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Effects of grass (*Hyperenia* spp.) mulching rate on development and yield of okra *(Abelmoschus esculentus*) under drip irrigation

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Mulching minimizes water evaporation from cropped surfaces and increases efficiency of water utilization by the crops. A study was conducted between January to March and August to November 2015 in Zimbabwe, to establish the effect of different densities of thatch grass (*Hyperrhenia filipendula*) mulch on growth and yield of okra (*Abelmoschus esculentus*) under drip irrigation. The experiment was laid in a Randomized Complete Block Design (RCBD), with five grass mulch rate treatments (0, 0.5, 1.0, 1.5 and 2.0 kg/m^2) in three replications. Assessments were done on days to emergence, germination percentage, inter-flower distance, and stem thickness and fresh pod yield. There were significant differences (P<001) in the number of days to emergence under different mulching densities. The differences in stem thickness, inter flower distance and crop yield were also significant (P<0.001) among the different mulch rate treatments. The 1.5 kg/m^2 mulching rate of thatch grass (*H. filipendula*) had least number of days to emergence, highest germination percentage, lowest inter flower distance and highest yield and, therefore, were the optimal rate for okra production

Key words: Okra, *Hyperrhenia filipendula,* mulching rate, moisture conservation, inter flower distance, stem thickness, fresh pod yield.

INTRODUCTION

Okra (*Abelmoschus esculentus*) is an important vegetable grown in tropical and subtropical parts of the world (Duvauchelle, 2011). Okra belongs to the Malvaceae family. It is a perennial flowering plant cultivated for its pods and at times for the tender leaves. Many varieties are grown in Zimbabwe and these are distinguished by height, degree of branching, flower colour, pod length, shape and presence or absence of spine (Sistrunk et al.,

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1960).

Okra (*A. esculentus*) and other indigenous vegetables have played crucial roles in food security and improving nutritional needs of marginalized communities (Siemonsma, 1982). Okra is now considered an important resource in the diet of most Africans (Street et al., 2016, 2011; Ratta et al., 2015) and most small scale farmers are venturing into okra production due to its increasing demand (Roy et al., 2014).

Okra performs best especially in well drained soils rich in organic matter and have pH of 5.8-6.5; which is slightly acidic (Smith et al., 2009). It also performs well in areas that receive annual rainfall of 1000 mm. Adequate moisture is greatly needed for optimum growth and yield. A regular irrigation schedule of 350 mm of water every seven days is recommended for maximum yields (Konyeha and Alatise, 2013). This major requirement of moisture is becoming a great challenge in the tropics because of climate change related rainfall reduction and poor distribution (Gukurume, 2014).

According to Konyeha and Alatise (2013), okra yield can be increased by irrigation water during dry and off-seasons. Climate change has caused a reduction in rainfall and a change in the rainfall pattern (Gukurume, 2014). Water sources are depleted due to global warming. Most water sources have silted, meaning inadequate water for farming purposes (Chenje et al., 1998). Moisture stress affects yield and growth of most horticultural crops. Farmers have to adopt various recommended measures that can improve water use efficiency in order to mitigate climate change related moisture reduction.

According to Wu et al. (2016) mulching using grass is one of the measures that can be used to improve water use efficiency in crops and moderates soil temperature. Mulch promotes greater root development by conserving moisture through reducing evaporation of water from the soil surface, thus improving moisture availability to crops.

The objective of the study was to determine the effect of different mulching densities using thatch grass (*Hyperrhenia filipendula*) on seedling emergence, growth performance and yield of okra and to determine the optimum density of thatch grass (*H. filipendula*) mulch that supports optimum growth and yield. Thatch grass is robust perennial tufted grass, 1 to 3 m tall. It occurs in deciduous woodland, wooded grassland and along riverbanks in the high and middle veld of Zimbabwe, on roadsides and in disturbed areas from December to June (Hyde et al., 2017).

It is hypothesized in this study that thatch grass (*H. filipendula*) mulch supports improved growth and yield of okra under drip irrigation and that different thatch grass (*H. filipendula*) mulch densities differ in their moisture conservation ability and therefore in the way they influence growth and yield of okra (*A. esculentus*). Results from the study will be useful to farmers in semi arid tropics who have serious need to conserve moisture by reducing evaporation from the soil surface caused by increasing climate change related moisture stress.

