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Effect of Irrigation Frequency and Mulching Material on Growth and Yield of Radish (*Raphanus sativus* L.)

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ABSTRACT

A field experiment was conducted to determine the effects of irrigation frequencies and mulching materials on the growth and yield of radish (*Raphanus sativus*) variety 'Beeralu rabu'. This experiment was carried out in a factorial Randomized Complete Block Design with eight treatments, which included combinations of irrigation frequencies [3 days irrigation intervals (3 DIL), 5 days irrigation interval (5 DIL)] and organic mulching materials (no mulch, paddy straw, shredded wood and coir fibre). Each treatment was replicated six times. The tested treatments were applied after 12 days of seed sowing. The number of leaves, leaf area, leaf fresh and dry weights, tuber length, tuber girth and fresh and dry weight of tuber were measured at harvest to assess the growth of the crop and the yield. The results revealed that 3 days irrigation interval performed well for most of the parameters except the mean number of leaves and tuber girth at 5 days irrigation interval. In the overall performance of mulch, coir mulch showed maximum performance in all parameters while shredded wood mulch showed second higher growth and yield parameters of the crop. In the present study, all mulching materials used are waste materials, which could be obtained for free or at a very low cost. Hence, the mulching practice is better to be adopted by the farmer as it enhances the growth and yield of radish, by conserving the soil moisture and suppressing the weeds in the field.

Keywords: Coir fibre, Irrigation frequency, Mulch, Shredded wood

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INTRODUCTION

Radish (*Raphanus sativus* L.) is a tuberous vegetable crop, belonging to the family Brassicaceae. It is a popular root vegetable in both tropical and temperate regions in the world. Radish has several benefits for human health as it contains antioxidants and other compounds, which help to prevent cancer (Coogan *et al*., 2001). The yield

and quality of radish are mostly influenced by soil water (Kang and Wan, 2005). The increased crop yield in semi-arid regions can be attained by fertilization; however, increasing fertilization may not be sufficient to maintain higher yields in the long term (Huang *et al*., 2003).

The most important environmental factors are temperature and rainfall, which affect the growth and development of plants. To attain better control and management of water in crop production, irrigation should counterpart to crop requirements (Maggio *et al*., 2002). The main pathways for increasing water use efficiency in irrigated agriculture are to increase the output per unit of water (engineering and agronomic management aspects), reduce losses of water to impracticable sinks and decrease water degradation (ecological aspects), and transfer water to higher priority uses (sociological aspects) (Howell, 2006). Consequently, there is a great probability of increasing crop yield, if the water is available (Huang *et al*., 2005). The limiting factors for undertaking agriculture in many arid and semi-arid regions of the world considered are the quality and quantity of irrigation water (Munns, 2002). The largest water consumer in the world is Agriculture, which accounts for 70 % of total use (Qin *et al*., 2018). To increase water use efficiency by agricultural crops, reduction of soil-water evaporation is essential in irrigated agriculture (Doring *et al*., 2005).

A natural or artificially spread layer of plant residues or other material on the surface of the soil is called mulch. Mulching is important in agriculture as it conserves moisture, controls temperature, prevents surface compaction, reduction of runoff and erosion, improvement in soil structure and weed control (Ranjan *et al*., 2017). To reduce soil evaporation, mulching is an effective technique however its efficiency depends on the meteorological conditions and the characteristics of mulching materials (Zribi *et al*., 2015). A mulch cover of various materials on soil conserves water and enhances soil health (Montenegro *et al*., 2013). Although inorganic mulching materials are popular, organic mulching possesses an exceptional value for its ability to increase the cation exchange capacity of the soil and in the retention of nutrients close to its particles (Bonini *et al*., 2015). Therefore, this study aimed to detect the growth and yield of radish

(*Raphanus sativus* L.) as influenced by the irrigation frequencies and mulch types in sandy regosol.

