Original Research Article

Evaluation of Tillage and Mulch Practices on the Growth of Selected Cereal and Legume crops in the Foothills Agro-ecological Zone of Lesotho

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ABSTRACT

The trial was conducted to evaluate the influence of tillage and mulch practices on growth response of maize and selected forage legumes. With three replications, the experiment was carried out using a split-plot design. Mulch and no mulch were used as the major plot treatments Mulch was maize straw left from the previous cropping season. The subplot treatments were different tillage practices namely Minimum (0.2 m) and Deep tillage (0.35 m).The research was carried out in the Foothills of Lesotho in Ha-Matela in Nazareth, east of Maseru District, during summer season for four months (December, January, February, and March). A mouldboard plough was used to prepare the experimental field, and it was harrowed to get fine tilth. The broadcasting method was used to plant the legume species namely soybean (*Glycine max* L), lablab (*Lablab purpureus* L) and grazing vetch (Vicia villosa), whereas a planter was used to sow maize seeds at a rate of two per hole, 0.25 m apart, and 0.05 m deep. For maize and the forage legumes, 12.5 kg of NPK inorganic fertilizer was applied per plot. Low moisture content and poor soil conditions under minimum tillage and no-mulch resulted in low plant growth. Maize and forage legumes plant height was significantly (P<0.05) higher under deep tillage and mulch. Vegetative characteristics in respect of leaf, stem, and root lengths were also significantly (P<0.05) higher under deep tillage and mulch. Cereal maize had a low and positive correlation relationship between its growth indices whereas; legume crops had a high correlation relationship and were significant. Therefore, maize and forage legumes may be produced under deep tillage and mulch to support improved plant growth.

Keywords: Agronomic practices, maize, soybean, grazing vetch, lablab

1. INTRODUCTION

Maize is a common cereal crop mostly used as staple food by the Basotho, mainly produced for home consumption and feeding animals. Maize can be grazed after harvest, continuously or rotationally by farm animals depending on management practice of the farmer. Rotational grazing improves livestock distribution and allows rest period for new forage which later will be used for feeding purpose [6]. Continuous grazing delivers highest animal production as animals have access to feed preferences and, continuous grazing also requires minimum daily management [13]. Moreover forage legumes are also produced for home consumption and feeding livestock and they include alfalfa, lablab, clover, peas, soybeans and peanuts. Legumes may be conserved as silage for purpose of feeding farm animals [8].

Forage species are able to noticeably change physical, chemical, and biological soil properties [25]. Plants take up water and mineral nutrients through their roots, and deliver organic matter back to the soil through litter fall, roots and root exudates [5]. Forages undergo various processes during growth. The three most important processes regulating growth are the uptake of water, photosynthesis, and uptake of minerals [29]. Water in plants maintains cell turgidity for formation and growth. Water allows easy nutrients and organic compounds to flow throughout the plant. It serves as a raw material for various chemical processes, including photosynthesis [20]. Photosynthesis is responsible for producing and maintaining oxygen for forage crops to use and supplies all of the organic compounds and energy forage crops require for survival [7].

Despite the importance of cereal and forage legumes, their yield has remained low in most areas in Lesotho. The low productivity could be attributed to low and poorly distributed rainfall, mismatching of varieties, ineffective and unsustainable land, and inappropriate agronomic practices by farmers. Sole cropping practiced by farmers resulted to reduced soil nutrients and use of harmful chemicals as farmers have to introduce artificial products that could replicate the functions and nutrients lost like use of herbicides and fertilizers. Grazing animals to fields without living plant residues for mulching resulted to increased weed invasion hence reducing valuable soil nutrients available for plants use [15]. It also decreased the productivity of forages due to the competition for natural resources. All mentioned factors result in poor forage growth hence affecting animals' productivity due to unsustainable grazing pastures to supply animals with forage throughout the grazing period.

Although maize and forage legumes are cultivated in Lesotho, it is important to understand important factors like tillage practices and mulching which influence and determine their growth. Tillage plays an important role in improving maize and forage legumes growth. This is through breaking the hard subsoil layer providing suitable seed bed for forage crops, boosting chemical reaction and thereby improving the physicochemical condition of soil which in turn affects forage growth and development [30]. Similarly, [1] reported highest maize plant height under deep tillage. While on forage legumes, [31] reported lower soil temperature in deep tillage which had favorable effect on legume nodulation and led to increased plant height and leaf length. [19] reported an increase in plant height in legume crop under deep tillage compared to minimum tillage and was due to reduced soil bulk density which allowed easy nutrients circulation for good plant growth.

Management practices that leave crop residues on soil surface have shown to enhance crop growth [22]. Mulching is one of the most beneficial practices one can utilize for improved plant development [14]. Mulch on maize and forage legumes influences soil properties by giving rise to growth due to increased soil water content resulting from reduced evaporation and increased infiltration [22]. Moisture availability speeds up the germination rate and in return enhances good plant growth. [9] observed the shortest leaf length of maize under no-mulch as compared to mulched plot where leaf length was increased due to plants grown under favorable environment conditions.

[28] and [2] reported highest plant height of maize under mulch compared to no-mulch; this was due to moisture retention in the soil and decomposition of organic matter in the soil and this gave rise to plant development. [26] reported the highest soil moisture under mulched plots which enhanced root proliferation and increased nutrient availability to plant's roots and this allowed easy nutrient circulation throughout the plant and resulted in to good harvest for animals to feed on.

