

The Efficacy of Different Mulching Materials in Influencing Growth, Yield, Soil and Quality Parameters of Ginger Cultivated in Low Country Intermediate Zone (IL1) of Sri Lanka

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Abstract

Even though mulching is a well-known fact among cultivators they are seemingly unaware of its contribution to growth and yield of Ginger and its ability to cope with temperature and water stress. Therefore, a field experiment was conducted at the Intercropping and Betel Research Station, Narammala to investigate the effect of different mulching materials on growth, yield, quality parameters of Ginger and the soil parameters in the Low country intermediate zone (IL1) of Sri Lanka. The study was also extended to find out the best mulching material for Ginger under certain field conditions. The findings are expected to contribute to eliminate the uncertainty faced by farmers when selecting suitable mulch for Ginger. The mulches tested were straw, gliricidia leaves, coconut leaves, coir dust and polythene. A control treatment was used without the use of mulch. Experiment was carried out as a Randomized Complete Block Design (RCBD) with three replications. Plant and soil parameters were measured at monthly intervals. All the treatments showed better performances than the control treatment which did not use

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mulch. The maximum number of sprouted plants was obtained in plots mulched with gliricidia. Further, the significantly highest plant height and number of pseudostems per clump were observed in gliricidia mulched plants. Fresh weight and dry weight of rhizomes too followed the similar pattern of measured growth parameters. Plots that did not use mulch recorded the lowest growth rate and yield of Ginger. Soil moisture conservation was significantly higher in the treatments with mulch than the control treatment. Polythene mulch was more effective for conserving of soil moisture than other mulches. However, all the soil parameters significantly contributed to the highest yield of Ginger in Gliricidia mulch treatment. The pungency level of Ginger was significantly higher in the control treatment. In this study gliricidia mulch positively contributed to increase the yield of Ginger (43.66% per hectare) more than the average yield denoted by DEA. Keeping the above facts in view, gliricidia proved to be the best mulch for Ginger cultivation in the low country intermediate zone (IL1) of Sri Lanka. Therefore, the results of this study will help the farmers to use the correct mulch to get significantly higher yield.

Key words: Ginger, Mulches, Pungency, Growth, Yield, Moisture

Introduction

Ginger (*Zingiber officinale* Roscoe) belongs to the family Zingiberaceae and is one of the economically-important crops in Sri Lanka. Rhizome of the plant is used as a delicacy, medicine and spices. Ginger is widely propagated by planting rhizome pieces. Ginger is used to prepare value-added products such as Ginger bread, cookies, crackers, cakes, Ginger-ale and Ginger beer. Ginger is grown in all over the country but wet and intermediate zones are the major growing areas. Total cultivated extent and production in 2017 were 1,883 ha and 16,326 Mt (DEA 2018). In Sri Lanka farmers cultivate three main types of Ginger: local, Chinese and Rangoon. Mulching in Ginger is a common cultivation practice. Mulching is the process or practice of covering the soil/ground to make favorable condition for plant

growth, development and efficient crop production. Mulching controls weed infestation, reduces run off and soil loss, improves physical, chemical and biological properties of soil which leads to better yield of crop (Singh et al., 1976, Aggarwal et al., 2002 and Subrahmaniyan et al., 2011) And also mulching provides multiple benefits such as enhancing soil temperature and moisture retention, accelerating crop growth with increased yield (Tiwari et al., 2003; Ghosh et al., 2006; Kasirajan and Ngouajio, 2012). Mulching also improves crop-water use efficiency, minimizes salt build-up in the crop root zone and reduces fertilizer leaching during rainy periods (Dong et al., 2009; Yuan et al., 2009; Almeida et al., 2015). Mulching has been found to increase the yield of Ginger (Aclan, 1976 and Mohanty and Sharma, 1978). Hanada (1991) and Salau et al., (2002) reported that the mulching stimulates the microbial activity in soil through improvement of soil agro-physical properties. Mulching also minimizes the use of Nitrogen fertilizer (Jones et al., 1977). Organic mulch can be defined as application of a layer of some suitable plant or animal residue such as straw, leaves, manure, or sawdust to the soil surface to protect the soil surface and provide a more favorable environment for plant growth. Organic mulches are also available, which are environmentally friendly and are also available at low cost. Apart from that synthetic mulches like transparent polythene and colored polythene can be used to increase the yield (Thankamani et al., in 2016).

Problem statement and justification the research

Normally Ginger cultivation is carried out in the *Yala* season from March or May under rain-fed conditions. However, rain-fed cultivation is unreliable due to the increase in atmospheric temperature and unpredictable and or low rainfall due to the impact of climate change in future (De Silva, 2006). Frequently, Ginger cultivators face severe drought condition during the plants' vegetative stage and maturity stage which adversely affects the growth and yield of Ginger. Kushwah *et al.*, in 2012 reported that moisture is one of the major biotic factors which affects the production of the crop. And also, Kushwah *et al.*, in 2012 reported that covering of soil with mulch prevents the extreme changes in soil temperature and creates a micro environment in which moisture loss through evaporation comes down. And also, heavy

rainfall is a factor that leads to the reduction of a yield, because it causes soil erosion as well as leaching loss of nutrients (Issaka *et al.*, 2017). Apart from these problems excessive water also increases the incidences of diseases to the crop. Due to high weed population in the field, plants unable to get enough water and nutrient from the soil (Lee *et al.*, 1981). It is also one reason which can could cause the reduction of a Ginger yield. Microorganisms are very important to increase the physical, chemical and biological properties of soil and their presence is also vital to enhance the stability of soil aggregation and improve soil properties which could provide favorable environmental condition for better growth of the plant. Singh *et al.*, (1976), Aggarwal *et al.*, (2002) and Subrahmaniyan *et al.*, (2011) reported that mulching controls weed infestation, reduces run off and soil loss, improves physical, chemical and biological properties of soil which leads to better yield of crop. They further predicted that the increase in temperature due to climate change will pose serious threats to soil temperature (De Silva *et al.*, 2007). Montague *et al.*, (2004) reported that mulching is important to reduce surface temperature of the soil.

