Asian Journal of Agricultural Sciences 4(3): 183-187, 2012
ISSN: 2041-3890

Submitted: January 03, 2012 Accepted: January 25, 2012 Published: May 05, 2012

Effect of Mulch and Irrigation on Growth, Yield and Quality of Radish (*Raphanus sativus* L.) in a Semi-Arid Sub-Tropical Environment

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Abstract: Radish is grown as an irrigated crop which can not tolerate water shortage. However, it has received relatively little research pertaining to its mulching and water requirements. The objective of this experiment was to investigate optimum water requirements of radish when using different mulching materials. The experimental design was a randomized complete block design with 12 treatments, replicated three times. The treatments were (three mulching matarials) grass mulch, black polyethylene cover, clear plastic cover and no cover (control), with each subjected to three irrigation regimes (100, 70 and 50% MC). The data collected on plant parameters included plant height, number of leaves, leaf length, leaf width, root diameter, % Total Soluble Solids (% TSS) of extracted juice, fresh mass of leaves and roots. Significant ($p<0.05$) plant growth increases were observed from treatment of grass mulch at 100% MC on plant height, root diameter, TSS (%) and fresh mass when compared to the other treatments. This was followed by clear plastic at 100% MC, black plastic at 100% MC and lastly the treatment of no cover at 100% MC. Similar results were obtained at 70 and 50% MC. There were no significant interaction between treatments (M × MC) for growth and yield parameters measured. Only grass mulch at 100% MC produced significantly ($p<0.05$) higher number of leaves than all the other treatments which had similar number of leaves. Root diameter varied significantly ($p<0.05$) across all treatments. The widest root diameter was obtained from grass mulch at 100% MC followed in decreasing order by no mulch at 100% MC, grass mulch at 70% MC and lastly black polyethylene at 100% MC.
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Key words: Growth parameters, moisture content, mulch, *Raphanus sativus*, total soluble solids

INTRODUCTION

The shortage of water is one of the most limiting environmental factors in crop production world wide since plants require a considerable amount of water to produce their biomass (Marr, 1996). Marr (1996) reported that in the subtropics where annual rainfall is limited, supplementary irrigation is probably the most beneficial resource in the growth and development of vegetables.

The main source of water in Swaziland is rainfall, however, in many places rainfall is not enough to meet the water needs of plants. In other places, the distribution of the rainfall limits the production of many crops to certain months of the year. In such cases, water must be supplied from other sources through irrigation. Crop water needs are influenced by sunshine, temperature, humidity and wind speed. The water needs will vary with the stages of crop growth (Mwendera, 2000).

Mulching is the application of any soil cover that constitutes a barrier to the transmission of light, heat or moisture on the soil surface (Rosenberg *et al.*, 1983). Mulches can be organic or inorganic materials. Organic mulches are derived from plant or animal residues and examples include grass, leaf litter, chicken manure, horse manure, wood shavings and many other plant or animal remains. Artificial mulches are derived from man-made materials such as study and coloured or clear plastic (polyethylene) sheets. Live mulches can be used in some instances whereby plants are planted in the under-story of the crop for the specific purpose of providing soil cover which may provide benefits such as reduced evapotranspiration and suppression of weed growth (Kramer, 1983). Developed countries that have used both organic and artificial mulches in horticulture have enjoyed multiple benefits. Studies by Eckart (1914) in the Hawaiian islands where study mulch was used in the production of pineapples on a large scale, reported that mulching was effective in weed control and that the soils had higher moisture content and daily mean temperatures.

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Mulching therefore may be beneficial to vegetable production, including radish.

Radish (*Raphanus sativus*) is a vegetable which is rich in vitamins and mineraAls and has medicinal values. Radish is mainly used for salad and decorative purposes and it is in high demand in the hotel industry. Radish is a cool season vegetable root crop which grows well under tropical conditions. However under tropical conditions, all time sufficient moisture availability is a challenging condition. Therefore, under tropical conditions there is need to optimize sufficient moisture availability for radish growth. The objective of this experiment was to investigate optimum water requirements of radish when using different mulching materials in a semi-arid environment.

MATERIALS AND METHODS

Description of study area and weather pattern: The experiment was conducted during 2004/2005 cropping season in a lath-house situated at the Crop Production Farm, Faculty of Agriculture, Luyengo Campus of the University of Swaziland. The farm is located in the Middleveld at 26º34′ S and 31º21′ E. The average altitude of this area is 750 m, and the mean annual precipitation is 980 mm/year falling mostly between October and April. Drought hazard is about 40%. The average winter and summer temperature are15 and 27ºC, respectively. The soils of Luyengo are Ferrasolic to Ferralitic with sandy loamy texture (Murdoch, 1970).

