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Research Paper

Study on effect of organic mulching on soil properties, survival and progressive growth of *Aquilaria malaccensis* Lamk. (Agar) seedling

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Abstract

An experiment was conducted in Sibsagar district of upper Assam, India with different mulching materials and its effect on soil properties, survival, progressive growth and development of *Aquilaria malaccensis* Lamk. (Agar) seedlings. Treatments were (a) Mulching with green grass and leaves (GGL), (b) Mulching with dry grass (DG), (c) Mulching with rice straw (RS), (d) Mulching with dry leaves (DL), (e) Without mulching (WM) as control. Results showed that soil pH changed significantly, it was 4.4 to 4.6 in 0-20 cm and 4.6 to 4.9 in 20-40 cm soil depth. It decreased in GGL, DG and RS mulching, remained unchanged in 0-20 cm and increased in 20-40 cm soil depth under DL mulching. Organic carbon (%) increased from 1.31 to 1.99 in GGL, 1.33 to 2.05 in DG, 1.01 to 1.96 in RS and 1.02 to 1.32 in DL mulching at 0-20 cm. Mulching effect was statistically insignificant on available nitrogen but available phosphorous and potassium decreased significantly. Soil moisture content follows the trend, RS> DG > GGL > DL > WM. Seedlings survived to 95 percent under treatment with RS followed by GGL (91%), DL (90%) and DG (88.33%). Height growth rate become much higher under RS mulching and was recorded 184.9 cm after 1 year followed by DG (146.70 cm), DL (129.60 cm) and then GGL (128.20 cm). Basal diameter was recorded maximum under RS mulching, it was 4.24 cm in one year old seedling followed by DG (3.77 cm), GGL (3.34 cm) and then DL (3.27cm). RS mulching treatment gave maximum number of primary branches (22) followed by DG (19), GGL (15) and DL (12).

Keywords: *Aquilaria malaccensis, development, growth, mulching, soil properties.*

Introduction

Aquilaria malaccensis (agar) tree has high commercial value because of agar wood. Agar wood is black resin formed only in infected (diseased) trees; it is used in extraction of oils formed due to host and pathogen interaction. Agar wood oils have multipurpose use in aromatic, incense, perfume, soap, beverage, ornamental and pharmaceutical industry. *A. malaccensis* has become rare in natural habitat due to indiscriminate felling and are now cultivated by farmers in their homestead gardens in many ways. Agar tree is major livelihood option in upper Assam (India) and therefore is an important plantation crop and major source of economy in Nagaon, Golaghat, Jorhat, Sibsagar and Dibrugarh districts. Sustainable and large scale production of agar is only possible through proper scientific cultivation and management practices.

In recent years the major abiotic stress faced by large scale plantation is due to erratic and unsteady rainfall in the region. In large scale successful commercial cultivation seedling survival rate is an important factor. Declining seedling survival rate particularly because of climate change driven abiotic stress *i.e.* local weather change, low rainfall, and change in relative humidity, local temperature increase *etc*. Rainfall study from (1997-2014) indicates that rainfall in north-east region of India has gradually dropped and faced frequent unprecedented drought, probability of drought was 54 percent during 2000-2014,[1] North Eastern Space Application Centre (NESAC)[2], Meghalaya, India (2011-2012) has reported severe drought in Golaghat, Jorhat and Sibsagar district during 2005-2006 though this humid region comes under class of rare drought events and frequency of drought once in 15 years. Intergovernmental panel on climate change (IPCC) emphasized adaptation strategy that includes adjusting land management practice, organic agriculture, mulching *etc*. This study was undertaken with the objective to study the effect of different easily, locally available and economical mulching materials on survival of *A. malaccensis* seedlings and come with a recommendation to farmer with best suitable mulching materials for their farm.

Soil mulching is the process of covering bare surface of the soil (land) with organic or inorganic materials to conserve soil moisture, control weed growth, arrest soil erosion by rain water and wind. Many organic materials such as fallen leaves, green leafy materials, straw, husk materials, saw dust are in use. Sometimes old newspaper, unused jute bags are also seen in use. Long plastic sheet are found in use in large horticultural and agricultural fields commercially. Mulching materials directly affects soil properties it may be in terms of physical, chemical as well as biological. It affects soil temperature by regulating influx and out flux of solar radiation, controls soil moisture by affecting water penetration and evaporation loss form soil surface, regulates nutrient availability to plants, and also soil micro and macro faunal population. Scientists[3] found a positive correlation of microarthropod population with the lignin content of soil organic matter. Soil nematode community compositions are very much affected by mulch materials. Termite populations are found to increase by application of wood and straw mulch. Wood and straw mulch were used to create a temporary habitat for termite[4].