Even though mulching is a well-established fact among the scientific community, farmers are not convinced and remain uncertain about selecting suitable mulch for different crop species. Kader *et al.*, 2017 reported that the different mulch materials have different effects on soil environment and crop yield. In this study Ginger was taken as an example as it provides income for small farmer communities who produce the crop for the export market.

The objective of this research was to examine the efficacy of different mulching materials to affect the growth, yield, soil and quality parameters of Ginger cultivated in the Low country intermediate zone (IL1) of Sri Lanka and then find out the best mulching material for local Ginger under the field conditions

Methodology

Location and Variety selection

The study was carried out in a field at the Intercropping and Betel Research Station, Department of Export Agriculture, Narammala, (IL1) during the period from January to December 2017. The Soil type of the plot was sandy loam with a pH ranging from 5.74 to 6.58, having total nitrogen 0.13%, available phosphorus 320 ppm and available potash 0.017%. Local type of Ginger was selected for this experiment.

Land preparation

The site was mechanically prepared with the aid of a tractor. Land preparation was done by clearing, ploughing, harrowing and making of beds. Eighteen beds of 130cm in length and 105cm in width were prepared.

Preparation of planting material and planting

The test crop was Ginger (local type) obtained from the Intercropping and Betel Research Station, Narammala. The rhizome was cut into plant-able sett size of 30-40 g (DEA) and care was taken to ensure that each set contained at least two buds. Seed treatment involved dipping the rhizomes 50°C hot water and solution of recommended fungicides Captan (N-trichloromethylthio-4-cyclohexene-1) for about two minutes in the evening of the day preceding the act of planting. Then seed Ginger were planted in shallow holes of 4cm deep at a spacing of 30cm X 70cm. Basal fertilizer was applied after planting and before mulching according to the recommendation of Department of Export Agriculture.

Experiment design

Six treatments consisting of mulching with straw (T2) at the rate of 1.5 kg per plot (fresh weight), gliricidia (T3) at the rate of 5 kg per plot (fresh weight) , 25 microns polythene sheet (T4), coconut leaves (T5) at the rate of two coconut branch per plot , coir dust (T6) at the rate of 5 kg per plot (dry basis), and control (T1) (without mulch) were laid in Randomized Complete Block Design (RCBD) with three replications.

Application of mulching

Different types of mulching materials were applied according to the recommendation of DEA. Straw was collected from a paddy field near the research station and kept under shade condition. 1.5kg of straw (fresh weight) was measured and it was applied to one plot once per 12 weeks. Five kilo grams (5 kg) of Gliricidia (fresh weight) were applied to another plot once per six weeks. Two coconut branches were added to one plot. 5 kg of coir dust (fresh weight) was applied per plot once per 7 weeks. 25 microns polythene sheet was applied to the other plots according to the experimental design. The control preparation was without mulch.

Field Layout

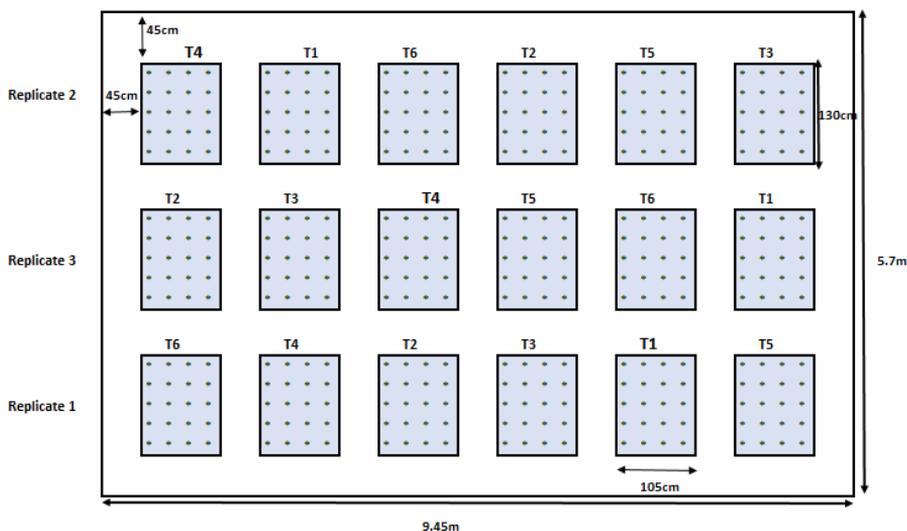


Figure 1: Field Layout

Intercultural practices

Plants were watered sufficiently in the propagation period except on rainy days. After that, watering was done once a week. Every morning plants were examined for investigation of diseases, disorders and data collection. All the soil-related cultural practices were kept at minimal level not to disturb the soil fauna.

Irrigation

Watering was done manually. On rainy days watering was disregarded and 35 L amount of water (1/5 amount of field

capacity) was applied to each plot once per week. This irrigation interval and the amount were selected to minimize water usage with mulching. The field capacity of soil was measured using volume basis method and pressure plate apparatus (Cresswell *et al.*, 2008). Soil moisture was measured by gravimetric method (Jalota *et al.*, 1998).