MATERIALS AND METHODS

Location

The field study was conducted to study the effect of irrigation frequencies and mulching on the growth and yield of radish (*Raphanus sativus* L.). The experiment was carried out in 2020 at a farmer- field in the Western province of Sri Lanka. The site was located at an elevation of 1.0 m to 3.5 m from mean sea level which comes under the Wet Zone Low Country 3 (WL3) agroecological region of the country. The annual rainfall of the experimental site ranges from 2500 mm - 3500 mm and the mean annual temperature varies between 26.5 ^{0}C - 28.5 ^{0}C.

Treatments and Experimental Design

The experiment was laid out in a Factorial Randomized Complete Block Design (RCBD) with eight treatments and each treatment was replicated six times. Treatments included irrigation frequencies [3 days irrigation interval (3 DIL), 5 days irrigation interval (5 DIL)] and organic mulching materials comprised of without mulch (M1), paddy straw mulch (M2), shredded wood mulch (M3) and coir fibre mulch (M4).

The radish variety 'Beeralu rabu' was planted at spacing of 30 cm × 10 cm. Irrigation and mulching treatments were started after 12 days of sowing. Mulching materials were applied in two inches thickness around the plants leaving two inches distance between mulches and crop root zone. Weeding and thinning out practices were done prior to the treatments. Chemical fertilizers were applied as basal (90 kg/ha of Urea, 110 kg/ha of Triple Superphosphate and 65 kg/ha of Muriate of potash) and top dressing (90 kg/ha of Urea and 65 kg/ha of Muriate of potash after 3 weeks of sowing) as recommended by the Department of Agriculture, Sri Lanka.

At harvest, number of leaves, leaf area, fresh and dry weights of leaves, tuber length, tuber girth, fresh and dry weights of tubers, plant weight and yield per hectare were recorded. All the data were subjected to analysis of variance (ANOVA) using SAS statistical analysis package and the treatment means were compared by

Tukey's honest significant difference test at the 5 % significant level.

RESULTS AND DISCUSSION

Effect of Irrigation Interval and Mulching on Leaf Traits

Number of Leaves

There were highly significant differences ($P<0.001$) in the average number of leaves among the mulching and irrigation frequency interval treatments at harvest (Table 1). In 5 day-irrigation-interval (5 DIL) treatment, the average number of leaves per radish plant was highest (18.7) in the plants mulched with coir fibre and followed by shredded wood mulching (17.3). In 3 day-irrigation-interval (3 DIL), plants in coir mulch gave the highest leaf number, which was 16.0.

A similar result was noted by Godawatte *et al*. (2011) for the plants mulched with coir fibre which showed the highest number of leaves. Granatstein and Mullinix (2008) stated that mulching reduced cumulative irrigation application by 20 % to 30 % and water depletion was greatest under un-mulched treatments.

In both irrigation intervals, a minimum leaf number was noted in plants where no mulch (control treatment) was applied. It was 14.0 cm in 3 DIL and 11.7 cm in 5 DIL. The second higher leaf number was obtained in shredded wood mulch. The highest difference was observed between non-mulch (11.7) and coir mulch (18.7) under 5 DIL. Sudeshika *et al*. (2018) also reported that the highest leaf number was observed in coir fibre medium and the lowest number was recorded in topsoil medium in carrots. In the present study, also coir mulch was the best mulching treatment under both irrigation treatments.

Leaf Area

Table 1 shows the mean leaf area of radish plants after the application of treatments. It indicates that the irrigation frequency and mulching treatment exhibited highly significant differences in leaf area. It was observed that at 3 DIL, the highest leaf area of 979.61 cm^2 was obtained in plants under coir fibre mulch. It may be due to an adequate amount of water supply to the plants at right time. In 5 DIL, also coir mulch treatment showed the highest leaf area of 965.29 cm^2. The control treatment showed the

Table 1. Effect of irrigation interval and mulching on the mean number of leaves, leaf area and leaf weights of radish plant.