Soil bulk density reduces due to termite tunneling. Termites in soil aids in decomposition of cellulose materials, increase water infiltration and aeration in soil profile. Mulching materials after decomposition when mixed with surface soils it increases soil organic carbon. It increases soil moisture content to a longer period[5,6] due to decrease in evaporation rate. Naturally accumulated plant residues over the surface of the soil layer were found to cool the underlying soils as compared to un-mulched soils[7]. Mulching also has positive effect on nutrient availability to plants and sometimes acts as bio fertilizer and organic manure when nitrogen rich organic materials such as green leaves of leguminous trees are used as mulching materials, thus mulching can cut off the use of inorganic fertilizers in the field. Increased level of nitrogen and carbon was found under hardwood mulching[8]. Mulching increases the rate of seedling survival particularly in moisture deficit condition and during offseason *i.e*. post monsoon season plantation. Scientists have reported seedling survival rate[9] and up to 47 percent increase in yield[10,11]. Mulch addition had a pronounced and positive effect on survival of *Populous* spp and *Robinia pseudoacacea*[12].

Materials and Methods

Site description

This experiment was conducted in Namti village, Sibsagar district of upper Assam, India. Namti is situated between $26^0 51^/$ N latitude and $94^0\ 38^/$ E longitude. The soils of Namti region have developed from alluvial sediments of river Brahmaputra. Region receives about 2000 mm rainfall annually. Relative humidity remains very high 86-92 percent in summer and 45-60 percentages in winter seasons. Average summer temperature ranges from 28^0C to 32^0C and winter temperature ranges between 14^0C to 16^0C. Geologically study site comes under recent alluvium. Soils are well developed and deep.

Experimental design

Experiment was conducted during 2018-2019. Healthy *Aquilaria malaccensis* seedlings of 25 – 30 cm height, 2-3 branches and 0.3-0.4 cm basal diameter were planted in monsoon (rainy) season in the experimental plots. Figure (A-F) shows different mulching treatment applications in the field. Experimental design consists of 5 treatments and 3 replications. Treatments were (a) Mulching with green grass and leaves (GGL), (b) Mulching with dry grass (DG), (c) Mulching with rice straw (RS), (d) Mulching with dry leaves (DL), (e) Without mulching (WM) as control. Mulching was done during moisture deficit periods *i.e*. in the month of October. Sixty seedlings were planted for each treatment in plot size of 10 m x 10 m by maintaining a distance of 1 m x 2 m. Proper drainage was maintained and weeding and other operations were done regularly. Data analyzed following standard statistical procedures in excel software.

A: GGL (green grass and leaves), B: DG (dry grass), C: RS (rice straw), D: DL (dry leaves) E: WM (without mulching).

Figure 1: Application of different mulching treatments in *Aquilaria malaccensis* seedlings

Soil sampling and analysis

Soil samples were collected from entire experimental plot prior to land preparation by grid method from 0-20 cm and 20-40 cm soil depths for analysis of initial soil properties and also from rhizosphere zone of *Aquilaria malaccensis* seedlings one year after. Soil physicochemical properties were analyzed in soil science laboratory of RFRI, Jorhat. Collected soil samples were air dried, grinded and passed through a 2mm mesh size sieve. Soil pH was determined with systronic (361 models) pH meter in 1:2.5 soils: water suspension, Soil organic carbon by titrimetric method[13], available N by alkaline permanganate method[14], whereas available P was extracted by Bray I reagent and determined by blue colour method[15]. Available K was extracted by neutral normal ammonium acetate and estimated with the help of flame photometer[16] Mechanical analysis was done following international pipette method. Soil moisture was determined by gravimetric method. Soil moisture content was determined in the moisture deficit period for the soils under each mulching treatments to find out the most effective treatment for moisture conservation. Soil bulk density was determined by soil tube core method.

Seedling growth data

Progressive growth of ten representative seedlings from inner core area of each plot was recorded quarterly with respect to height, basal diameter and number of primary branches. Seedling survival was calculated using the method given below

$$Survival\ \%\ rate = \frac{Number\ of\ seedlings\ at\ the\ end\ of\ each\ quarter}{Total\ number\ of\ seedling\ at\ the\ time\ of\ mulching} \times 100$$

a) Seedling height (cm): The total length of the plant starting from the base of the seedling to the tip of the main branch was measured in the field using measuring tape.

b)Basal diameter (mm): Diameter of the main stem was measured using digital calliper at the base/ground level.

c)Number of primary branch: Total number of branches arising from the main stem was counted per seedling.