Collection of Data

Observations were recorded on growth parameters such as the number of sprouting plants, number of pseudo stem per clump, plant height, and yield parameters such as number of rhizome fingers, fresh and dry weight of rhizomes and soil parameters such as soil moisture, total nitrogen, available phosphorous and available potassium. Soil pH and soil EC were recorded once per month and the quality parameters such as pungency of Ginger was recorded at the age of about 6 months. All of the measured data (Table 01, 02) were subjected to Analysis of Variance (ANOVA) using SAS software package. Mean separation was done by Least Significant Difference Test (LSDT) at 0.05 level of probability.

Observation on plant growth and yield parameters

Table 1. Plant Parameters

Plant Trait	Method of trait measurement
Plant height (cm)	Plant height was taken from the ground level to the tip of the longest shoot. Data was recorded from randomly selected two plants from each replicate.
Number of emerged plants from the soil	Number of emerged plants was counted in each replicate.
Fresh and dry weight of the rhizome (kg/ha)	After harvest, rhizomes were cleaned and fresh weight was taken by electronic balancer. Dry weight was taken by drying the rhizome in the oven in 70 °C temperature to obtain constant weight. After that weight was taken by using an electronic balancer.

Weed biomass (g)	Weed was taken from each replicate and fresh weights were taken and then dried in the oven in 70 °C temperature until constant weight and dry weights were recorded.
Number of rhizome fingers	Count rhizome fingers of rhizome. Two plants were taken from each replicate.
Total biomass (g)	Total biomass weight was taken from two plants from each replicate.
Pseudo stems per clump	Pseudo stems per clump were counted from two plants from each replicate.

Observation of soil parameters

Table 2. Soil Parameters

Soil Trait	Method of trait measurement
Soil pH	Soil pH was measured by pH meter (McLean, 1982)
Soil EC (mS)	Soil EC was measured by EC meter (Rhoades, 1982).
Soil moisture content (%)	Soil moisture was measured by Gravimetric method (Jalota <i>et al.</i> , 1998) before irrigation.
Soil total nitrogen content (%)	Soil nitrogen content was measured using Kjeldahl method (Nelson <i>et al.</i> , 1980).
Soil available phosphorus content (ppm)	Soil phosphorus was measured colorimetrically using ammonium molybdate procedure by Spectrophotometer according to Chapman and Pratt (1961) and Jackson (1973).
Soil available Potassium content (%)	K content was measured by using Ammonium acetate extraction method. (Helmke and Sparks, 1996).

Observation of quality parameters

Pungency of rhizome

Sensory evaluation was done to test pungency level of Ginger using Friedman Rank Sum Test with five-point hedonic scale. Tea was prepared to test the pungency of rhizome. 25ml of water was used to prepare one sample of tea with 10g of rhizome piece according to the treatments. Six tea samples were prepared for six treatments and one additional tea was prepared without Ginger as a control and were given to thirty persons to taste and were asked them to give marks according to the pungency level of rhizome. Marks were given according to the five-point hedonic scale as follows and data were analyzed by SPSS package.

Pungency level	Mark
Extremely low pungency	1
Slight pungency	2
Moderate pungency	3
Very much pungency	4
Extremely high pungency	5

Results and Discussion

Growth Parameters

Number of sprouting plants

Treatments T3 (gliricidia) and T2 (straw) showed significantly ($p < 0.05$) the highest number of emerged plants in the 2nd month and treatment T6 (coir dust) showed the lowest number of sprouted plants (Table 3). All the treatments have totally completed their germination (100%) at the moment of the third-month data collection and because of that there was no significant difference in the number of emerged plants in the third month.

Plant height

The results presented in Table 3 indicated that different mulching materials significantly ($P < 0.05$) influenced the plant height. Maximum plant height was recorded in mulching with leaves of gliricidia (T3), which was significantly superior over the treatments of T1, T4 and T6. However, it was not significantly ($P > 0.05$) different from the treatments of T2 (straw mulch) and T5

(coconut leave). The minimum plant height was recorded in the case where mulch (T1) was not used and it might be due to the expose of seed Ginger to the direct sun light. Therefore, the plant became weak when compared to other treatments. Mohanty *et al.*, (1999) reported that the plant height was low in treatment without mulch. Gliricidia mulch (T3) was the effective agent that influenced the plant height, and that might be due to the release of organic ions to the soil because of its high decomposition rate when compared to other organic mulch treatments. Montague *et al.*, (2004) reported that the mulches which decomposed faster, released nutrients into the soil that can be used by plants and microbes.

Number of Pseudostem per clump

The number of pseudostems per clump responded significantly to different mulching materials. Pseudo stem per clump showed an increasing trend pattern during the study period. The highest number of pseudostem was obtained in gliricidia mulch (T3) which was significantly different ($P < 0.05$) from the control as well as other treatments (Table 3). Treatment T2 (straw) and T5 (coconut leave) were at par with each other and showed better results than treatments of T1, T4, and T6. The lowest number of pseudostem per clump was recorded in treatment (T1) control and it was significantly different ($P < 0.05$) from all other treatments.