Treatments		Number of leaves	Leaf area (cm^2)	Fresh weight of leaves (g)	Dry weight of leaves (g)
Irrigation	**Mulching**				
3 days interval	No mulch	14.0±1.1	557.34±79.12	35.44±3.99	4.10±0.62
	Paddy straw	14.7±1.7	696.12±29.05	49.29±4.27	5.86±0.41
	Shredded wood	15.0±0.4	800.94±54.79	46.24±2.84	6.06±0.56
	Coir fibre	16.0±0.8	979.61±83.01	59.53±3.80	7.88±0.43
5 days interval	No mulch	11.7±0.6	423.29±67.60	32.11±4.12	4.04±0.41
	Paddy straw	14.7±0.2	558.87±42.81	35.22±1.76	4.37±0.36
	Shredded wood	17.3±0.8	731.28±82.18	38.31±5.31	5.39±0.75
	Coir fibre	18.7±0.9	965.29±116.74	54.73±4.17	7.61±0.52
P-value	Irrigation	0.0001	0.0001	0.0001	0.0001
	Mulching	0.0001	0.0001	0.0001	0.0001
	Irrigation*Mulching	0.0001	0.0001	0.0001	0.0001

Values represent mean ± standard error of six replicates.

minimum leaf area, which was 423.29 cm^2.

The different irrigation intervals affected the leaf area with a high significant variance ($P<0.001$). The present study is in line with the Xiang *et al*. (2018) who reported that as the growth period progressed, above-ground biomass and leaf area per plant gradually increased, and their growth rate was faster in the late growth stage in mini Chinese cabbage in response to irrigation amount and irrigation frequency. Leaf area is a prominent parameter when considering photosynthesis. While leaf area increases, the photosynthetic rate also increases (Imthiyas and Seran, 2017). The overall mean leaf area performance of mulch for both irrigation intervals is presented in Figure 1. Control treatment without mulch recorded 490.3 cm^2 leaf area and coir mulch had increased leaf area up to 972.4 cm^2. Organic mulch encourages restoration of degraded soils and improves soil

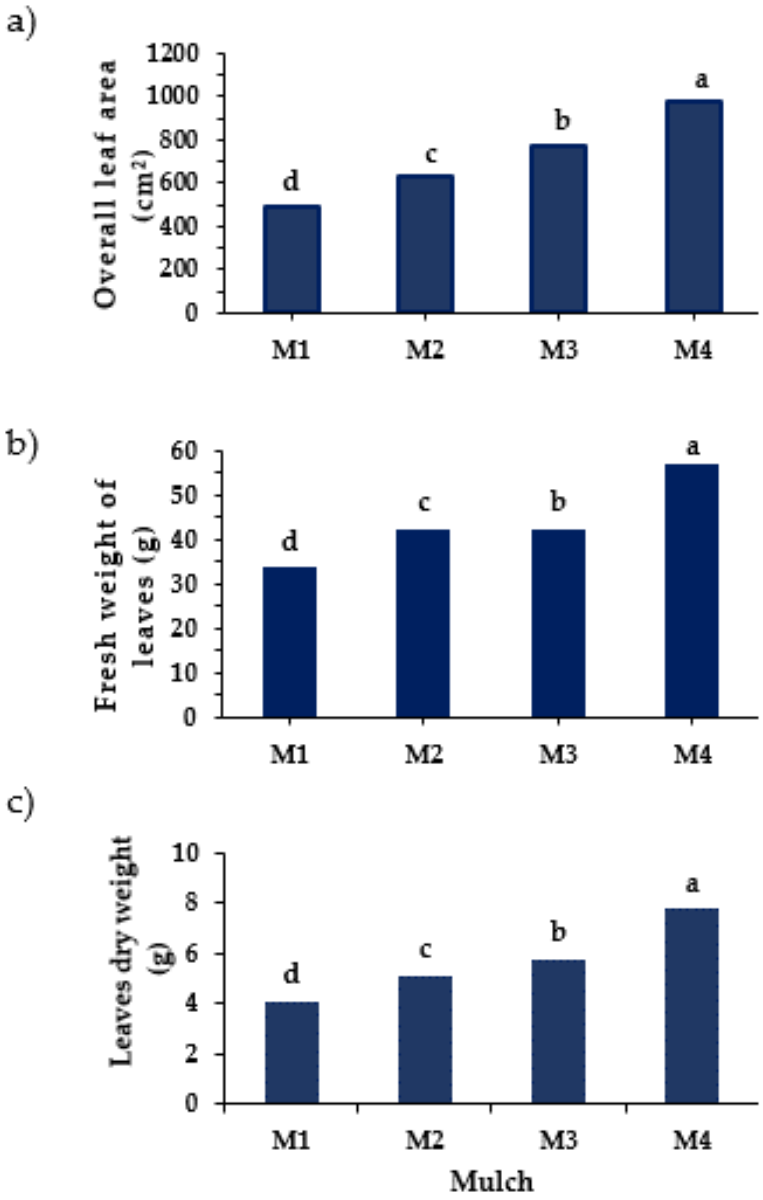
fertility, leading to better crop productivity (Fang *et al*., 2007). Due to these characteristics of coir mulch, it was able to record the highest leaf area in radish crop in this experiment.