Results and Discussion

Soil analysis data is presented in table 1 and 2. It shows the soil physicochemical properties of experimental site before and one year after application of mulching treatments. Soils are found mostly in strongly acidic range. Soil pH was more acidic in surface then in subsurface soils. It was 4.5 to 4.8 in 0-20 cm and 4.6 to 5.1 in 20-40 cm soil depth before application of mulches. After mulching soil pH change significantly, it was 4.4 to 4.6 in 0-20 cm and 4.6 to 4.9 in 20-40 cm soil depth. Soil pH decreased in GGL, DG and RS mulching. It remained unchanged in 0-20 cm and increased in 20-40 cm soil depth under DL mulching. Soil pH increased in 0-20 cm and remained unchanged in 20-40 cm soil depth in control (table 1). Soil organic carbon was found to increase significantly under each mulching treatments in both surface (0-20 cm) and subsurface soils (20-40 cm). Before application of any mulching treatments it was recorded 1.01 to 1.33% in 0-20 cm and 0.33 to 0.63 percent in 20-40 cm soil depth. One year after, it increased significantly under mulching treatment, it was found 1.32 to 2.05% in 0-20 cm and 0.64 to 0.73 in 20-40 cm soil depth. Percentage of organic carbon has increased from 1.31 to 1.99 in GGL, 1.33 to 2.05 in DG, 1.01 to 1.96 in RS and 1.02 to 1.32 in DL mulching at 0-20 cm. It was found that organic carbon has decreased in soil without any mulch. Highest soil organic carbon was recorded in rhizosphere soils under dry grass mulching treatment (2.05%).

Soil bulk density showed a change after application of different mulching treatments but it was statistically not found significant between the treatments however there was a significant variation in soil bulk density with soil depth both before and after the treatment application. Available soil nutrients showed some changes before and after the application of mulching treatments, but it was found to be statistically insignificant in case of available nitrogen and was highly significant in case of available phosphorous and available potassium in the soil.

Available nitrogen was recorded 235.20 to 322.01 kg ha^{-1} before and 272.40 to 304.63 kg ha^{-1} after mulching in 0-20 cm soil depth and 216.38 to 326.14 kg ha^{-1} before and 240.49 to 296.14 kg ha^{-1} after mulching in 20-40 cm soil depth. Available phosphorous decreased significantly with depth after mulching, it was found 38.50 to 46.63 kg ha^{-1} in 0-20 cm depth before and 31.25 to 39.90 kg ha^{-1} after mulching. Phosphorous also decreased in 20-40 cm soil depth, it was found 25.14 to 34.50 kg ha^{-1} before and 12.42 to 28.51 kg ha^{-1} after mulching. Available potassium too decreased significantly after mulching, it was recorded 121.76 to 185.47 kg ha^{-1} in 0- 20 cm depth before and 106.31 to 135.24 kg ha^{-1} after mulching, and 73.24 to 128.12 kg ha^{-1} before and 43.70 to 79.11 kg ha^{-1} after mulching in 20-40 cm depth. Soil particle size distribution (texture) of the experimental site is presented in table 2. This property of the soil was determined only before the application of mulching treatments and since it is almost a permanent property of soils so it was not determined after mulching treatments. Soils texture was found in finer part and it was clay loam to clay.

Table 1: Soil physicochemical characteristics before and after the mulching treatments