Table 3. Growth Parameters of Ginger

Treatments	Number of Sprouted plants (%)	Plant height	Number of pseudostems per clump
T1	45 ^{cd}	80.67 ^d	15.83 ^e
T2	80 ^a	99 ^a	22.5 ^b
T3	81.67 ^a	102.167 ^a	28 ^a
T4	55 ^{bc}	93 ^{bc}	20.83 ^c
T5	65 ^{ab}	96.83 ^{ab}	22 ^{bc}
T6	31.67 ^d	87.67 ^c	18.83 ^d
Treatment	$P < 0.05$	$P < 0.05$	$P < 0.05$
CV (%)	4.45	3.39	4.97

Treatments are significantly different if they do not share a letter (s) in common adjusted P value < 0.05.

Yield Parameters

Fresh weight and dry weight of rhizome

The results presented in Figures 2 and 3, clearly revealed that the yield (kg/ha) of Ginger was significantly ($P < 0.05$) influenced by the use of different mulching materials. Fresh and dry weight of rhizome showed an increasing trend pattern during the study period. These findings are in line with those of Senguptha in 2009. Gliricidia mulch produced a pronounced effect ($P < 0.05$) with regard to plant yield against the other treatments. Gliricidia mulch readily decomposes compared to other examined mulches, and it is a constant and quick supplier of available nutrients for plants. Use of coir dust was less effective towards increasing the yield of the crop. However, the maximum and minimum dry weight of rhizome were recorded from gliricidia (T3) and control (T1), respectively. Minakshi (1959) reported that mulching is vital for increasing the growth rate of rhizome. Therefore, fresh weight of rhizome has increased in a similar pattern, as T3 (Gliricidia) > T2 (straw) > T5 (coconut leaf) > T4 (polythene) > T6 (coir dust) > T1 (control). Kumar *et al.*, (2018) reported that the higher rhizome yield with organic mulches was due to the improved growth attributes, reduced competition by weeds and improved soil conditions.

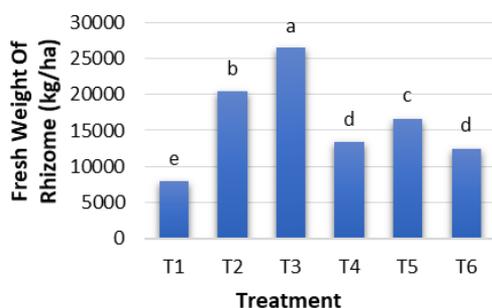


Figure 2: Fresh Weight of Rhizomes (kg/ha)

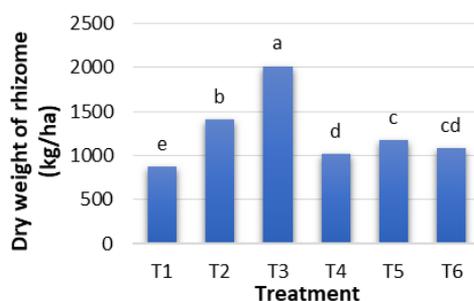


Figure 3: Dry Weight of Rhizomes (kg/ha)

(Treatments are significantly different if they do not share a letter (s) in common adjusted P Value < 0.05)

Number of rhizome fingers

The number of rhizome fingers per clump was significantly ($P < 0.05$) influenced by the use of different mulching materials. The highest number of rhizome fingers was obtained in gliricidia mulch (T3) which was significantly different ($P < 0.05$) from all other treatments. Mulching with straw (T2) secured second place. The minimum number of rhizome fingers was recorded in the case where mulch (T1) was not used and it might be due to the direct exposure to the sun light and poor moisture conservation due to higher evaporation than other treatments. Similar results were reported by Ram Chandra and Govind (2000). The number of rhizome fingers has increased in a similar pattern, as T3 (Gliricidia) > T2 (straw) > T4 (polythene) > T5 (coconut leave) > T6 (coir dust) > T1 (Control).

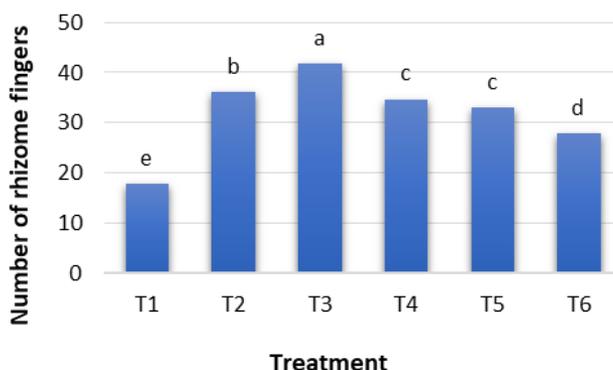


Figure 4. Number of Rhizome Finger, Six Months after Planting

Treatments are significantly different if they do not share a letter (s) in common adjusted P value < 0.05

Soil parameters

Soil pH

The lowest pH was obtained in gliricidia mulch (T3) (Table 4) and it was significantly different ($P < 0.05$) from control (T1), polythene (T4) and Coir dust (T6) treatments. Lowest pH value in Gliricidia mulching treatment might be due to the release of organic acids to the soil when it decomposed. Earlier studies have shown that soil pH decreases when organic mulches are used (Tukey and

Schoff, 1963; Billeaud and Zajicek, 1989 and Duryea *et al.*, 1999). Treatments with organic mulch showed lower pH value than the control treatment. The same results were reported by Himelick and Watson in 1990, they observed that mulch induced pH reduction results from the addition or retention of organic matter, with organic acids produced from decomposition of plant-derived materials accumulating or leaching into the soil. The effect of mulch appears to depend on the relative difference between the soil pH and that of the mulch. pH showed a decreasing trend pattern during the study period. When plants grow, plants absorb more ions from the soil as nutrient. As a result of the absorption of nutrient by the plant, H⁺ ions were released to the soil. And also, application of urea in 45 days and 90 days after planting resulted in the decrease of soil pH due to acidification resulting from dissociation of urea to produce H⁺ ions.