The higher soil moisture status indicated that mulch plays a role in conserving the moisture in soil, though the effects among mulches varied (Chakraborty *et al*., 2008). The effect of the mulch factors studied showed highly significant variation in leaf area (Figure 1). When coir fibre is added to soil, it increases soil moisture content and the amount of coir fibre present in the medium is positively correlated with moisture content (Seran *et al*., 2011). Incorporation of organic matter such as coir fibre would be much more suitable for reclamation of sandy soils as they can withstand environmental degradation compared to the other organic materials.

Fresh Weight of Leaves

There was a highly significant effect ($P<0.001$) in mean fresh weight of leaves of radish (Table 1) for the treatment interaction effect, irrigation frequency and mulching. Mulching and irrigation can change the characteristics of the soil surface and hence influence the hydrothermal properties of the soil (Zhang *et al*., 2009). The results showed that the incorporation of waste coir fibre into the soils is much beneficial in ameliorating their physical conditions, moisture status and nutrient retention capacity. Among the mulching treatments, coir mulch treatment recorded the highest fresh weight of leaves.

Irrigation frequency showed a highly significant variation among treatments. The highest fresh weight of leaves was observed under 3DIL treatment. The overall performance of mean leaf fresh weight showed vast differences among treatments (Figure 1). Control treatment, which recorded the least fresh weight (35.44 g under 3 DIL and 32.11 g under 5 DIL) of leaves significantly, differed from the other three mulching treatments.



Mean values with the same letters are not significantly different according to the Tukey's honestly significance difference test at 5% significant level.

Figure 1: Effect of mulching (M1: No mulch, M2: Paddy straw, M3: Shredded wood, M4: Coir fibre) on overall mean values of leaf traits per plant a): leaf area, b): leaf fresh weight, c): leaf dry weight.

Coir mulch had the highest mean value (59.53 g under 3 DIL and 54.73 g under 5 DIL) for fresh weight of leaves per plant than all other treatments. In rain-fed agriculture, use of coir pith is found to be extensive as it regulates the moisture level in soil thereby conserving more water (Udayana *et al*., 2017).

Dry Weight of Leaves

The mean dry weight of leaves was maximum in coir mulch treatment (Table 1). The interaction of mulching and irrigation frequency had influenced on dry weight of leaves with a highly significant effect ($P<0.001$). Scagel (2003) also reported that leaf and stem dry weight, the number of leaves and stem length increased with increasing proportion of coir in the medium while root dry weight either increased (*Kalmia latifolia*), decreased (*Rhododendron*, *Gaultheria*) or was not influenced by increasing the proportion of coir in the medium. Irrigation interval also showed a significant effect on leaf dry weight of radish. This finding is in line with Gencoglan *et al*. (2006) who stated that irrigation frequency is one of the important factors in irrigation management, especially for porous soil.

