Sesbania spp., which can develop symbiotic associations with a great variety of N2-fixing bacterial species (Gold, 2020; Sileshi *et al*., 2014). Despite the great potential of these trees, not much is known about their response to drought. To maximize the potential value of these legume trees, there is a need to understand the physiological responses to irrigation intervals and light intensity. Therefore; the objective of this study was to examine the effect of light intensity and watering interval on the growth of three tree species at the nursery stage.

Materials and Methods:

This experiment was conducted at Hudieba Research Station, Northern Sudan (17.57’N and 33.8’ E). The investigated tree species were *Sesbania formosa*, *Leuceana leucocephla* and *Sesbania sesban*. Every species was tested separately. The experiment was arranged in a spilt plot design with three replicates. The main plots were assigned to light intensity, and the sub-plot to

watering interval. The levels of light intensity factor were 50% (under plastic net) and 100% (under direct sun light); the watering intervals were 3, 6 and 9 days.

The seeds were treated using the recommended pretreatment method for each tree species. They were sown at the rate of three seeds per polythene bag of 15 X 20 cm size. The seedlings were irrigated every two days for three weeks, and then three irrigation intervals treatments were applied. The seedlings were thinned Three weeks after sowing, to one plant per polythene tube. The seedlings were left to grow in the nursery bed for three months. Then, they were carefully freed from the soil by gentle washing with water and nodules were carefully picked. Each plant further separated into shoot and root, and the shoot separated into leaf and stem. The fresh weight of each plant fraction was determined immediately. Data collected were, leaves and nodules number, stem length, shoot (leaves and stem), root and nodule fresh and dry weight (oven dried at 70 ^{0}C for 24 hr). The data were then statistically analyzed using the Genstat Package.

Results and discussion

As shown in Fig 1., the survival percentage of the three tree seedlings after three months in 50% light intensity under the different watering intervals ranging between (90-100%), the survival percentage of the two sesbania seedlings under full sun light and 3 days watering intervals was (87.5%). However, Leucaena seedlings exhibit sensitivity to 100% light intensity during germination and growth, even when watering intervals are reduced. Light availability is a major ecological factor influencing seed germination, seedling survival, and establishment (Guenni *et al*., 2008).The successful afforestation requires planting quality seedlings with optimal potential for high rate of survival and growth (height and basal diameter) overtime (Grossnickle and MacDonald 2017).

1- *Sesbania formosa*

The light intensity had a significant effect on *S. formosa* seedlings during their juvenile stage, and also stem length for seedlings under partial shade was significantly higher than in 100% light intensity, because seedlings search for sun rays, required for photosynthesis. There were no differences between shoot dry weights under the two light intensities. Root dry weight showed significant differences, although there were no differences in root length. As light intensity increased from 50 to 100%, root and nodule weight increased significantly (Table 1.1). All

parameters increased significantly as the watering interval decreased. There were highly significant differences in the dry weight of all parameters, root and nodules dry weight increased significantly as the watering interval decrease (Table 1.2). The combination of 100% light intensity, watering every 3 days treatments gave the highest shoot, root and nodules dry weight (Table 1.3). The study reveals that the optimal watering intervals of every three days led to excellent growth performance across all three species. For tree nurseries, regular watering is necessary to produce good quality seedlings at economical rate. This finding aligns with previous research indicating that both water availability and timing are critical factors influencing seedling development, Khan *et al*. (2005) studied the influence of four irrigation intervals (3, 6, 9 and 12) on the growth and yield of bell pepper (Capsicum annuum), and they found that 3 days of irrigation interval gave the highest shoot height compared to other treatments.

2- *Sesbania sesban*

Light intensity had a significant effect on *S. sesban* seedlings during their juvenile stage. The stem length of the seedlings under partial shade was significantly higher than under 100% light intensity. All growth parameters concerned were significantly increased as the light intensity increased from 50 to 100% except root length. Although there were no significant differences between the root lengths in the two light intensities, the dry weight of root length demonstrated highly significant differences between the two treatments (Table 2.1).

