

Full Length Research Paper

Vegetative biomass of maize, soybean, lablab and grazing vetch under different tillage and mulch practices in the foothills agro-ecological zone of Lesotho

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A field trial was conducted to determine the effect of tillage and mulch practices on the biomass response of cereal maize and soybean, lablab and grazing vetch which are legumes, when planted as fodder crops. The experiment was conducted using split-plot design with three replications. The main plot treatments were two mulch levels (Mulch and No-Mulch). The mulch was maize straw left from previous cropping season. The subplot treatments were minimum tillage (0.2 m) and deep tillage (0.35 m). The parts of the four crops quantified were leaf, stem and roots. The combination of deep tillage and mulch practices resulted in significant ($P < 0.05$) increase in the leaf, stem and root biomass of maize and, soybean, lablab and grazing vetch. Minimum tillage and no-mulch combined depressed ($P < 0.05$) the leaf, stem and root yield of maize while, for soybean, lablab and grazing vetch there was no definite trend of significantly ($P < 0.05$) depressed biomass for the leaf, stem and root yield under minimum tillage and no-mulch, and deep tillage and no-mulch. There was low correlation and positive significant relationship between leaf, stem and root and legume crops whereas, maize had a high correlation relationship with its biomass parameters. It is recommended that maize, soybean, lablab and grazing vetch can be grown as forage crops under combined deep tillage and mulch practices in the Foothills agro-ecological zone of Lesotho to obtain enhanced biomass.

Key words: Cereal, legume, leaf, stem root, forage.

INTRODUCTION

Environmental factors play significant role in plant biomass. Generally, light, temperature and moisture are important environmental factors that control the vegetative development and maturation of forages (Hatfield et al., 2011).

Light, moderate temperature and moisture assist in the photosynthesis process where plant manufactures its own food. There are processes involved in biomass production in the forages, like interception of solar radiation by the forage leaves, change of the intercepted

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energy to plant biomass and partitioning of the biomass produced between plant components (Medlyn et al., 2002).

Plant roots are the major components of terrestrial ecosystems and function to sustain the supply of nutrients and water to the plant. Biomass yield is greatly dependent on the root system (Guan et al., 2014).

The root system serves as a link between the impacts of agricultural practices on soil and changes in shoot function and harvested yield. Biomass is a part of plant material which contains essential nutrients; energy, protein, fibre, vitamins and minerals and they contribute significantly in the production potential of the animals. As animals consume forage of high biomass, they obtain multiple nutrients for the purpose of somatic maintenance, development, growth and reproduction (Das et al., 2004), relying on their different behavioral and physiological regulatory mechanisms to absorb the optimal mixture of nutrients to meet energetic and structural needs referred to as their intake target (John, 2005).

Maize and forage legume yield seems to decline in Lesotho. Low biomass yields have been attributed to the fact that most forages in Lesotho are produced under rain fed conditions where the rainfall is usually inadequate, short in duration, poorly distributed and highly variable between and within seasons of the year. Low biomass yield negatively affects production potential of the animals. All these are consequent upon the environment in which the plant is grown, which lowers plant development and maturation.

Maize and forage legume biomass production may be improved through the use of various agronomic practices like good tillage and mulch practices, which ensure more efficient use of resources to improve the growth of crops resulting in high biomass. Tillage is a fundamental practice that increases biomass yield by breaking the hard subsoil layer (Ahmad et al., 2009). It loosens and causes aeration of the top layer of soil, which facilitates planting of crops to give good biomass. Furthermore, tillage causes mixing harvest residues, organic matter and nutrients evenly into the soil which can be available for plant to use in order to increase biomass production (Ray, 2013). When forages are produced on suitable soil conditions, they grow and perform all necessary processes leading to improved biomass yield and animals benefit most from biomass accumulated by these forages.

In recent studies, Shahid et al. (2016) reported highest vegetative biomass harvested on maize planted under deep tillage while lowest biomass was recorded from minimum tillage. Memon et al. (2013) found that deep tillage yielded high production of biomass in maize, and improved essential nutrients required by livestock.

In recent studies with forage legumes, Karunatilake et al. (2000) observed highest plant biomass on soybean planted under deep tillage. Similarly, Ohyama et al. (2009)

reported an increase in plant biomass under deep tillage as compared to the control treatment and high biomass yield of forages allows livestock to meet their nutritional requirements. Mulching is an effective method of manipulating forage growing environments in order to increase biomass yield and improve product quality by controlling temperature, conserving soil moisture and enhancing organic matter content of the soil for forage to use (Patrick, 2004).

A study performed by Reddy et al. (2002) and Diaz-Zorita (2000) indicated highest vegetative biomass on maize under mulch due to reduced soil temperatures and soil moisture content which allowed good development and productivity of the forages.