The least mean value for leaf dry weight was observed in non-mulch treatment of this study (Figure 1). Arora *et al*. (2011) stated that increased soybean yield was recorded under mulching. Diaz *et al*. (2005) had shown that organic mulches reduce the evaporation of water depending on their characteristics. The favorable chemical and physical properties of coco peat are a determining factor in its ability to support plant development (Ilahi and Ahmad, 2017). Coir fibre was able to record the highest mean value followed by shredded wood mulch, indicating that coir fibre is an amazing component, which can be used as a medium as well as mulch.

Effect of Irrigation Interval and Mulching on Tuber Traits

Tuber Length

The average tuber length among the treatments ranged from 9.45 cm to 13.75 cm in mulched plants under both irrigation frequencies. The tuber length of plants was statistically significant ($P<0.05$) among the mulch treatments (Table 2). This benefit was ascribed to weed control, greater nutrient uptake, and a higher population of micro-flora with mulching as reported by Hundal *et*

al. (2000). Paddy straw under 3 DIL (13.60 cm) and coir under 5 DIL (13.75 cm) mulches had the highest tuber length of radish. Chaudhry *et al*. (2004) reported that mulching treatments had a positive impact on plant growth, but the intensity of the effect can be peculiar with different treatments. Rahman *et al*. (2006) reported that organic mulches conserve soil water, reduce evaporation, reduce leaching of nutrients, reduce soil temperature and reduce weed growth resulting in a higher plant yield with improved fruit quality and better plant growth in tomato.

The irrigation frequencies ($P>0.05$) and mulch and irrigation interval interaction ($P>0.05$) did not show a significant effect on tuber length among the treatments. In 5 DIL, coir mulch (13.75 cm) performed well followed by shredded wood mulch (12.53 cm). Coir dust and shredded wood mulch may have a suitable environment for root penetration even in stressful temperature.

The highest soil potassium content was reported from coir fibre mulched treatment followed by sawdust treatment (Godawatte and De Silva, 2014). Sawdust could be used to minimize the soil degradation due to higher temperature stress in natural environment (Godawatte *et al*., 2011). When considering the overall performance of mulches (Figure 2), the coir mulch showed a remarkable increment in tuber length compared with non-mulch treatment.

Table 2: Effect of irrigation interval and mulching on tuber traits of radish.

Treatments		Tuber length (cm)	Tuber girth (cm)	Fresh weight of tuber (g)	Dry weight of tuber (g)
Irrigation	**Mulching**				
3 days interval	No mulch	9.45±1.18	6.98±0.82	45.85±3.74	2.74±0.17
	Paddy straw	13.60±1.42	7.73±0.62	59.19±4.13	4.25±0.31
	Shredded wood	11.78±1.72	8.32±0.63	51.15±3.11	3.71±0.24
	Coir fibre	12.82±1.46	8.33±1.23	76.89±3.41	5.22±0.25
5 days interval	No mulch	9.63±0.92	6.85±0.82	50.30±4.79	3.14±0.35
	Paddy straw	11.28±1.05	8.11±0.66	56.16±5.55	3.88±0.69
	Shredded wood	12.53±1.31	8.45±0.85	54.54±4.00	4.02±0.11
	Coir fibre	13.75±1.59	9.01±0.86	63.24±5.46	4.54±0.45
P-value	Irrigation	0.9022	0.6585	0.0001	0.0001
	Mulching	0.0374	0.1986	0.0001	0.0001
	Irrigation *Mulching	0.5677	0.9681	0.0001	0.0001

Values represent mean ± standard error of six replicates.