METHODOLOGY

Study site

The experiment was conducted in Chinhoyi peri urban area in Zimbabwe. The area is at 17°22'S, 30°12'E, and 1140 m altitude (CLIMATEMPS, 2014). Chinhoyi is in Natural Region IIA of Zimbabwe and the area receives annual rainfall amount of 850 mm, distributed in 16 to 18 wet pentads per annum (CLIMATEMPS, 2014). The project location has sandy to clay loam soils, slope of 2 and 5%. Crops mostly grown in this zone are maize, soya beans, field beans, winter wheat and barley and tobacco. The average temperature is 18°C (FAO, NEPAD, GoZ, 2004) (Figure 1).

Land preparation and sowing

The land was pre-irrigated in the first week of November and for 9 h to field capacity using sprinkler irrigation. The site was disc-ploughed and later harrowed to attain a fine tilth. Drip irrigation lines were lined and the site was then subdivided into three blocks of fifteen plots each.

Planting holes were made and the seeds were sown at a spacing of 100 cm inter row by 30 cm in row. The seeds were sown *in-situ* and one seed was placed at a station in single rows. Grass (*Hyperrhenia* species) mulch which had been fine chopped and weighed using a Nicholas scale was applied to the plots (Table 1). The thatch grass (*Hyperrhenia* spp.) was used because it grows abundantly in this area. After the application of mulch, the site was again watered to field capacity using sprinklers in order to settle the grass mulch so that it would not be carried away by wind and to ensure a good seed to soil contact. After establishment, water application was done using drip irrigation.

Fertilizer application

As recommended by NTS (2016) compound D (N7:P14:K7) fertilizer was applied as a basal at the rate of 60 g/m^2 and was well incorporated before sowing, while ammonium nitrate fertilizer (34.5 N) was applied as a top-dressing at the rate of 100 kg/ha at 4 weeks after planting and later, when flowering commenced.

Watering

Drip irrigation was used in this experiment to ensure that moisture was available all the times (Chikobvu, 2008).

Pest and disease control

Table 1 shows the management of pest and disease as recommended by Chikobvu (2008).

Mulch

Hyperrhenia spp. was used as mulch.The grass was cut, brushed to remove seed, and chopped into pieces measuring 25 cm using a

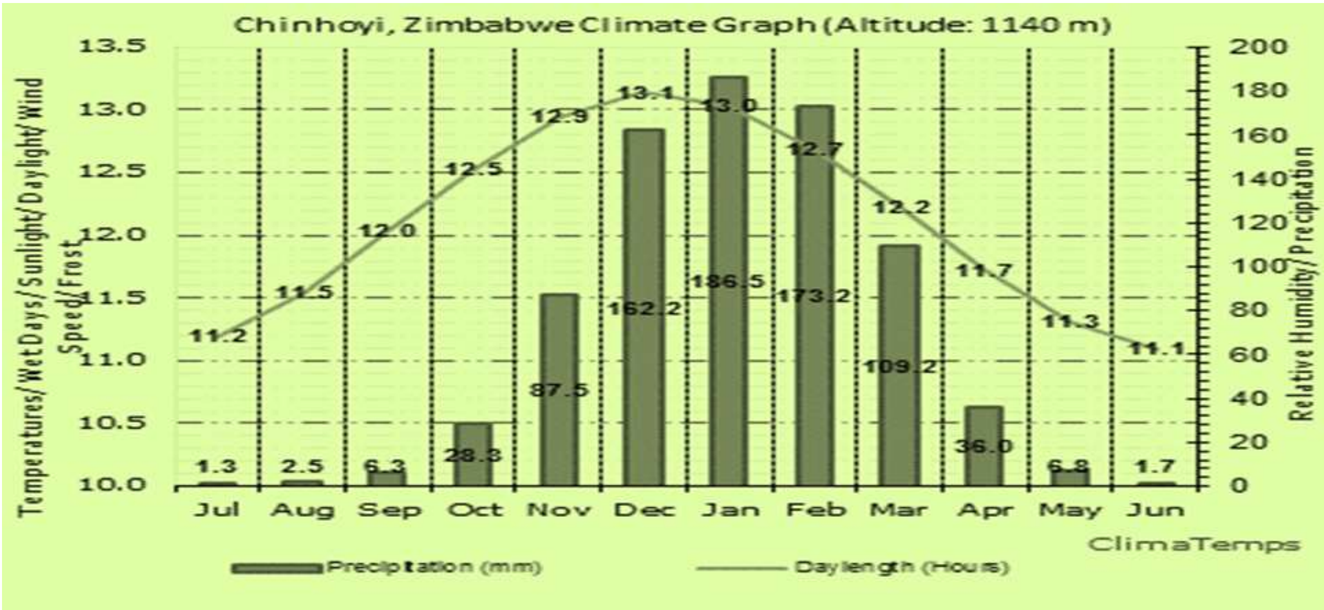

Figure 1. Chinhoyi climate graph (Climatemps.com, 2014).