All parameters increased significantly as the watering interval decreased. There were highly significant differences in the dry weight of all parameters among different watering intervals (Table 2.2). *S.sesban* under direct sun light (100% light intensity) with the different watering interval gave the highest dry weight of shoot, root and nodule. The combination of 100% light intensity and watering every 3 days gave the highest shoot, root and nodules dry weight (Table 2.3). Our results indicated that the two species *Sesbania formosa* and *Sesbania sesban* performed optimally when planted directly under 100% light intensity, This fact indicates that two species are a light demanded and therefore the 50% light intensity is insufficient to offer the solar energy required for proper photosynthetic process.

3- *Leuceana leucocephala*

Under partial shade (50%) all growth parameters except for the root length, nodule fresh and dry weight significantly out yielded those under direct sunlight (Table 3.1). The study showed that there were highly significant differences between different watering intervals, as the watering interval increased from 3to 6 to 9 days all parameters decreased (Table 3.2). Sheikh and Khan (1985) demonstrated that in a nursery experiment the plant height, growth and biomass production of *Leuceana leucocephala* seedlings were improved with increasing irrigation. The results of the study indicate that stem length decreased as the light intensity increased, on average the stem length ranges between 17.3 and 6.1 under direct sunlight, whereas the stem length ranges between 61.5 and 39.3 cm under partial shade. Stem and root dry weight under partial shade significantly out yield those under direct sun light. The combination of 50% light intensity and watering every 3 days gave high stem length and high nodules, shoot and root dry weight (Table 3.3). Leuceana *leucocephala* seemed to be a shade demanded during its juvenile stage. In contrast, extended watering intervals negatively affected seedlings growth, likely due to water stress that hampers physiological processes such as nutrient uptake and photosynthesis. According to Bargali and Tewari (2004), the small size, shallow roots and little food storage make seedlings less tolerant to harsh environments.

Recommendations

More research is needed in the physiology and growth of legume trees to follow their field performance and adaptation is required. The study recommends the following combination of treatments for raising well established nursery seedlings of the 3 species:

- For Sesbania Formosa and Sesbania sesban it is recommended to sow seeds under direct sun light (100% light intensity) and providing watering every 3 days.
- For Leuceana leucocephala it is recommended to be sown under partial shade (50% light intensity) and providing watering every 3 days.