Growing medium: A soil mix of the Crop Production Farm soil obtained according to Brady (1990), kraal manure and sand at a ratio of 1:1:1 was used in the experiment. This medium was first treated with basamid fumigant to destroy disease causing agents, weeds and weed seeds. The kraal manure used was from a local farm. The soil and kraal manure samples were chemically analysed at the Malkerns Research Station, Malkerns, Swaziland. The soil had a pH ($CaCl_2$) of 5.1, available P 0.37 mg/kg, available K 163 mg/kg and organic C 3.10. The kraal manure had available P of 0.54 mg/kg and available K of 25.1 mg/kg.

Trial design: The experiment was a 3×3 factorial laid in a Randomized Complete Block Design (RCBD) with 12 treatments, replicated three times. The mulching materials used were control (bare soil); grass mulch at 10 cm thickness; black polyethylene; and clear plastic. The mulches covered an area of 97.48 cm^2/plant for all cover types. The three irrigation regimes used were 100, 70 and 50% MC equivalent ot 5.l, 3.5l and 2.5l per pot, respectively (Table 1).

Table 1: Treatments of mulch and irrigation of radish (*Raphanus sativus* L.)

Treatment code	Irrigation regime (%MC*)	Quantity of water (l)	Mulching material
1	100	5.0	Control (no mulch)
2	100	5.0	Grass
3	100	5.0	Black polyethylene
4	100	5.0	Clear plastic
5	70	3.5	Control (no mulch)
6	70	3.5	Grass
7	70	3.5	Black polyethylene
8	70	3.5	Clear plastic
9	50	2.5	Control (no mulch)
10	50	2.5	Grass
11	50	2.5	Black polyethylene
12	50	2.5	Clear plastic

*MC: moisture content

Table 2: Weekly water evaporation and rainfall for the growing period

Week	Evaporation (mm)	Rainfall (mm)
1-J	15.0	39.5
2-J	16.0	89.0
3-J	41.0	35.0
4-J	38.5	0.0
5-F	28.8	0.0

University of Swaziland Weather Station (Luyengo Campus)

Meteorological data: Meteorological data was collected from the local weather station and reported as weekly evaporation and weekly rainfall (Table 2).

Crop management and moisture determination: The ‘Red silk’ Radish, variety was planted directly from seeds. The seeds were drilled in pots with inside bottom diameter and top diameter of 25.5 and 35.0 cm, respectively. Each treatment had four plants, with one plant per pot. After planting, irrigation was done uniformly for the first 5 days to make sure that all the plants were established. After that different irrigation levels were applied and nutrition was maintained uniformly where a compound fertiliser N:P:K, 2:3:2 (22) was applied 5 days after seedling establishment at the rate of 250 kg/ha. Hand weeding was done periodically during the course of the experiment when necessary.

The soil moisture content was determined by the use of a tensiometer (Soil Moisture Equipment Corp., Santa Barbara, CA, USA). Three tensiometers were installed for the different moisture regimes in order to schedule irrigation. Water was applied when ever the soil matric potential reached 10 bars.

Data collection and analysis: At four weeks after planting data were collected on plant height (cm), number of leaves, leaf width (cm) and leaf length (cm). At five weeks after planting the plants were harvested and data were also collected on fresh mass (g), root diameter (cm) and Total Soluble Solids (TSS).

Table 3: Effect of mulch and irrigation on radish (*Raphanus sativus* L.) growth parameters at 4 weeks after planting.

	Growth parameter			
Treatment description	Height (cm)	Leaf number	Leaf area (cm^2)	Leaf Area Index (LAI)
No mulch, 100%MC	5.2ef *	9.0b	90.5cd	8.34a
Grass, 100%MC	8.2a	11.0a	126.0a	14.20ab
Black plastic, 100%MC	5.9cde	10.0ab	97.4bc	9.99a
Clear plastic, 100%MC	7.4ab	9.0b	104.7b	9.67a
No mulch , 70%MC	5.1ef	9.0b	82.2de	7.59a
Grass.70%MC	7.1abc	10.0ab	97.2bc	9.97a
Black plastic, 70%MC	6.1cde	10.0ab	72.6efg	7.54a
Clear plastic,70% MC	6.8bcd	9.0b	80.4def	7.42a
No mulch, 50% MC	4.5f	9.0b	59.2h	5.47a
Grass , 50%MC	6.1cde	10.0b	77.4def	7.94a
Black plastic, 50%MC	5.7def	9.0b	62.3gh	5.75a
Clear plastic, 50%MC	4.5f	9.0b	67.3fgh	6.21a
CV (%)	11.3	7.5	7.9	6.9

*: Different letters within columns indicate significant differences at p<0.05 (Mean separation by Duncan's New Multiple Range Test)

The number of leaves per plant was obtained by counting the leaves of all four plants in each treatment and calculating the average. Plant height was measured using a 50 cm steel rule on all four plants per experimental block, and an average was computed. The height was taken from the top surface of the pot (soil level) to the apex of the plant.