T	D(cm)	pH (1:2.5)		Organic carbon (%)		Bulk density (g/cc)		Av. N Kg ha^{-1}		Av. P Kg ha^{-1}		Av. K Kg ha^{-1}	
		B	A	B	A	B	A	B	A	B	A	B	A
GGL	0-20	4.60	4.50	1.31	1.99	1.53	1.50	313.60	288.49	38.50	31.25	121.76	114.70
	20-40	5.10	4.90	0.33	0.73	1.59	1.60	326.14	294.90	25.14	18.45	73.24	43.70
DG	0-20	4.50	4.40	1.33	2.05	1.55	1.30	235.2	294.60	43.60	39.90	155.10	108.35
	20-40	4.80	4.60	0.63	0.67	1.78	1.60	244.61	278.70	26.71	28.51	128.12	73.85
RS	0-20	4.80	4.50	1.01	1.96	1.54	1.40	316.74	304.63	43.40	38.50	168.80	135.24
	20-40	5.10	4.60	0.61	0.73	1.78	1.42	216.38	296.14	34.50	19.47	117.73	79.11
DL	0-20	4.50	4.50	1.02	1.32	1.52	1.49	322.01	272.40	46.63	39.79	185.47	106.31
	20-40	4.60	4.70	0.41	0.64	1.93	1.60	216.38	240.49	27.18	12.42	93.54	59.81
WM	0-20	4.50	4.60	1.03	0.98	1.52	1.50	257.15	247.23	38.56	27.50	131.25	90.83
	20-40	4.70	4.70	0.59	0.55	1.67	1.70	241.47	224.40	29.75	11.91	141.12	78.43
P value for Treatment		0.00753		0.003943		0.11742		0.13134		0.00161		0.00181	
Depth		0.03678		0.015005		0.02028		0.70368		0.00140		7.73E-05	
SED		0.09		0.20		0.08		NS		3.47		11.39	
CD (0.05)		0.19		0.41		0.17				25.16		23.82	

T: Treatment D: Depth B: Before A: After

Table 2: Soil particle size distribution and textural class

Treatment	Depth(cm)	Soil particle size (%)			
		Sand	Silt	Clay	Texture
GGL	0-20	30.3	37.5	32.2	Clay loam
	20-40	28.0	34.6	37.4	Clay loam
DG	0-20	29.1	30.9	40.0	Clay loam
	20-40	30.3	32.8	36.9	Clay loam
RS	0-20	27.3	30.5	42.2	Clay loam
	20-40	29.0	34.0	37.0	Clay loam
DL	0-20	32.5	31.4	36.1	clay loam
	20-40	49.7	8.8	41.5	clay
WM	0-20	32.5	46.0	21.5	Clay
	20-40	26.7	38.3	35.0	clay

Percent soil moisture content was recorded for three months when there was no rainfall to find out the effect of mulching. Moisture content was found highest in rhizosphere zone of seedlings under RS mulching. It was 31.54% in November, 2019; 23.71% in December, 2019; and 14.35% in January, 2020. Lowest soil moisture was recorded for without mulch cover. Soil moisture content follows the trend, RS> DG > GGL > DL and then WM for all the three months (table 3).

Table 3: Soil moisture in rhizosphere soils with respect to mulching.

Treatment	Mean soil moisture (%) ±SEM		
	November, 2018	December, 2018	January, 2019
GGL	24.77 ± 0.80	22.42 ± 0.07	11.89 ±0.10
DG	29.12 ± 0.58	22.79 ± 0.02	12.56 ± 0.09
RS	31.54 ± 1.02	23.71± 0.19	14.56 ± 0.16
DL	22.56 ± 0.23	21.74± 0.35	10.43 ± 0.01
WM	21.59 ± 0.34	20.07 ± 0.03	9.09 ± 0.10

Seedling survival rate is presented in table 4. Seedling survival were recorded quarterly for one year and converted to percent survival. It was observed that *Aquilaria malaccensis* seedlings survived to 95 percent under treatment with RS followed by GGL (91%), DL (90%) and DG (88.33%). Seedling survival rate was low in case of without mulching treatment.

Table 4: Survival rate of seedlings with respect to mulching

Treatment	Survival of seedlings (%)			
	3 months	6 months	9 months	12 months
GGL	96.66	93.33	91.66	91.66
DG	95.00	93.33	88.33	88.33
RS	96.66	95.00	95.00	95.00
DL	91.66	90.00	90.00	90.00
WM	81.66	80.00	76.00	76.00

Progressive growth in height of seedlings with respect to mulching treatments is presented in table 5. Progressive height growth of ten representative seedlings from the inner core area of the plots was monitored and data recorded quarterly for one year. It was found that seedling growth rate was better under DL initially. However growth rate become much higher later under RS mulching and was recorded 184.9 cm after 1 year followed by DG (146.70 cm), DL (129.60 cm) and then GGL (128.20 cm).