Similarly, Hou et al. (2012) indicated that mulch enhanced soil moisture and organic matter resulting to high plant biomass. Liu et al. (2009) reported that mulch provided soil with moderate temperatures and kept soil water content stable, which resulted in faster growth of the crop and resulting in to higher plant biomass. Soil moisture conservation helps in plant development and biomass yield due to photosynthetic process.

In studies with legume forages, organic mulch appreciably influenced nitrogenization and nodulation of legume forages, which resulted into highest plant biomass (Siczek and Lipiec, 2011). Albiach et al. (2000) reported high vegetative biomass in lablab grown under mulching compared to control treatment due to uniform moisture, and temperature regimes by organic mulching which provided a better conducive rhizospheric condition and in turn assisted plants to boost their growth remarkably. Improved forage growth will result in feeds of high feed value, and thus reduce the physiological stress and lowered productivity of ruminants associated with long search for pasture during dry spells. Therefore, this study was undertaken to determine the vegetative and root biomass of maize, a cereal and, soybean, lablab and grazing vetch, three selected forage legumes under tillage and mulch practices.

MATERIALS AND METHODS

Study site

The study was conducted during the 2018/2019 growing season (December, January, February and March), in the Foothills of Lesotho at Ha-Matela located in Nazareth, east of Maseru District. Nazareth is about 1842 m above sea level having Latitude 29°23'55.79" S and Longitude 27°48'15.48" E. The average monthly temperature during 2018/2019 growing season was 22°C (minimum temperature 18.76 °C and maximum temperature 25.55 °C). The average monthly rainfall was 25.2 ml, with minimum rainfall of 6.76 and 59.14 ml maximum. Monthly temperature and rainfall data is presented in Table 1. Before sowing, the experimental soil was analysed for physicochemical properties using the procedure of Snyder and Trofynow (1984) which revealed that the experimental field was sandy-loam with pH 6.24 (Table 2).

Table 1. Rainfall and temperature data during 2018/2019 growing season.

Months	Temperature (°C)	Rainfall (ml)
December	23.33	59.14
January	25.55	19.50
February	20.54	15.23
March	18.76	6.76

Source: Lesotho Meteorology Services.

Table 2. Physicochemical properties.

Soil characteristics	Available amount
Organic carbon (%)	1.64
Clay (%)	14.22
Silt (%)	14.04
Sand (%)	33.22
pH	6.24
K (ppm)	0.85
N (%)	14.40
P (ppm)	14.12
Mn (ppm)	14.12
Cu (ppm)	1.15
Fe (ppm)	5.96
Zn (ppm)	0.85

Land preparation

Land was prepared through the use of mouldboard plough with the depth of 0.3 m on deep tillage and harrowed to bring the soil to fine tilth. Soil sample was taken and analyzed for physical and chemical characteristics and soil minerals. The soil sample was obtained from the upper soil surface layer (0-0.15 m) using an auger before sowing. The sample was air dried for analysis to establish the initial soil physicochemical properties of the experimental field. About 5 g of air-dry soil was taken, put in a glass beaker and 10 ml of distilled water was added.

The contents were thoroughly mixed with glass rod and allowed to stand for 30 min. The soil pH was measured with the EQUIP-TRONICS Digital pH meter model EQ-610. The soil sample was digested on Labcon digester at 300°C in a mixture of hydrogen peroxide, sulphuric acid, selenium and salicylic acid (Okalebo et al., 2002). The digest was analyzed for P, K, Fe, Zn, Cu and Mn (Okonwu and Mensah, 2012). The total N content in the digest was obtained through Kjeldahl method (AOAC, 2002).

Planting of forage seeds

The seeds of maize (*Zea mays*), a cereal and soybean (*Glycine max*), lablab (*Lablab purpureus*) and grazing vetch (*Vicia villosa*), legume species were planted 19th December 2018. Maize seeds at the rate of 2 per hole were sown using a planter at 0.25 m spacing between and 0.05 m deep while, the broadcasting method was applied to the legume species.

Nitrogen, phosphorus and potassium (NPK) inorganic fertilizer was applied at the rate of 12.5 kg per plot for maize and the forage legumes. Weeds were manually controlled by the use of hoe five

weeks into plant growth. Pests and diseases were controlled through the use of hybrid seeds which were disease resistant, and Malathion an insecticide which was applied per plot of maize after mixing 5 ml with 5 L of water.

Experimental design

The experiment was a split-plot design with three replications. The main plot treatments were two mulch levels; Mulch (M) and No-Mulch (N). The mulch material was maize straw left from previous cropping season, the subplot treatments were two (2) tillage depths of 0.2 m (minimum tillage) and 0.35 m (deep tillage) coded as M and D, respectively. The treatment combinations were thus MN (Minimum tillage + No-mulch), DN (Deep tillage + No-mulch), MM (Minimum tillage + Mulch) and DM (Deep tillage + Mulch). Mouldboard plough was used for soil preparation and the size of each plot was 30 m x 16 m.