The leaf area was computed using the formula (1) of a mean leaf length multiplied by mean leaf width then multiplied by the correction factor for *Raphanus sativus* (0.578).

Leaf Area Index (LAI) was determined as a ratio of the total leaf area to pot spacing area on the ground :

Leaf area = mean leaf length × leaf width × (0.578). (1)

Data collected at 5 weeks after planting included root diameter, TSS, fresh and dry weight. A caliper was used to measure root diameter and the maximum attainable diameter (cm) was considered then an average was computed per plant. The juice was extracted using a fruit juice extracting device and then strained with the aid of a cheese cloth. A drop of the sample was placed on the prism surface to determine the TSS using a Fisher hand refractometer.

Dry weight and moisture content determination: Plant samples from all the different treatments were first weighed and then dried in the oven for 48 h at a temperature of 70ºC, then weighed to find the amount of dry matter and moisture content.

Data analysis: Data were analyzed using MSTAT-C statistical package (Nissen, 1989) where the analysis of variance (ANOVA) was done. Significant differences between treatment means were separated using Duncan's New Multiple Range Test (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Plant height: After four weeks plant height was significantly ($p<0.05$) higher in grass mulch with 100% MC followed by no mulch with 100% MC, then clear plastic with 100% MC and lastly black plastic with 100% MC (Table 3). All other treatments were not significantly different from the control. Findings by Anonymous (2004) indicated that yields of root vegetables were highest when mulched and that harvest was seven days earlier when compared with non-mulched plantings. This was evident in this experiment because all treatments that were mulched had higher growth parameter values than those that were on bare soil. The height of radish under grass mulch was significantly ($p<0.05$) taller than all the other treatments. There was no significant difference between black polyethylene and the control (no mulch) and these treatments resulted in the lowest plant height. Water quantity had a direct influence on the plant height. An increase in the quantity of water resulted in taller radish plants. This demonstrated that application of water to field capacity promoted more growth in radish when compared with less water application. These results are in agreement with previous findings by Shongwe *et al.* (2008) who reported an increase in plant height of tissue-cultured banana with increasing irrigation water levels.

Number of leaves: The leaf number obtained from the grass mulch with 100% MC was significantly ($p<0.05$) higher than the rest of the treatments as observed at four weeks after planting (Table 3). With the rest of the treatments there were no significant ($p<0.05$) differences with means of the control (Table 3). Grass mulch promote moisture conservation and suppress weed growth (Rosenberg *et al*., 1983; Kramer, 1983) and this promotes crop growth as indicated by increased number of leaves. These results are consistent with the reports just described.

Table 4: Effect of mulch and irrigation on radish (*Raphanus sativus* L.) root diameter, %TSS, fresh and dry weight at 5 weeks after planting

Treatments	Root diameter (cm)	TSS (%)	Fresh weight (g)
No mulch,100%MC	3.1b*	4.1bc	120.5ab
Grass,100%MC	3.7a	4.8 a	129.0a
Blackplastic,100%MC	2.9b	3.1ef	107.6abc
Clear plastic, 100% MC	2.8bc	3.1ef	94.5bcd
No mulch,70%MC	2.5cd	4.3b	75.1de
Grass,70%MC	3.1b	3.3ef	88.7cd
Black plastic,70%MC	2.3de	4.8a	78.0cde
Clear plastic,70%MC	2.0ef	3.3ef	79.0cde
No mulch ,50%MC	1.4h	3.1ef	54.7e
Grass, 50%MC	1.9fg	3.4de	70.2de
Black plastic,50%MC	1.6gh	3.8cd	63.6de
Clear plastic, 50%MC	1.4h	2.9f	56.0e
CV (%)	8.81	5.85	21.5

*: Different letters within columns indicate significant differences at $p<0.05$(Mean separation by Duncan's New Multiple Range Test)

Leaf area and leaf area index: At week four, mean leaf area was significantly ($p<0.05$) higher from plants grown under grass mulch with 100% MC compared with the other treatments except the treatment with clear plastic and 70% MC (Table 3). Leaf area was significantly ($p<0.05$) lower from no mulch plants with 50% MC, black plastic with 50% MC black plastic with 50% MC, plastic cover with 50% MC (Table 3) compared to the other treatments. LAI was significantly ($p<0.05$) highest from grass with 100% MC compared with all other treatments except the clear plastic with 70% MC (Table 3). Leaf area and LAI are growth parameters which are significantly affected by moisture availability to the plant. The grass mulch with 100% MC and black plastic with 70% MC may have created conditions which promoted plant growth through moisture availability and weed suppression resulting in high LAI values. Conducive conditions to plant growth imparted by mulches have been reported previously (Eckart, 1914; Rosenberg *et al*., 1983).