Table 5: Progressive growth in height of seedlings

Treatment	Average height of seedlings (cm) and SEM value			
	3 months	6 months	9 months	12 months
GGL	28.8 ± 0.86	43.0 ± 2.23	102.2 ± 4.07	128.2 ± 4.83
DG	28.9 ± 1.55	51.9 ± 3.04	114.7 ± 3.77	146.70 ± 3.81
RS	28.8 ± 2.74	45.0 ± 10.79	119.0 ± 14.11	184.9 ± 20.73
DL	33.1 ± 5.42	56.0 ± 7.87	106.6 ± 18.63	129.6 ± 12.96
WM	27.6 ± 4.40	38.2 ± 5.11	82.5 ± 15.60	117.5 ± 13.72

Progressive growth in basal diameter of seedlings with respect to different mulching treatment is presented in table 6. Results showed that RS mulching gives better girth growth as compared to all the other treatments. It was 0.54 cm in three months, 0.85 cm in six months, 2.03 cm in 9 months and 4.24 cm in one year old seedling. It was followed by DG (3.77 cm), GGL (3.34 cm) and then DL (3.27cm).

Table 6: Progressive growth in basal diameter of seedlings

Treatment	Average basal diameter of seedlings (cm) and SEM value			
	3 months	6 months	9 months	12 months
GGL	0.49 ± 0.09	0.82 ± 0.13	1.84 ± 0.28	3.34 ± 0.58
DG	0.52 ± 0.11	0.83 ± 0.08	1.87 ± 0.13	3.77 ± 0.43
RS	0.54 ± 0.18	0.85 ± 0.07	2.03 ± 0.18	4.24 ± 0.85
DL	0.49 ± 0.11	0.82 ± 0.10	1.89 ± 0.26	3.27 ± 0.34
WM	0.49 ± 0.12	0.78 ± 0.14	1.89 ± 0.26	2.97 ± 0.25

Newly planted seedlings had 2-3 branches, 3 months later number of primary branches started budding in each treatments. Number of branches arouse from main stem were counted and calculated the average for each quarter, the results presented in table 7. RS mulching treatment gave maximum number of primary branches (22) followed by DG (19), GGL (15) and DL (12).

Table 7: Average number of primary branches of seedlings

Treatment	Average number of branches of seedlings and SEM value			
	3 months	6 months	9 months	12 months
GGL	4 ± 0.14	9 ± 0.50	11 ± 0.50	15 ± 0.79
DG	3 ± 0.22	7 ± 0.47	14 ± 0.27	19 ± 1.39
RS	4 ± 0.22	12 ± 0.41	16 ± 0.50	22 ± 1.10
DL	2 ± 0.36	7 ± 0.27	9 ± 0.36	12 ± 0.50
WM	3 ± 0.45	5 ± 0.12	9 ± 0.22	10 ± 0.41

Effect of different mulching treatment on growth performance with respect to height, basal diameter and production of new primary branches showed that materials used for mulching had significant influence on *A. malaccensis* seedlings (table 8). Seedling growth rate was significantly higher under mulching treatments as compared to seedlings without any mulching treatment (control). Maximum growth rate was observed in rice straw mulching in every aspect.

Table 8: Growth performance of seedlings with respect to mulching treatment

Treatment	Height (cm)	Basal diameter (cm)	Number of Primary branch
GGL	128.2	3.34	14.9
DG	146.7	3.77	18.7
RS	184.9	4.24	22.1
DL	129.6	3.27	12.1
WM	117.5	2.94	10.3
P value	7.1E^{-14}	1.99 E^{-05}	2.02E $^{-12}$
SED	5.44	0.23	4.47
CD (0.05)	10.98	0.46	9.03

In this experiment different mulching materials were evaluated for their efficiency in upper Assam climatic condition on performance of agar seedlings. Majority of soils under agar plantation in Assam are clay loam to loam, these types of soils has more clay so becomes sticky and holds more moisture when there is water around but becomes harder and compact when dry. Mulching had pronounce effect over control on survival and progressive growth and development of *A. malaccensis* seedlings which might be because of favorable conditions endow with mulching. Soil pH decreased significantly in 0-20 cm soil depth in green grass and leaf, dry grass and rice straw mulching. It also decreased in 20-40 cm soil depth of dry grass and rice straw mulching. However it remained unchanged at 20-40 cm soil depth in green grass and leaf treatment and increased in dry leaf materials. Decrease of soil pH under mulching had been reported by several scientists[17-20.] Multiple causes are associated with lowering of pH. It might be due to the nature or chemical composition of the organic mulching materials, rate of decomposition, total soil surface cover, effect on soil moisture and temperature and these entire factor have direct or indirect effect on soil pH. It is a known fact that all the organic materials when decompose releases organic acids, high density carboxyl and phenolic substances[21].