Plant sampling and biomass determination

The biomass indices determined from all the crops were leaf, stem and roots, and in addition grain for maize. Five plants each were chosen randomly from a total of 4 plots at maturity stage, which was 12 weeks in maize, 10 weeks in grazing vetch, 12 weeks in lablab and 12 weeks in soybean. The fresh weight (W_1) of leaves, stem and roots per plant, was obtained from average of five plants using a Mettler Toledo Scale. The samples were oven dried for 24 h in a Gallenkamp oven set at 105°C, left to cool then re-weighed to determine the dry matter weight (W_2). The percent moisture (% H_2O) was calculated as:

Table 3. Effects of tillage and mulch practices on maize shoot and root biomass (% DM).

Plant part	MN	DN	MM	DM	SEM
Leaf biomass	45.35 ^b	52.33 ^{ab}	58.63 ^a	61.26 ^a	±3.20
Stem biomass	19.73 ^d	41.13 ^b	34.18 ^c	60.35 ^a	±1.57
Roots biomass	39.05 ^c	46.75 ^b	41.29 ^{bc}	56.67 ^a	±2.19

Means with different superscripts within same row differed significantly ($p < 0.05$). SEM=Standard Error of Mean, MN= Minimum tillage + No Mulch, DN= Deep tillage + No Mulch, MM= Minimum tillage + Mulch and DM= Deep tillage + Mulch.

Table 4. Effect of tillage and mulch practices on forage legumes shoot and root biomass (%DM).

Legume forage	MN	DN	MM	DM	SEM
Grazing vetch					
Leaf biomass	41.06 ^b	34.59 ^c	51.92 ^a	55.99 ^a	±1.69
Stem biomass	21.39 ^c	30.95 ^b	39.21 ^a	44.11 ^a	±2.34
Root biomass	10.84 ^c	17.57 ^b	29.69 ^a	23.84 ^a	±1.94
Soybean					
Leaf biomass	27.34 ^c	18.78 ^d	38.61 ^b	53.02 ^a	±1.42
Stem biomass	30.79 ^b	22.57 ^c	27.34 ^b	42.84 ^a	±1.80
Root biomass	18.84 ^a	19.54 ^a	19.02 ^a	23.83 ^a	±1.83
Lablab					
Leaf biomass	43.85 ^c	50.81 ^b	57.74 ^a	59.01 ^a	±2.36
Stem biomass	27.34 ^d	32.27 ^c	45.69 ^b	60.93 ^a	± 2.04
Root biomass	27.30 ^b	21.20 ^c	29.72 ^b	42.11 ^a	±1.83

Means with different superscripts within same row differed significantly ($p \leq 0.05$). SEM=Standard Error of Mean, MN= Minimum tillage + No Mulch, DN= Deep tillage + No Mulch, MM= Minimum tillage + Mulch and DM= Deep tillage + Mulch.

W1 - W2

2

% Dry matter yield = 100 - % H₂O.

Data analysis

The data collected were manually inputted in Microsoft excel spreadsheet and transferred into SPSS (2012) version 20.0 for analyses. General Linear Model (GLM) was employed to determine the effect of tillage and mulch practices on biomass yield for cereal maize, and soybean, lablab and grazing vetch which are legume crops. In all the analyses, confidence level was held at 95% and P-value of less than 0.05 was considered as significant.

RESULTS AND DISCUSSION

The effect of tillage and mulch treatments on biomass of the leaf, stem and root of maize is as shown in Table 3. Significant ($p < 0.05$) variation occurred in the biomass yield of the three plant components across the treatment. The highest vegetative (leaf and stem) and root biomass was obtained in maize planted under deep tillage and mulch and the lowest yield was under minimum tillage and no-mulch. Maize planted under deep tillage and

mulch obtained highest vegetative and root biomass probably because deep tillage resulted into good soil texture whereas, mulch conserved moisture for crops.

In support of this results, Shahid et al. (2016) reported highest plant biomass of maize under deep tillage. Similarly, Hou et al. (2012) recorded an increase in plant biomass of maize under mulch. The result of the effect of the tillage depth and mulch type on the leaf, stem and root biomass of grazing vetch, soybean and lablab is presented in Table 4. The treatments were observed to affect the leaf, stem and root yield significantly ($p < 0.05$).