Table 1. Management of pest and disease as recommended by Chikobvu (2008).

Pest/Disease	Chemical	Rate	When applied
Leaf eaters	Thunder	5 ml/15 L water	Based on scouting results
Aphids	Confidor	2 ml/15 L water	Based on scouting results
Fungal diseases	Mancozeb and copper	30 g/15 L water	Every week Every week
Powdery mildew	Lime Sulphur	30 g/15 L water	Every week
Cutworms	Karate	2 ml/15 L water	Just after germination

machete. The seed was eliminated in order to avoid contamination of the experiment by *Hyperrhenia* spp. seed. The mulch was then weighed using a Nicholas scale into respective weights in order to suite the different treatments that were under study. Mulch was spread evenly according to treatment requirements into respective beds.

Experimental design

The experiment was laid in a Randomized Complete Block Design (RCBD) with five treatments (Table 2). Data was collected from 4th day after emergence.

Measurements

Ten plants were randomly selected from each plot and tagged for data measurements. From these plants, days to emergence, germination percentage, stem thickness, inter flower distance and yield were assessed and recorded. The measurements were collected on a weekly basis at 7 day interval from the fourth day after crop emergence (DACE).

Number of days to crop emergence

Observations were made from four days after sowing to eight days. Physical counts were done.

Germination percentage

Observations were made and a simple formulae was used in calculating the germination percentage:

Total germinated / Total planted × 100

Stem thickness

A string was used in measuring diameter of the stem and the string

Table 2. Treatment structure.

Treatment number	Description (kg grass mulch/m^2)
1	0
2	0.5
3	1
4	1.5
5	2.0

Table 3. The effect of mulching rate on okra emergence.

Treatment	Number of days to emergence
1. 0 kg grass mulch /m^2	7.6^b
2. 0.5 kg grass mulch/m^2	7.0^b
3. 1.0 kg grass mulch/m^2	6.4^b
4. 1.5 kg grass mulch/m^2	4.2^a
5. 2.0 kg grass mulch/m^2	6.6^b
Grand mean	6.36
P value	<0.001
CV	14.4
LSD	1.229

Means which follow different letters in the same column are significantly different.

was placed on a ruler in order to deduce the thickness in centimeters. The middle part of each plant was measured for stem thickness.

Yield of harvested okra

A digital scale was used in measuring the weight of harvested okra. It was harvested from each bed, and then weighed. The yield was converted to kilograms per hectare.

Data analysis

Data collected was subjected to two-way analysis of variance using GENSTAT software 14th edition.

RESULTS

Effect of mulch on days to emergence of okra

There were significant number of days to emergence differences among the different mulching rate treated plots (P<0.001). The days to emergence in 0 kg grass mulch/m^2 treated plots were similar (p >0.05) to the 0.5, 1.0, and 2.0 kg grass mulch/m^2 treated plots. The plots which received a 1.5 kg grass mulch/m^2 treatment took significantly lower (p < 0.05) period to emergence than the control plot (0 kg grass mulch/m^2 treatment) (Table 3).

The effect of mulching densities on percentage germination of okra

There were significant differences (P<0.05) in the percentage okra germination among the treatment means. The treatment plots with 0 kg grass mulch/m^2 had a significantly lower germination percentage than 1.5 kg grass mulch/m^2, 0.5 kg grass mulch/m^2, 1.0 kg grass mulch/m^2 and 1.5 kg grass mulch/m^2 (Figure 2).

Effect of mulching rate on the stem thickness of okra

There were significant differences (P<0.001) in the girth of stem in (mm) produced by okra among the treatments. The treatment plot with 0 kg grass mulch/m^2 had the highest stem thickness, which was comparable with that for treatment plots 2.0 kg grass mulch/m^2 (Table 4).

Effect of mulching rate on inter flower distance of okra

There were significant differences (P<0.05) in the inter-flower distance among the treatment means (Table 5). The inter flower distance in 0 kg grass mulch treated plots and that for the 0, 0.5, and the 2 kg grass mulch/m^2 treatment plots were statistically similar (p<0.05). The 1.5 kg/m^2 of grass mulch had the least distance of 56.2 mm.