Scientists have described organic acids produced from decomposition of plant derived materials their accumulation and subsequent leaching into soil[22]. Nitrification and ammonification are another two important chemical properties associated with change of soil pH[23]. Nitrification takes place in dry soil (oxidized) and ammonification takes place in moist soil (reduced) condition. Rice straw mulching forms a thick mat and can hold moisture for a longer period as compared to dry leaf, fresh green materials and dry grass probably that might be the reason for more lowering of soil pH. In case of no mulching treatment, bare soil surface aided loss of moisture and thus nitrification process prevailed which kept pH unchanged in 20-40 cm soil depth and increased in 0-20 cm soil depth. Any organic materials when added to soil it is acted upon by many macro and microorganisms and subsequently under goes decomposition. Decomposed materials are organic matter, 50 percent of it is organic carbon. Thus when organic mulches are added on soil surface it increases the percentage of organic carbon in soil, similar effects was observed in this experiment also, mulching significantly increased soil organic in both 0-20 cm and 20-40 cm soil depth. Highest soil organic carbon was recorded in rhizosphere soils under dry grass mulching treatment (2.05 percent), the reason might be due to herbaceous nature of dry grass which is easily decomposable. Rate of increase was highest in soils with RS mulch treatment due to bulky nature of RS. Bulk density of soil reduced after mulching, that can be related with the soil organic carbon. Similar results were also observed earlier[24,25].

Increase in soil organic carbon helps in soil aggregate formation thus reduce compaction. Soils under mulching were found to have greater structure stability[26]. Improved aggregation helps in greater retention of soil moisture in root zone of seedlings so it decreases seedling mortality. Effect of mulching on bulk density depends on soil properties, climate and type of mulch[23]. Clay and clay loam in presence of sufficient organic matter forms porous granules, increases total pore space and lower bulk density. Bulk density of clay loam and silt loam soils ranges from 1.00 to 1.60 Mg/cc[27]. Addition of organic mulches on soil surface increases the nutrient contents of soils this is due to mineralization of organic materials by macro organisms and microbes and subsequent release of trapped nutrients into the soil. Mulching increases soil nitrogen[8,23,28-32,]. Available nitrogen was recorded low after mulching in this experiment the reason can be explained that sampling was done in June *i.e.* monsoon season in Assam (India). Heavy rainfall leached down the NH_4^+, NO_3^- and NO_2^- nitrogen, so concentration was recorded high in some cases in 20-40 cm soil depth. At the time of sampling seedlings are 1 year old and vigorously growing extracted nitrogen from soil for their vegetative growth. Similar is the case with available phosphorous and potassium, both nutrients were found to decrease. Though phosphorous is less labile and get fixed in acid soils, and potassium is semi - labile they are also needed by growing plant in maximum amount.

Seedling survival rate was recorded more in mulched then un-mulched treatments and highest (95 %) in RS mulching. Optimum soil moisture in water deficit period, 31.54 percent in November, 23.71 percent in December and 14.56 percent in January might have provided an ideal condition under RS mulching. Rice straw forms an excellent cushion like cover around seedling as compared to GGL and DG mulching. Soil strength was found to limit root growth[33], addition of mulching materials increases porosity, high root density[34] and vertical root growth of seedlings[35] thus helps in survival and growth. Growth and development of *A. malaccencis* seedlings was found more vigorous under RS mulching, this might be due to remarkable effect of RS mulching on soil. Encouraging effect of RS mulch was also found on soil organic carbon, nutrient[36-39]. And on soil moisture[40] weed control[41-43] and other growth promoting factors.

Conclusion

Mulching had pronounced effect on soil physico- chemical properties as well as survival, growth and development of *A. malaccensis* seedlings. RS (Rice straw) was found to be better mulching material in upper Assam soil condition because seedling survival percentage was highest and also progressive rate of growth and development was better in RS mulching as compared to GGL, DG and DL mulching. Rice straw able to maintain optimum moisture in rhizosphere zone and reduced soil compactness.

Recommendation

From this experiment, we can recommend that rice straw (RS) can be used extensively in *A. malaccensis* plantation as mulching material for greater seedling survival and vigorous growth and development as RS has multiple benefits. Rice is a major crop in Assam and RS is easily and abundantly available in farmer’s field. RS is cost-effective, therefore can be easily carried in huge amount without much economic trouble to agar planters.

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