Soil Electrical conductivity (EC)

The highest EC was shown in gliricidia mulch (T3) and it was significantly different from the other treatments. The lowest EC was shown in polythene mulch (T4) and it might be due to high moisture conservation in T4 treatment. Higher moisture content increased the solubility of ions. As a result of that soil EC decreased. Iles and Dosmann (1999) reported that due to high moisture conservation and high solubility of ions, soil EC decreased.

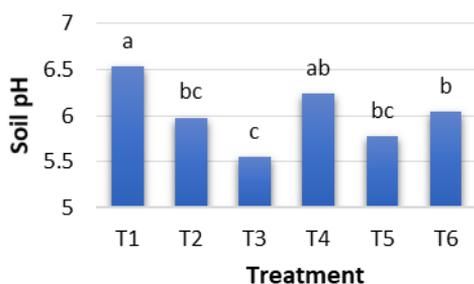


Figure 5. Soil pH

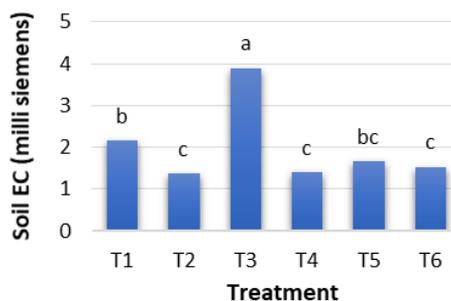


Figure 6. Soil EC

Treatments are significantly different if they do not share a letter (s) in common adjusted P value < 0.05

Soil moisture content (%)

Ni *et al.*, in 2016 reported that different mulches have variable effects on the soil moisture content. The highest percentage of moisture was obtained in plots mulched with polythene mulch (T4) and it was significantly different ($P < 0.05$) from other treatments. Jones *et al.*, (1977) reported that the highest moisture conservation was observed under the polythene mulch mostly due to prevention of evaporation from the soil surface. Plots mulched with gliricidia (T3) also showed high moisture percentage. Treatment T1 (control) showed significantly the lowest percentage of moisture and it might be due to higher soil evaporation than the other treatments. Therefore, moisture conservation ability of each mulch can be shown as T4 (polythene) > T3 (gliricidia) > T2 (straw) > T6 (coir dust) = T5 (coconut leave) > T1 (control). All the treatments which consisted of mulch showed better performances than the treatment of control. Khurshid *et al.*, (2006) found similar results: mulching improves the ecological environment of the soil and increases soil water contents.

Soil total nitrogen

The highest percentage was shown in gliricidia mulch (T3) and it was significantly different ($P < 0.05$) from all the other treatments (Figure 11). Gliricidia leaves produce a high quantity of biomass that contains a low concentration of lignin and active polyphenol that makes it decompose rapidly (Vanlauwe, 1996; Kwesiga *et al.*, 2003; Subramanian *et al.*, 2005). Subsequently this highest soil nitrogen percentage under Gliricidia mulch has significantly contributed to the growth and yield parameters of Ginger. The lowest percentage of soil nitrogen was obtained in the control treatment (T1). All the treatments which consisted of mulch showed higher soil nitrogen percentage than the control treatment. Alharbi in 2017 reported that the total N in surface layer in mulch treatment was higher than treatment that did not use mulch. Ginger plant is more sensitive to N fertilizers (DEA, 2011). Therefore, the plant growth rate was high in all the treatments which consisted of mulch than the control treatment—

that may be due to positive correlation of soil total nitrogen percentage and vegetative growth of the plant.

Soil available phosphorous

There is tendency towards a higher amount of available phosphorus in the soil in plots that did not use mulch. Coir dust (T6) mulch on available phosphorus had the most influence but it was not significantly different from treatment T3 (gliricidia). The lowest available phosphorous content was shown in Treatment T1 (control). Similar results were obtained by Green lee and Rakow (1995) who mentioned that phosphorus availability under mulch treatment increased in comparison with no mulched treatment.

Soil available potassium

The positive effect of gliricidia (T3) mulch on available potassium in the soil was estimated and it was significantly different ($P < 0.05$) from the other treatments. The lowest ($P < 0.05$) amount of soil available potassium was obtained in control (T1). Alharbi in 2017 reported that the soil K was significantly affected by the mulching process ($p < 0.05$). Furthermore, he recorded that the available K in the soil for treatment with mulch was higher than treatments with zero mulch.

Table 4. Soil Properties

Treatments	Soil moisture content (%)	Soil total nitrogen (%)	Soil available phosphorous (ppm)	Soil available potassium (%)
T1	4.858 ^d	0.116 ^c	314.5 ^d	0.0187 ^e
T2	8.894 ^{bc}	0.188 ^b	362 ^c	0.0311 ^b
T3	9.698 ^b	0.262 ^a	384.16 ^{ab}	0.0389 ^a
T4	12.363 ^a	0.187 ^b	378.76 ^b	0.0251 ^{cd}
T5	7.865 ^c	0.182 ^b	360.33 ^c	0.0200 ^{de}
T6	8.739 ^{bc}	0.146 ^{bc}	395 ^a	0.0294 ^{bc}
Treatment	$P < 0.05$	$P < 0.05$	$P < 0.05$	$P < 0.05$
CV (%)	11.33	18.47	1.79	10.88

Treatments are significantly different if they do not share a letter (s) in common adjusted P value < 0.05

Keeping the above facts in view, all the soil parameters significantly contributed to the highest yield of Ginger in Gliricidia mulch treatment.