Tuber Girth

The results presented in Table 2 revealed that irrigation frequency did not show a significant difference (P>0.05) in the mean tuber girth of radish. Plants mulched with coir dust in 5 DIL (9.01 cm), showed slightly higher values of tuber girth than that in 3 DIL (8.33 cm). The irrigation interval change did not significantly affect tuber girth in the treatments. The interaction effect was not significant (P>0.05) on tuber girth. The water evaporation from mulched soil decreases comparatively to bare soil and more water is available for beneficial crop transpiration (Sarkar *et al*., 2007). Mulching treatment also showed a non-significant variation (P>0.05) in tuber girth. Although tuber girth was statistically insignificant under all treatments, coir mulch treatment had the highest values in tuber girth (8.33 cm under 3 DIL and 9.01 cm under 5 DIL) and the lowest tuber girth was noted in non-mulched

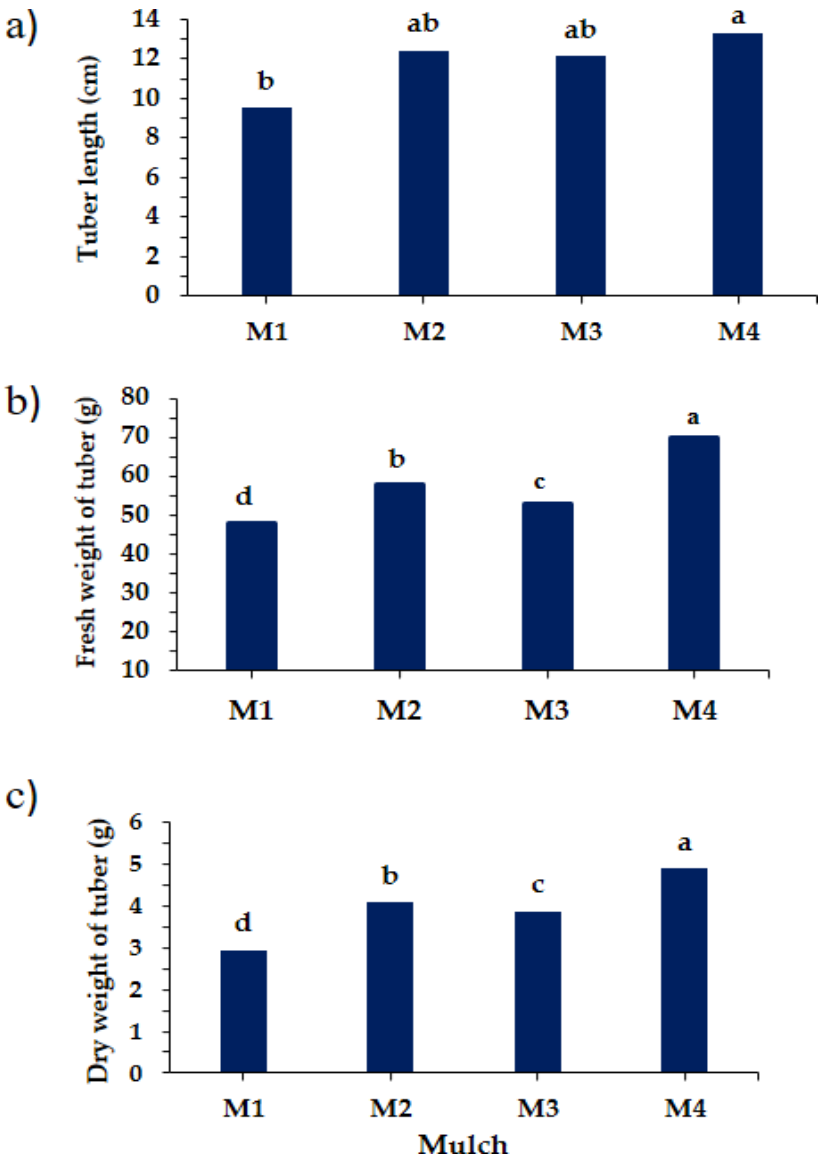


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Figure 2: Effect of mulching (M1: No mulch, M2: Paddy straw, M3: Shredded wood and M4: Coir fibre) on overall mean values of tuber traits per plant a): tuber length, b): fresh tuber weight, c): dry tuber weight).