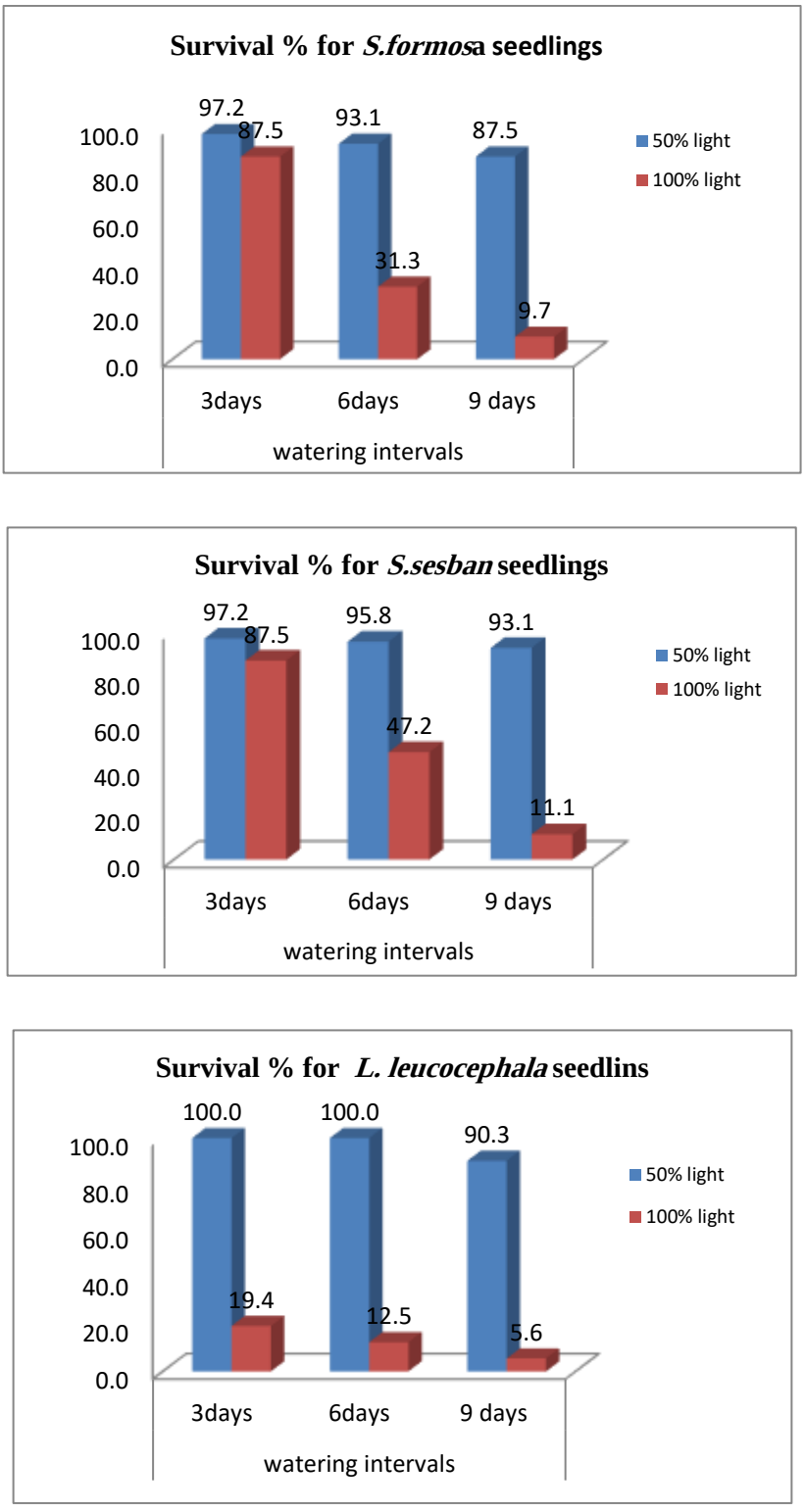

Fig. 1 Survival percentage of the three tree seedlings after three months

Table 1.1: Effect of light intensity on *Sesbania formosa* seedling growth parameters

Parameter	100% Light inte	50% Light inter	S.E+/-	Sig
Leave numbe	6.5	7.73	0.175	*
Stem length (cn	14.5	28.6	0.855	**
Root length (cn	26.6	26.2	3.0	Ns
Nodules numb	15.1	5.2	0.318	**
Fresh weight (g				
Leaves	2.49	1.74	0.103	*
Stem	4.4	3.12	0.272	*
Shoot	1.83	1.38	0.115	Ns
Root	2.61	0.523	0.075	**
Nodules	0.118	0.017	0.002	***
Dry weight (g)				
Leaves	0.61	0.472	0.054	Ns
Stem	0.360	0.357	0.017	Ns
Shoot	0.97	0.83	0.091	Ns
Root	0.924	0.303	0.056	*
Nodules	0.0573	0.0139	0.005	*

Ns: Not significant. *, **, *** Significant at $p \leq 0.05$, 0.01 and 0.001 respectively.

Table 1.2: Effect of watering intervals on *Sesbania formosa* seedling growth parameters

Parameter	Watering intervals			S.E+/-	Sig
	3-days	6-days	9-days		
Leave number	8.8	6.8	5.73	0.45	***
Stem length (cm	32.7	19.4	12.5	1.71	***
Root length (cm	31.1	25.2	23.03	1.47	**
Nodules numbe	20.7	6.05	3.67	0.86	***
Fresh weight (g)					
Leaves	4.27	1.06	1.022	0.159	***
Stem	8.03	1.82	1.42	0.314	***
Shoot	3.65	0.76	0.399	0.143	**
Root	3.88	0.51	0.31	0.17	***
Nodules	0.179	0.016	0.008	0.004	***
Dry weight(g)					
Leaves	1.072	0.311	0.24	0.064	***
Stem	0.809	0.210	0.056	0.024	***
Shoot	1.81	0.522	0.26	0.121	***
Root	1.36	0.341	0.14	0.044	***
Nodules	0.094	0.008	0.006	0.005	***

** , *** Significant at $p \leq 0.01$ and 0.001 respectively.

Table 1.3: Effect of light intensity, watering intervals on *Sesbania formosa* seedling growth parameters