Quality parameters

Pungency of rhizome

Pungency is mainly varied according to type of Ginger but environmental conditions also slightly affected the pungency level of Ginger (DEA, 2011). According to Figure 7, the highest pungency level was obtained in control (T1) and it was significantly different ($P < 0.05$) from all other treatments. Lower soil moisture content might have resulted in the higher concentration of chemical constitution of the Ginger in the control (T1) treatment. Therefore, it might be the reason for the high pungency level in the control (T1) treatment. The lowest pungency level was obtained in T4 (polythene sheet) and it might be due to highest moisture content contributed to the dilution of chemical constituents. However, the type of mulching materials had no significant impact on the pungency level of Ginger.

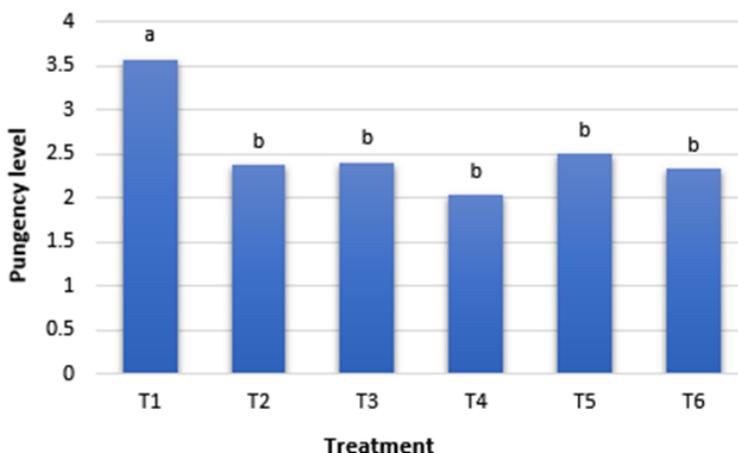


Figure 7. Pungency of Ginger in Treatments Six Months after Planting.

Treatments are significantly different if they do not share a letter (s) in common adjusted P value < 0.05

Conclusions and Recommendations

Mulch significantly affected the soil chemical properties, growth and yield parameters of Ginger as it increased soil moisture contents, soil total nitrogen, available phosphorous, available potassium, plant height, number of pseudo stems per clump, number of rhizome fingers, fresh and dry weight of rhizomes and decreased soil pH and pungency levels. The best significant performances in plant and yield parameters were observed in gliricidia mulch treatment (T3). Treatment performances on growth and yield parameters can be shown as gliricidia (T3) > straw (T2) > coconut leaf (T5) > Polythene (T4) > coir dust (T6) > control (T1). Treatment T1 (control) showed the lowest growth rate, yield and soil improvements. Poor plant performances of T1 treatment might be due to exposure to sunlight, evaporation, high weed growth and runoff. Polythene mulch had a good ability to conserve moisture than the other treatments.

With the increase in temperature and decrease in rainfall due to global warming, farmers need to follow adaptation measures to maintain the potential yield of Ginger. Average yield of Ginger was estimated as 6000 kg/acre by DEA. According to this study, application of gliricidia mulch positively affected the increasing yield of Ginger at 43.6% per hectare more than average yield denoted by DEA. Therefore, farmers are advised to use gliricidia mulch, which is freely available, to achieve a good yield in Ginger cultivation.

This study has been conducted in intermediate zone (IL1) of Sri Lanka and the results of this experiment might be different for the other climatic conditions. Therefore, further investigation is needed and is suggested for different agro-ecological region of Sri Lanka in order to confirm the present findings.

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References

- Aclan, F. and Quisumbing, E. C. (1976). Fertilizer requirement, mulch and light attenuation on the yield and quality of Ginger, *Philippine Agriculturist*, 60 : 183-91.
- Aggarwal. S., Korla, B. N., Sharma. V., (2002). Effect of dates of planting and mulch materials on growth and yield of Ginger (*Zingiber officinale* Rosc.) Haryana *J Hort Sci* 31(1&2):108-110.
- Aggarwal, S., Korla, B. N., Sharma. V. (2002). Effect of dates of planting and mulch materials on growth and yield of Ginger (*Zingiber officinale* Rosc.) Haryana. *J Hort Sci*, 31(1&2):108110.
- Aiyadurai. S. G., (1996). A review of Research on spices and cashew in India, *Indian council of Agricultural Research, New Delhi*, p. p. 85-103.
- Alharbi, A. (2017). Effect of mulch on soil properties under organic farming conditions in center of Saudi arabia, *scientific proceedings international scientific-technical conference "agricultural machinery"* volume 2, p. p. 230-236.
- Almedida, W. F. D., Lima, L. A., Pereira, G. M., (2015). Drip pulses and soil mulching effect on American crisphead lettuce yield, *Engenharia Agrcola* 35,1009-1018,
<https://doi.org/10.1590/1809-4430Eng.Agric.v35n6p10091018/2015>
- Billeaud, L. A., Zajicek, J. M. (1989). Influence of mulches on weed control, soil pH, soil nitrogen content, and growth of *Ligustrum japonicum*. *J. Environ. Hort.* 7:155–157