Root diameter, %TSS, fresh mass: The highest root diameter was obtained from grass mulch with 100% MC followed by no mulch with 100% MC, grass mulch with 70% MC, and lastly black plastic with 100% MC in decreasing order (Table 4). The least root diameter were obtained from the treatments of clear plastic with 70% MC, no mulch with 50% MC grass mulch with 50% MC, black plastic with 50% MC, and clear plastic with 50% MC in decreasing order. It appears that conditions with increased soil moisture content promoted growth, hence increasing root diameter. This was evident under mulched conditions. Hayat and Ali (2010) reported better water use efficiency of subsequent wheat under rainfed conditions due partly to the mulching effect of remains of previously grown summer legumes. Yield and most yield components were improved with application of irrigation water in chickpea genotypes (Bakhsh *et al*., 2007). There is documented evidence that water plays a major role on the yield and quality of radish. Park and Fritz (1984) reported similar results of increased yield of radish with high levels of irrigation and fertilizer. High levels of irrigation resulted in ample amounts of water being available to the radish plants and in addition, mulching could have further assisted in moisture conservation. Irrigation increased the size and weight of root vegetables and prevented defects such as toughness, strong flavour, cracking and misshapen roots (Sander, 1997). Wa and Kang (2005) used six irrigation frequencies: once every 1, 2, 3, 4, 6 and 8 days. They reported that there was no significant difference among the six treatments on radish development and yield, but there were significant differences in radish roots distribution and market quality. There was a greater effect on root quality since radishes irrigated once every 3 days had well-developed roots throughout the crop period and had the lowest cracking rate and the least number of radishes of poor grade. These reports confirm what was earlier reported that a frequent, uniform supply of water is extremely important for radish growth, yield and quality (Singh and Cheema, 1972; Park and Fritz 1984; Barker *et al*., 1983). Park and Fritz (1984) investigated the combined effects of fertiliszer and irrigation on radish. They reported that higher irrigation and fertilizer treatments resulted in an increase in yield. Furthermore, there was only little effect of irrigation on the pithiness of the root;, but pithiness was intensified in association with higher fertilization. On the other hand texture was reduced by increased water and nutrient supply. Our study however was not aimed at the effects of fertilizer levels on yield and quality of redish.

Total Soluble Solids (% TSS) varied with mulch type and irrigation treatments. The levels that were significantly ($p<0.05$) higher than the control were obtained with grass mulch with 100% MC and black plastic with 100% MC. Treatment of no mulch with 100% MC was not significantly different from the no mulch with 70% MC, while the rest of the other treatments resulted in significantly ($p<0.05$) lower %TSS values compared with the control (Table 4). A situation of high moisture availability is promoted by increased irrigation levels complemented by grass mulch and black plastic mulch, in decreasing order. High moisture availability increased yield and % TSS. Higher % TSS content were similarly reported by Lu *et al.* (2008) who found a positive correlation of % TSS and increased weight for different genotypes of radish.

Treatments of no mulch with 100% MC, grass mulch with 100% MC and black plastic with 100% MC did not differ significantly ($p>0.05$), but had higher fresh mass than the other treatments. The least significant ($p<0.05$) fresh mass was obtained with no mulch and 50% MC as well as clear plastic with 50% MC (Table 4). This showed that the type of mulch used had an influence on the fresh mass of radish. Water is critical for plants to produce their biomass (Marr, 1996). Optimum amounts of water coupled with other favourable factors for growth such as provision of mulches which conserve moisture lead plants to incrementally grow to their fullest potential.

CONCLUSION

The study illustrated that grass mulch combined with adequate irrigation resulted in higher growth parameters of radish than all the other treatments. Based on the results of this study it is concluded that irrigation levels of 100% MC + grass mulch resulted in significantly higher growth parameters of radish than the other treatments. Low moisture content without mulch resulted in the least growth and development of radish, as was observed with the 50% MC + no-mulch treatment, and had subsequent root cracks. The results of this experiment also demonstrated that the type of mulching material had an influence on the yield components of radish, where treatments with grass mulch produced relatively higher fresh weight, followed by clear plastic, black plastic and lastly bare soil in decreasing order.

It is recommended that further studies be carried out to establish the water use efficiency of radish based on the fertilizer requirements and other sustainable production practices of the crop.

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