(6.98 cm under 3 DIL and 6.85 cm under 5 DIL) plants. These findings are in agreement with Montenegro *et al*. (2020) who mentioned that mulch cover with coir fibre seems to be a more suitable option than a cover crop grown with Palma cactus to enhance soil water content and improve agricultural soil fertility and crop productivity in semi-arid environments. Alwis and Herath,

(2012), have reported that fruit girth (fruit filling) in the pineapple crop showed a significant difference among mulch treatments and a similar trend in total yield, indicating a possible enhancement in girth parameter under different experimental conditions.

Fresh Weight of Tuber

There was a highly significant variation ($P<0.001$) in mean fresh weight of tuber under two irrigation frequencies (Table 2). The highest tuber fresh weight was observed in 3DIL treatment. Huang *et al. (*2012) stated that the enhanced dry root weight density in the no-tillage systems with residue mulch systems resulted in a better capability to take up water and nutrients, ultimately producing enhanced crop yields. The greatest root development and density were achieved using organic mulches compared to plastic mulch (Fausett and Rom 2001).

According to Gajc-Wolska *et al*. (2005), sweet pepper fruits cultivated on organic mulch obtained higher fresh smell, fragility and flesh succulence; those cultivated on polypropylene fibre had harder peels and a more sour taste Sarkar and Singh (2007) reported that the higher soil moisture status enhanced root proliferation and higher nutrient availability to the crop roots. The fresh tuber yield is the most important character of this crop as it is the marketable product.

Dry Weight of Tuber

Table 2 shows the mean dry weights of tubers under particular organic mulches and irrigation frequencies. The highest dry weight under mulches was observed in coir mulch, where a high amount of moisture has been retained. Inyang (2005) and Gbadebor (2006) revealed that mulch materials improve soil physicochemical properties, suppress soil temperature, reduce evaporation and increase the soil moisture, thereby creating enabling soil microclimatic conditions for the early sprouting of yams. Mulch improves the soil moisture regime by decreasing losses caused by surface runoff and evaporation and increasing the infiltration capacity during rainfall (Odjugo, 2008).

The overall performance of mean tuber dry weight has been indicated in Figure 2, indicating that non-mulch treatment recorded the minimum tuber dry weight. Proving this fact, Okoh (2004) showed that

mulch materials improve the soil condition for developing roots properly.

Effect of Irrigation Interval and Mulching on Yield at Harvest

Whole Plant Fresh Weight

Table 3 shows that mulching types have caused remarkable variations among treatments in the mean plant weight of radish. The radish plants harvested in each treatment were presented in Figure 3. Treatment 3DIL recorded better results compared to treatment 5DIL. The positive effects of mulching might be due to maintaining a conducive soil environment in terms of better soil moisture, lowering of soil temperature and better supply of nutrients, which ultimately favored better growth and vegetative biomass production (Ram *et al*., 2003). The overall performance of mulches is shown in Figure 4 indicating the same trend of results

Yield per Hectare

The Yield was measured as whole plant fresh weight per Hectare. The radish yield produced per hectare under mulching and irrigation frequency is presented in Table 3. The highest yield was recorded in coir mulch while the minimum reading was recorded in the control treatment (Figure 4) similar to the other parameters. A significant improvement in yield attributes with use of organic mulches may be due to conserved soil moisture, moderate plant water status, soil temperature and increased availability of plant nutrients as reported by Huang *et al*. (2008).

In the present study, irrigation and mulching have significantly affected radish tuber yield. Ramesh *et al*. (2006) stated that mulched plots stored the soil moisture effectively, thereby enhancing the vegetative growth and consequently the yield attributes were also higher. Sinkeviciene *et al*. (2009) reported that usually vegetable yield highly depends on the type of mulch applied to the soil as it conserves moisture.

Table 3: Effect of irrigation interval and mulching on plant mean fresh weight and yield of radish plant.