- Broschat, T. K. (2007). Effects of mulch treatment and fertilizer placement on weed growth and soil pH and nutrient content. *Hort Technology* 17:174–177.
<https://doi.org/10.21273/HORTTECH.17.2.174>
- Chapman, H. d. and Pratt, P. F. (1961). *Methods of Analysis for Soils, Plants and Waters*. Univ. California Div. Agr. Sci., Riverside, CA
- Cresswell, H. P., Green, T. W., MsKenzie, N. J. (2008). The adequacy of pressure plate apparatus for determining soil water retention, *Soil science society of America Journal*, Vol. 72, issue 1, pp. 41. <https://doi.org/10.2136/sssaj2006.0182>
- De Silva, C. S. (2006). Impacts of climate change on potential soil moisture deficits and its use as a climate indicator to forecast irrigation need in Sri Lanka. *Water Resources Research in Sri Lanka, Postgraduate Institute of Agriculture, University of Peradeniya.*, p8p79-90, ISBN 955-1308-05-0
- De Silva, C. S., E. K. Weatherhead, J. W. Knox., J. A. Rodrihuez-Diaz (2007). Predicting the impacts of climate change-A case study of paddy irrigation water requirements in Sri Lanka. *Journal of Agricultural Water Management* 93(2007)19-29. Elsevier Publishers, Amsterdam, Netherlands. <https://doi.org/10.1016/j.agwat.2007.06.003>
- Department of Export Agriculture (2011). *Performance and Accounts report*, PP: 47
- Dong, H., Li, W., Tang, Wei., Zhang, D., (2009). Early plastic mulching increases stand establishment and lint yield of cotton in saline fields. *Field Crops Research*. 111. 269-275. <https://doi.org/10.1016/j.fcr.2009.01.001>
- Duryea, M. L., English, J., Hermansen, L. A. (1999) A comparison of landscape mulches: Chemical allelopathic, and decomposition properties. *J. Arboriculture* 25:88–97
- Gill, B. S., Randhawa. R. S., Randhawa., G. S., Singh, J., (1999). Response of turmeric (*Curcuma longa* L.) to nitrogen in relation to application of farm yard manure and straw mulch. *Journal of Spices and Aromatic Crops* 8: 211-214.

- Green, Lee K. M., Rakow, D. A. (1995). The effect of wood mulch type and depth on weed and tree growth and certain soil parameters. *J. Arboricult.*, 21(5): 225-232.
- Hanada. T., (1991). The effect of mulching and row covers on vegetable production. Kyoto: Food and Fertilizer Technology Center.
- Helmke. P. A., Sparks, D. L. (1996). Lithium, sodium, potassium, rubidium, and cesium, p. 551-574. In: DL Sparks (ed.). Methods of soil analysis. Part 3. Chemical methods. Soil Sci. Soc. Amer, Madison, Wis.
- Himelick, E. B., Watson, G. W. (1990). Reduction of oak chlorosis with wood chip mulch treatments. *J. Arboriculture* 16:275-278
- Iles, J. K., and Dosmann, M. S. (1999). Effect of organic and mineral mulches on soil properties and growth of Fairview Flame red maple trees. *J. Arboriculture* 25:163-167
- Issaka, S., and Ashraf, M. A. (2017). Impact of soil erosion and degradation on water quality: a review. *Journal of Geology, ecology and landscapes*, 1, PP. 1-11. <https://doi.org/10.1080/24749508.2017.1301053>
- Jackson, M. L. (1973). Soil Chemical Analysis. pp. 178-182. Prentice-Hall of India Private Limited, New Delhi.
- Jalota, S. K., R. Khera, B. S., Ghuman, (1998). Methods in Soil Physics, pp: 65-67. Narosa Publishing House, New Delhi.
- Jha. R. C., Maurya, K. R., Pandey. R, P. (1986). Influence of mulches on the yield of Ginger in Bihar. *Indian Cocoa Arecanut and Spices J.* 9 (4): 87-90.
- Jones, T. L., Jones, U. S., Ezeli, D. O. (1977). Effect of irrigation and plastic mulch on properties of troupe sand on yield of "water tomato". *J. Amer. Soc. Hort. Sci.*, 102, 27-35.
- Ghosh, K. P., Dayal, D., Bandyopadhyay, K. k., Mohanty, M. (2006). Evaluation of straw and polythene mulch for enhancing productivity of irrigated summer groundnut. *Field Crops Research.*, <https://doi.org/10.1016/j.fcr.2006.03.004>

- Kader, M. d., Senge., Masateru., Mojid, M. A., Ito, K., (2017). Recent advances in mulching materials and methods for modifying soil environment. *Soil and Tillage Research*. 168. 155-166. <https://doi.org/10.1016/j.still.2017.01.001>
- Kasirajan,S and Ngouajio, M., (2012). Polyethylene and biodegradable mulches for agricultural applications: a review, *Agronomy for sustainable Development*, vo:32, pp 501-529. <https://doi.org/10.1007/s13593-011-0068-3>
- Khurshid, K., Iqbal,M., Arif ,M. S., Nawaz,A., (2006). Effect of tillage and mulch on soil physical properties and growth of maize. *Int. J. Agric. Biol.*, 8: 593–596
- Kumara,M., Swapnil,D., Dwivedi, P. K., Yadav,A. K., Mohit, K. (2018). Influence of Different Mulch Materials on Vegetative Growth and Yield of Ginger (*Zingiber officinale* Rosc.) under Drip Irrigation System. *Int. J. Curr. Microbiol. App. Sci.* 7(02): 2546-2551. <https://doi.org/10.20546/ijcmas.2018.702.310>
- Kushwah, S. S., Dwivedi, Y. C., Jain. P. K. (2013). Effect of mulching materials on growth and yield attributes and enhancing farm income through Ginger cultivation under rained rice-based production system. *Vegetable science* (40) 1: 96-98
- Kwesiga, F., Akinnifesi, F. K., Mafongoya, P. L., McDermott, M. H., Agumya, A. (2003). Agroforestry research and development in southern Africa during the 1990s: review and challenges ahead. *Agroforest. Syst.* 59: 173-186. <https://doi.org/10.1023/B:AGFO.0000005222.68054.38>
- Lee, M. T., Asher, C. J., Whiley, A. W. (1981). Nitrogen nutrition of Ginger: II. Effect of nitrogen supply on growth and development. *Field crops Res.* 4, 55-68. [https://doi.org/10.1016/0378-4290\(81\)90054-X](https://doi.org/10.1016/0378-4290(81)90054-X)
- McLean, E. O. (1982). Soil pH and Lime Requirement, *Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties*, 2nd edition, pp: 199–224. *Agronomy Monograph No. 9*, Madison, WI.