The highest leaf biomass was obtained on deep tillage and mulch for grazing vetch, soybean and lablab, and the lowest leaf biomass was obtained on deep tillage and no-mulch for grazing vetch and soybean, while lablab lowest leaf biomass was found on minimum tillage and no-mulch. These forage legumes; grazing vetch, soybean and lablab planted under deep tillage and mulch obtained highest leaf biomass possibly due to uniform moisture and temperature regimes caused by organic mulching. A similar finding has been reported for forage legumes by Karunatilake et al. (2000). The highest stem biomass was obtained on deep tillage and mulch for grazing vetch, soybean and lablab. The lowest stem biomass was obtained on minimum tillage and no-mulch for grazing

Table 5. Correlation between biomass parameters of maize.

Maize	Leaf biomass	Stem biomass	Root biomass
Leaf biomass	1.00	0.72**	0.52
Stem biomass	0.72**	1.00	0.87**
Root biomass	0.52	0.87**	1.00

** Correlation is significant at the 0.01 level (2- tailed). *Correlation is significant at the 0.05 level (2-tailed)

Table 6. Correlation between biomass parameters of selected forage legumes.

Legume forage	Leaf biomass	Stem biomass	Root biomass
Grazing vetch			
Leaf biomass	1.00	0.73**	0.70*
Stem biomass	0.73**	1.00	0.86**
Root biomass	0.70*	0.86**	1.00
Soybean			
Leaf biomass	1.00	0.92*	0.54
Stem biomass	0.92*	1.00	0.54
Root biomass	0.54	0.54	1.00
Lablab			
Leaf biomass	1.00	0.79**	0.44
Stem biomass	0.79**	1.00	0.81**
Root biomass	0.44	0.81**	1.00

*Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2- tailed).

vetch and lablab, while soybean lowest biomass was found on deep tillage and no-mulch. In line with this result is the report of an increase in stem biomass of forage legumes under mulch (Siczek and Lipiec, 2011).

The forage legumes root biomass obtained from tillage and mulch practices showed significant ($p < 0.05$) difference whereas, soybean root biomass was statistically similar across the treatments. The highest root biomass was obtained on deep tillage and mulch for soybean and lablab while, grazing vetch highest root biomass was found on minimum tillage under mulch practice.

The least root biomass was obtained on minimum tillage and no-mulch for grazing vetch and soybean, while lablab least biomass was found on deep tillage and no-mulch. Soybean and lablab planted under deep tillage and mulch had highest root biomass, while, grazing vetch gave highest root biomass under minimum tillage and mulch condition. It has been reported by Kihara et al. (2012) and Barrios et al. (2006) that the root biomass of forage legumes under deep tillage was highest as compared to control treatment. Correlation between biomass parameters of maize is presented in Table 5. Leaf biomass had a significant ($p < 0.05$) and positive correlation with stem biomass but, positive and no significant ($p > 0.05$) correlation with root biomass. Stem

biomass had a significant ($p < 0.05$) and positive correlation with root biomass. Good soil moisture content allowed easy circulation of nutrients through the soil to the plants for high yield.

In agreement of the results, Payero et al. (2009) and Mollasadeghi et al. (2011) observed positive and significant correlations among biological and grain yields in cereal maize. The result of the correlation between biomass indices and the legume crops is in Table 6. Leaf biomass of grazing vetch had a significant ($p < 0.05$) and positive correlation with stem and root biomass. Stem biomass and root biomass of grazing vetch were significant ($p < 0.05$) and positively correlated. Soybean leaf biomass was significant ($p < 0.05$) and positively correlated to stem biomass while, leaf and root biomass were not significantly ($p > 0.05$) correlated but had a positive relationship.

Soybean stem and root biomass had positive correlation but not significant ($p > 0.05$). Leaf biomass of lablab had a positive and significant ($p < 0.05$) correlation with stem biomass. Leaf and root biomass had positive correlation but not significant ($p > 0.05$). Stem and root biomass of lablab had a positive and significant ($p < 0.05$) correlation. This result is in line with that of Ma et al. (2010) and Schmidtke et al. (2010) who observed highly positive correlation among biomass parameters and

significant relationship between these parameters in leguminous forage.

Conclusion

In this study, variation in tillage depth and mulch practices had significant effect on biomass yield for cereal maize, and soybean, lablab and grazing vetch which are legume crops. The use of deep tillage and mulch resulted in high yield of forage both in the cereal and forage legumes. Vegetative biomass produced under deep tillage and mulch was highest, followed by minimum tillage and mulch in both cereal and forage legumes. Lowest vegetative biomass was produced under minimum tillage and no-mulch.

The highest leaf, stem and root biomass in maize and forage legumes was produced under deep tillage and mulch followed by minimum tillage and mulch. The legume crops had low and positive correlation relationship between its biomass indices whereas, cereal had high correlation relationship. It is recommended that soybean, lablab, grazing vetch and maize can be grown as forage crops under combined deep tillage and mulch practices in the Foothills agro-ecological zone of Lesotho to obtain enhanced biomass.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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