Treatments		Plant weight (g)	Yield (t/ha)
Irrigation	**Mulching**		
3 days interval	No mulch	81.28±3.23	27.09±5.07
	Paddy straw	108.48±0.35	36.16±1.17
	Shredded wood	97.39±1.85	32.46±3.16
	Coir fibre	136.43±5.67	45.47±1.89
5 days interval	No mulch	82.41±8.82	27.47±2.94
	Paddy straw	91.38±7.28	30.46±2.42
	Shredded wood	92.84±5.18	30.95±1.73
	Coir fibre	117.97±7.33	39.32±2.44
P-value	Irrigation	0.0001	0.0001
	Mulching	0.0001	0.0001
	Irrigation *Mulching	0.0001	0.0001

Values represent the mean ± standard error of six replicates.

Figure 3: The harvested radish plants are grown in the different irrigation intervals (W1: 3 days irrigation interval, W2: 5 days Irrigation interval) and mulching practices (M1: No mulch, M2: Paddy straw, M3: Shredded wood and M4: Coir fibre).

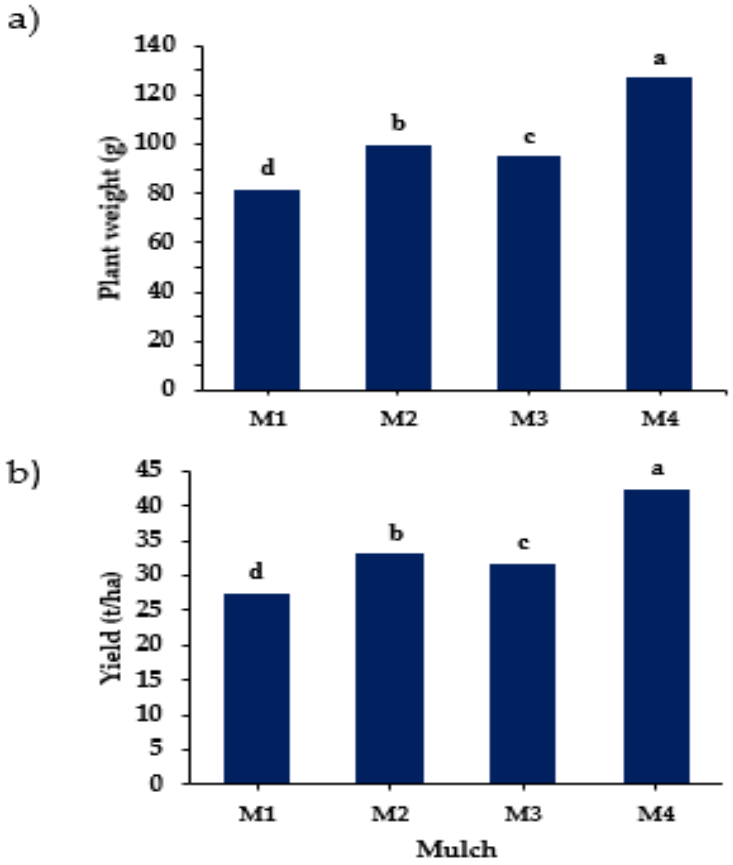

Figure 4: Effect of mulching (M1: No mulch, M2: Paddy straw, M3: Shredded wood, M4: Coir fibre) on overall mean values of a) plant weight and b) radish yield.

CONCLUSION

This study suggests that applying mulch with 3 or 5 days of irrigation frequency showed better growth and yield of radish than the non-mulched treatments. Further, it was noted that there were significant interactions ($P<0.001$) between irrigation interval and mulch application on leaf traits, tuber fresh and dry weights, plant weight and yield. An irrigation interval of 3 days gave higher mean values on leaf area, fresh and dry weights of leaves, tuber girth, fresh tuber weight, plant weight and radish yield with the application of coir fibre mulch. Coir can hold more moisture for giving better crop performance. This practice would be adaptable to produce better radish yield in areas where water availability is poor.

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