Ns: Not significant. *, *** Significant at $p \leq 0.05$, and 0.001 respectively

Treatments	Growth parameters				Fresh weight (g/seedling)			Dry weight (g/seedling)		
Light*watering	Leave num	Stem lengt (cm)	Root lengt (cm)	Nodules nu	Shoot	Root	Nodul	Shoot	Root	Nodul
100X 3-day	9.2	23.6	30.2	29.7	9.56	6.5	0.318	2.2	2.02	0.15
100x6-day	5.23	12.7	25.1	8.3	1.91	0.85	0.020	0.5	0.042	0.012
100x9-day	5.93	7.1	24.5	7.3	1.73	0.49	0.015	0.26	0.21	0.011
50 x 3-day	9.33	41.8	31.9	11.8	6.51	1.26	0.039	1.61	0.69	0.04
50 x 6-day	8.33	26.1	25.2	3.8	1.73	0.177	0.012	0.55	0.14	0.003
50 x 9-day	5.53	18.0	21.6	0	1.12	0.127	0	0.33	0.072	0
S.E+/-	0.547	2.15	3.45	1.05	0.454	0.120	0.005	0.116	0.075	0.007
Sig	*	ns	Ns	***	***	***	***	*	***	***
C.V%	11	7	9.7	14.7	14.5	18.8	9.3	16.2	12.4	23.5

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Table 2.1: Effect of light intensity on *Sesbania sesban* seedling growth parameters

Parameter	100% Light inte	50% Light inter	S.E+/-	Sig
Leave numbe	19.6	13.2	1.24	*
Stem length (cn	33.3	53	1.24	*
Root length (cn	27.1	25.2	1.28	Ns
Nodules numb	20.4	2.8	1.25	**
Fresh weight (g				
Leaves	2.73	0.99	0.104	*
Stem	6.42	2.6	0.136	**
Shoot	3.69	1.6	0.037	***
Root	3.28	0.641	0.057	***
Nodules	0.079	0.033	0.005	*
Dry weight (g)				
Leaves	0.691	0.23	0.014	**
Stem	1.127	0.626	0.031	*
Shoot	1.82	0.85	0.05	*
Root	1.304	0.266	0.012	***
Nodules	0.044	0	0.005	0.027

Ns: Not significant. *, **, *** Significant at $p \leq 0.05$, 0.01 and 0.001 respectively.

Table 2.2: Effect of watering intervals on *Sesbania sesban* seedling growth parameters

Parameter	Watering intervals			S.E+/-	Sig
	3-days	6-days	9-days		
Leave number	24.1	13.4	12.4	0.99	***
Stem length (cm	59.6	40.2	29.7	0.99	***
Root length (cm	29.9	24.6	23.9	0.92	**
Nodules numbe	18.9	7.9	8	0.51	***
Fresh weight (g)					
Leaves	4.07	0.922	0.59	0.103	***
Stem	9.7	2.48	1.39	0.188	***
Shoot	5.59	1.56	0.79	0.098	***
Root	4.802	0.707	0.371	0.084	***
Nodules	0.151	0.009	0.009	0.005	***
Dry weight(g)					
Leaves	0.965	0.263	0.154	0.022	***
Stem	1.87	0.536	0.226	0.067	***
Shoot	2.83	0.79	0.38	0.084	***
Root	1.69	0.419	0.244	0.055	***
Nodules	0.048	0.013	0.006	0.001	***

** , *** Significant at $p \leq 0.01$ and 0.001 respectively.

Table 2.3: Effect of light intensity and watering intervals on *Sesbania sesban* seedling growth parameters

Ns: Not significant*** Significant at $p \leq 0.001$.