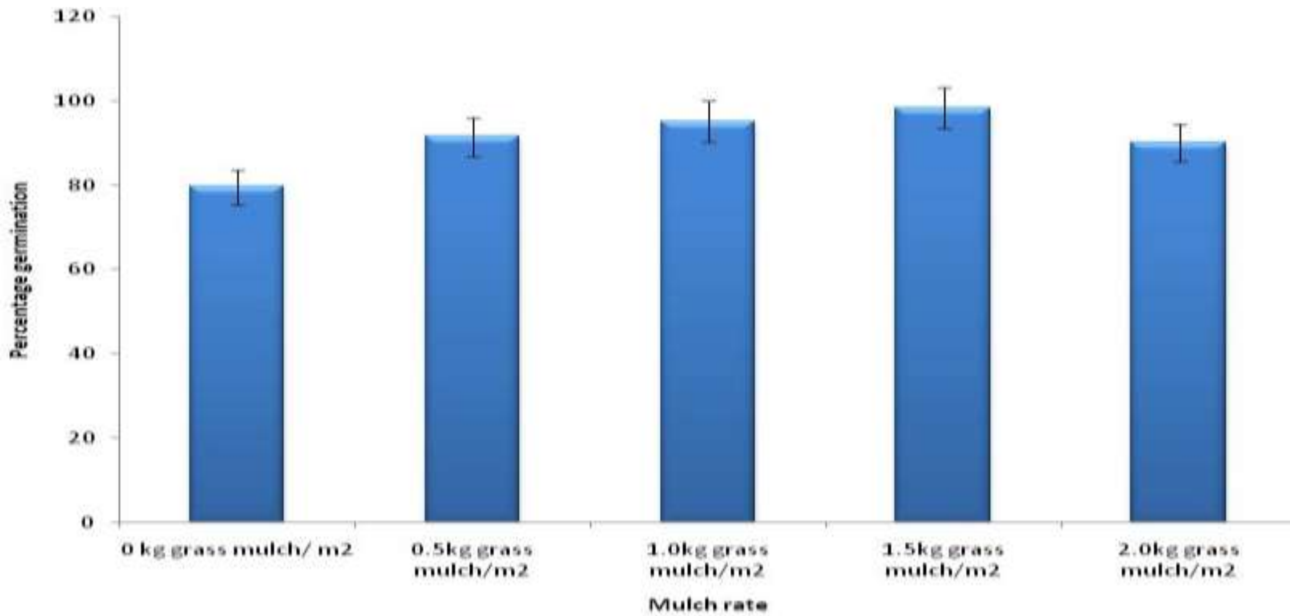

Figure 2. Effect of grass mulching rate on the percentage germination of okra.

Table 4. Effect of grass mulching rate on the stem thickness of okra.

Treatment	Stem thickness (mm)
1. 0 kg grass mulch/m^2	27.8[c]
2. 0.5 kg grass mulch/m^2	23.9[a]
3. 1.0 kg grass mulch/m^2	26.2[b]
4. 1.5 kg grass mulch/m^2	23.5[a]
5. 2.0 kg grass mulch/m^2	26.58[bc]
Grand mean	25.60
P value	<.001
CV	4.6
LSD	1.571

Means which follow different letters in the same column are significantly different at P<0.05.

Table 5. Effect of mulching rate on inter-flower distance of Okra.

Treatment	Inter-flower distance (mm)
1. 0 kg grass mulch/m^2	61.4[c]
2. 0.5 kg grass mulch/m^2	61.8[c]
3. 1.0 kg grass mulch/m^2	59.2[b]
4. 1.5 kg grass mulch/m^2	56.2[a]
5. 2.0 kg grass mulch/m^2	61.4[c]
Grand Mean	60
P value	<0.001
CV	2.7
LSD	1.025

Means which follow different letters in the same column are significantly different at P<0.05

Table 6. Effect of mulching rate on yield of Okra.

Treatment	Yield kg/ha
1. 0 kg grass mulch /m^2	2749^a
2. 0.5 kg grass mulch/ m^2	3028^{ab}
3. 1.0 kg grass mulch/ m^2	3405^b
4. 1.5 kg grass mulch/ m^2	4574^c
5. 2.0 kg grass mulch/ m^2	3448^b
Grand Mean	3441
P value	<0.001
CV	10.4
LSD	479.3

Means which follow different letters in the same column are significantly different at P<0.05.