- Minakshi, S. (1959). Ginger earns good income for the West Coast. *Indian Fmg.* 9: 12-13
- Mohanty, D. C., Sarma, Y. N., Panda, B, S. (1991). Influence of mulch materials and cover crops on the yield of turmeric crop under rainfed condition in Orissa. *Indian Cocoa Arecanut and Spices J.* 14 (3): 97-99.
- Mohanty, D. C. and Sarma, Y. N. 1978. Performance of Ginger in tribal areas of Orissa, India, as influenced by method of planting, seed treatment, manuring and mulching. *J. Plantation Crops*, 6: 14-16.
- Montague, T., Kjelgren, R. (2004). Energy balance of six common landscape surfaces and the influence of sur-face properties on gas exchange of four containerized tree species. *Sci Hortic.* 100: 229–249. <https://doi.org/10.1016/j.scienta.2003.08.010>
- Nelson, D. W., Sommers, L. E. (1980) Total nitrogen analysis of soil and plant tissues. *J Assoc Off Anal Chem.*; 63: 770–778.
- Ni, X., Song, W., Zhang, H., Yang, X., Wang, L. (2016) Effects of Mulching on Soil Properties and Growth of Tea Olive (*Osmanthus fragrans*). *PLoS ONE* 11(8): e0158228. <https://doi.org/10.1371/journal.pone.0158228>
- Rhoades, J. D. (1982). Cation Exchange Capacity, Methods of Soil Analysis, Part 2, Chemical and Microbiological Properties, 2nd edition. Agronomy Monograph No. 12.
- Salau, O. A., Opara-Nadi, O. A. and Swennen, R. (2002). Response of plantain to mulch on a Tropical ultisol. Part 1. Effect of different mulching materials on soil physical and chemical properties. *International Agro physics.* 6: (12): 55-66.
- Sengupta, D. K., Maity, T. K., Dasgupta, B. D. (2009). Effect of mulching on Ginger (*Zingiber officinale* Rose) in the hilly region of Darjeeling district, *journal of Crop and Weed*, 5 (1): 203- 205
- Singh, K, Vashistha, R. N., Pandita, M. L., Batra, B. R., (1976). Effect of mulching on growth and yield of cucurbits under rainfed conditions. *Haryana J. Hort. Sci*, 5(1&2):87-91.

- Subrahmaniyan, K., Zhou, W., Veeramani, P., (2011). Weed control through degradable, herbicidal plastics and organic mulches and their effect on crop growth and yield of winter rapeseed (*Brassica napus*). *Indian Journal of Agricultural Sciences* 81 (4): 348-352.
- Subramanian, P., Dhanapal, R., Sanil P., Palaniswami, C., Sairam, C. V., Maheswarappa H. P. (2005). *Glyricidia sepium* as green manure in improving soil fertility and productivity of coconut under coastal littoral sandy soil. *Journal of Plantation Crops* 33(3): 179-183.
- Thankamani, C. K., Kandiannan, K., Hamza, S., Saji, K. V. (2016). Effect of mulches on weed suppression and yield of Ginger (*Zingiber officinale* Roscoe.). *Scientia Horticulturae*, 207, pp: 125-130. <https://doi.org/10.1016/j.scienta.2016.05.010>
- Tiwari, K. N & Singh, Ajai & Mal, P. K. (2003). Effect of drip irrigation on yield of cabbage (*Brassica oleracea* L. var. capitata) under mulch and non-mulch conditions. *Agricultural Water Management*. 58. 19-28. [10.1016/S0378-3774\(02\)00084-7](https://doi.org/10.1016/S0378-3774(02)00084-7). [https://doi.org/10.1016/S0378-3774\(02\)00084-7](https://doi.org/10.1016/S0378-3774(02)00084-7)
- Tukey, R. B., Schoff, E. L. (1963). Influence of different mulching materials upon the soil environment. *Proc. Amer. Soc. Hort. Sci.* 82:69-76
- Vanlauwe, B. (1996). Residue quality, decomposition and soil organic matter dynamics under sub-humid tropical conditions. KUL-Press. Katholic University of Leuven, Leuven, Belgium. Pp 203.
- Yuan, Cuiping & Lei, Tingwu & Mao, L & Liu, Han & Wu, Yang. (2009). Soil surface evaporation processes under mulches of different sized gravel. *CATENA*. 78. 117-121. <https://doi.org/10.1016/j.catena.2009.03.002>