Treatments	Growth parameters				Fresh weight (g/seedling)			Dry weight (g/seedling)		
Light*watering	Leave num	Stem lengtl (cm)	Root lengt (cm)	Nodules nu	Shoot	Root	Nodule	Shoc	Root	Nodule
100X 3-day	31.2	55.5	30.8	29.5	8.59	8.04	0.202	4.32	2.86	0.095
100x6-day	13.3	24.6	24.7	15.8	1.56	1.17	0.018	0.75	0.653	0.025
100x9-day	14.2	19.7	25.8	16	0.9	0.63	0.017	0.38	0.401	0.012
50 x 3-day	17	63.7	29	8.4	2.59	1.57	0.1	1.35	0.527	0.001
50 x 6-day	13.5	55.8	24.4	0	1.55	0.25	0	0.82	0.185	0
50 x 9-day	10.6	39.6	22.1	0	0.68	0.11	0	0.38	0.088	0
S.E+/-	1.21	1.68	1.66	0.9	0.168	0.159	0.011	0.10	0.091	0.008
Sig	***	***	Ns	**	***	***	***	***	***	***
C.V%	11	5.6	8.6	10.8	9	10.5	23.6	15.5	17.1	12.5

Table 3.1: Effect of light intensity on *Leuceana leucocephala* seedling growth parameters

Parameter	100% Light inte	50% Light inter	S.E+/-	Sig
Leave numbe	7.4	13.2	0.12	***
Stem length (cn	10.6	49.7	0.83	***
Root length (cn	26.6	29.5	1.48	Ns
Nodules numb	10.2	15.6	0.91	Ns
Fresh weight (g				
Leaves	0.89	2.86	0.093	**
Stem	0.52	1.88	0.103	*
Shoot	1.41	4.66	0.141	**
Root	0.76	1.37	0.028	**
Nodules	0.051	1.03	0.005	Ns
Dry weight (g)				
Leaves	0.3	1.15	0.033	**
Stem	0.24	1.02	0.039	*
Shoot	0.541	2.7	0.171	**
Root	0.37	0.79	0.041	*
Nodules	0.025	0.023	0.12	Ns

Ns: Not significant. *, **, *** Significant at $p \leq 0.05$, 0.01 and 0.001 respectively.

Table 3.2: Effect of watering intervals on *Leuceana leucocephala* seedling growth parameters

Parameter	Watering interval			S.E+/-	Sig
	3-days	6-days	9-days		
Leave number	14.2	8.9	7.7	0.61	***
Stem length (cm	39.4	28.3	22.7	1.09	***
Root length (cm	34.2	17.6	22.2	1.0	***
Nodules numbe	31.8	4.2	2.8	0.62	***
Fresh weight (g)					
Leaves	2.83	1.68	1.11	0.136	***
Stem	2.02	1.01	0.57	0.061	***
Shoot	4.73	2.69	1.68	0.149	***
Root	2.14	0.63	0.42	0.079	***
Nodules	0.11	0.01	0.002	0.002	***
Dry weight(g)					
Leaves	1.16	0.61	0.41	0.03	***
Stem	1.09	0.51	0.29	0.043	***
Shoot	2.247	1.117	0.703	0.055	***
Root	1.12	0.37	0.26	0.037	***
Nodules	0.064	0.005	0.004	0.0019	***

*** Significant at $p \leq 0.001$

Table 3.3: Effect of light intensity, watering intervals on *Leuceana leucocephala* seedling growth parameters

Treatments	Growth parameters				Fresh weight (g/seedling)			Dry weight (g/seedling)		
Light*waterir	Leave num	Stem lengt (cm)	Root lengt (cm)	Nodules nu	Shoo	Root	Nodule	Shoo	Root	Nodul
100X 3-day	14	17.3	39.7	29.8	3.35	2.0	0.15	1.27	0.94	0.074
100x6-day	3.9	8.5	21.9	0.9	0.63	0.17	0.004	0.25	0.11	0.001
100x9-day	4.2	6.1	18.1	0	0.27	0.1	0	0.11	0.07	0.001
50 x 3-day	14.4	61.5	28.8	33.8	6.12	2.3	0.07	3.2	1.3	0.054
50 x 6-day	13.9	48.2	33.3	7.4	4.76	1.09	0.017	1.99	0.62	0.008
50 x 9-day	11.3	39.3	26.3	5.6	3.1	0.74	0.004	1.3	0.44	0.006
S.E+/-	1.07	1.51	1.88	1.16	0.22	0.1	0.005	0.1	0.06	0.004
Sig	**	*	***	Ns	*	Ns	***	**	Ns	**
C.V%	14.6	8.9	8.8	11.8	12	18.2	13	10	15.6	19.5

Ns: Not significant. *, **, *** Significant at $p \leq 0.05$, 0.01 and 0.001 respectively.

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