The 1.0 and 1.5 kg grass mulch/m^2 treatment plots had a statistically lower ($p < 0.05$) inter flower distance than the control (0 kg grass mulch/m^2) (Table 5).

Effect of mulching rate on yield of okra

The yield differences in plots treated with different grass mulching rates were also significant ($p < 0.05$). The 0 kg grass mulch/m^2 treated plots produced the lowest yield (2749 kg/ha), which was statistically similar to yield in the 0.5 kg grass mulch/m^2 treated plot (3028 kg/ha). The 1.5 kg grass mulch/m^2 treated plots produced the highest yield (4574 kg/ha). The yield from 1.0 kg grass mulch/m^2 (3405 kg/ha) and the 2.0 kg grass mulch/m^2 (3448 kg/ ha) were statistically similar ($p < 0.05$) (Table 6).

DISCUSSION

Different *Hyperrhenia* spp. mulching rate had effect on number of days to emergence of okra seed. The higher number of days to germination in 0 kg grass mulch/m^2 when compared with mulch treated plots may be attributed to absence of soil cover and higher evaporation rate. The lack of soil cover hindered availability of optimum moisture for seed imbibitions to commence metabolic processes of germination. Sarma and Gogoi (2015) observed enhanced germination and growth of okra seedling after organic amendments. On the other hand, Sanders (2002) indicated that there is more water use efficiency on mulched environments than bare soil; hence, germination is more under mulching. He further indicated that mulching is important for early seed development, because it protects the seed from desiccation. Adekali et al. (2008) indicated that seed germination under mulch is not influenced by the mulch but by genetic makeup of the variety. In this study, mulching could have become so important because of the prevailing hot condition during the period of study (Table 1). The 0 kg grass mulch/m^2 treatment produced the lowest percentage germination when compared with all other treatments. There are four important factors that influence germination of a seed and these are moisture, temperature, soil and light (Bennett, 1995). The hot summer conditions during the study period may have reduced soil moisture through high evaporation rate caused by the heat effect. The fluctuations in moisture availability to the seed in the control treatment could have led to failure to imbibe sufficient water to take the seed through the germination process (Dalorima et al., 2014). Depending on the soil physical and chemical properties, lack of adequate soil moisture due to absence of moisture conserving grass mulch may cause soil to cap and impair seedling emergence.

The higher stem girth in control treatment could have resulted from lack of competition because of a lower germination and crop stand reduction. Sanni and Eleduna (2014) in Nigeria also found plant height to be negatively correlated to stem girth in un-mulched okra, with highly populated plant tending to have thinner stem girth due to competition for sunlight.

The 0 kg grass mulch/m^2 had relatively higher inter-flower distance. According to Mamkagh (2009), the greater the crop inter-flower distance, the less the number of fruits produced and consequently the lower the yield produced. In the study, the relationship between mulch and inter-flower distance was however not clear, as significantly higher values were noted at both the lowest and highest mulch rate treatments.

Okra yield increased with mulching density to a maximum of 4574 kg/ha at a mulching rate of 1.5 kg grass mulch/m^2, beyond which the yield declined (Table 5). The conditions for growth in the 1.5 kg grass mulch/m^2 treated plots could have been optimal. Hotchmuth et al. (2001) emphasized the importance of controlling weed growth, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content as effective ways of manipulating crop growing environment to increase yield and improve product quality. According to Hotchmuth et al. (2001), mulch has a greater effect on yield of okra when compared with corresponding levels of drip irrigation without mulch. In this study, the quantity of mulch had greater influence on the yield because it could have enhanced early growth stages of the crop, such as emergence, which consequently had a bearing on crop stand.

CONCLUSION AND RECOMMENDATIONS

There was variable difference among treatment means in all parameters measured in the experiment. The different grass mulching rates significantly affected stem thickness, germination, inter flower distance, days to emergence and yield of okra under drip irrigation. However, out of all the parameters measured, the 1.5 kg grass mulch/m^2 treatment was optimal because it had significantly higher yield, germination rate and lower number days to emergence. The 1.5 kg grass mulch/m^2 can therefore be recommended for similar tropical and subtropical okra producing areas where okra yield is limited by high temperature induced moisture stress and under drip irrigation.

CONFLICT OF INTERESTS

Authors have declared that no competing interests exist.

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