Furthermore, Mulch improved soil water and temperature conditions, decreased soil water evaporation, and absorbed more water from the deep soil profiles to boost yield in grazing vetch [35]. Therefore, this study was undertaken to investigate the growth response of maize and selected forage legumes to tillage and mulch practices in Lesotho.

2. MATERIAL AND METHODS

2.1 Study site

The research was carried out in the Foothills of Lesotho in Ha-Matela in Nazareth, east of Maseru District, during the growth season of 2020–2021 (December, January, February, and March). Nazareth is located at latitude 29°23′55.79′S and longitude 27°48′15.48′E, or about 1842 meters above sea level. During the growing season, the monthly average temperature was 22.65 °C (with a minimum temperature of 18.86 °C and a high temperature of 25.65 °C). The smallest monthly rainfall was 6.56 ml and the maximum was 60.14 ml. The average monthly rainfall was 25.4 ml. Table 1 lists monthly rainfall and temperature data. Using the method of Snyder and Trofynow (1984), the experimental soil was examined for physicochemical characteristics prior to sowing, and it was discovered that the field was sandy-loam with a pH of 6.44 (Table 2).

Table 1. Rainfall and Temperature data during growing season

Months	Temperature (°C)	Rainfall (ml)
December	25.65	60.14
January	25.55	19.50
February	20.54	15.23
March	18.86	6.56

Source: Lesotho Meteorology Services

Table 2: Physicochemical properties

Soil characteristics	Available amount
Organic carbon (%)	1.54
Clay (%)	14.21
Silt (%)	14.04
Sand (%)	33.22
Ph	6.24
K (ppm)	0.85
N (%)	14.40
P (ppm)	14.12
Mn (ppm)	14.11
Cu (ppm)	1.15
Fe (ppm)	5.96
Zn (ppm)	0.86

2.2 Experimental design

A split-plot design with three replications was used for the experiment. Mulch (M) and No-Mulch (N), two degrees of mulch, were the principal plot treatments. The subplot treatments included two (2) tillage depths of 0.2 m (minimal tillage) and 0.35 m (deep tillage), which were designated as M and D, respectively. The mulch material was leftover maize straw from the previous cropping season. Thus, the different treatment options were MN (Minimum tillage + No-mulch), DN (Deep tillage + No-mulch), MM (Minimum tillage + Mulch), and DM (Deep tillage + Mulch). Each plot measured 30 m by 16 m, and the soil was prepared with a mouldboard plough.

2.3 Land preparation

A mouldboard plough was used to prepare the experimental field, and it was harrowed to get fine tilth. A soil sample was obtained, and its physical, chemical, and mineral composition was examined. Before seeding, a soil sample was taken with an auger from the top 0.15 to 0.15 meters of the soil surface. The sample was air dried before examination to determine the initial physiochemical characteristics of the experimental field's soil. A glass beaker containing 5 g of air-dry soil was filled with 10 ml of distilled water.

The mixture was completely mixed with the glass rod before being left to stand for 30 minutes. The EQUIP-TRONICS Digital pH meter model EQ-610 was used to determine the pH of the soil. The soil sample was digested on a Labcon digester at 300 ^{o}C in a solution of hydrogen peroxide, sulphuric acid, selenium, and salicylic acid (Okalebo et al., 2002). The digest was examined for P, K, Fe, Zn, Cu, and Mn (Okonwu and Mensah, 2012). The Kjeldahl method was used to determine the digest's total N content (AOAC, 2002).

2.4 Planting of forage seeds

In December, grazing vetch (Vicia villosa), a type of legume, was sown along with the seeds of lablab (Lablab purpureus L), soybeans (Glycine max L), and maize (Zea mays L), a cereal. The broadcasting method was used to plant the legume species, whereas a planter was used to sow maize seeds at a rate of two per hole, 0.25 m apart, and 0.05 m deep. For maize and the forage legumes, 12.5 kg of NPK inorganic fertilizer was applied per plot. Five weeks into the plant's growth, weeds were manually removed with a hoe. Insecticide Malathion, which was applied to each plot of maize after mixing 5 ml with 5 liters of water, was used to manage pests and diseases. Disease-resistant hybrid seeds were also employed.

2.5 Sample collection for forage growth features

2.5.1 Plant height

Using a Pasture disc meter and three replications for each treatment, the plant height of the forage legumes and corn was monitored weekly while being subjected to mulching and tillage techniques. After germination and during plant growth, the height of randomly chosen plants was measured. Readings were taken when the disc was raised above the chosen plant.

2.5.2 Vegetative growth characteristics

Vegetative growth attributes measured were leaf length, stem length and roots length. Five plants were chosen randomly from each plot at maturity stage. The length of leaves, stems and roots per plant was obtained from average of five plants.
The leaf and stem length was measured by measuring tape. Root samples were collected at maturity stage using spade of 1.2 m and 12.3 mm diameter at 20 cm to 23.4 cm soil depth. The root lengths were recorded using measuring tape.

2.6 Data Analysis Section

The acquired data was manually entered into an Excel spreadsheet and then imported to SPSS (2012) version 20.0 for analysis. The impact of tillage and mulching strategies on the growth of cereal maize and the legume crops soybean, lablab, and grazing vetch was studied using a general linear model (GLM). A P-value of less than 0.05 was deemed significant in all analyses, and the confidence level was maintained at 95%.

3. RESULTS AND DISCUSSION

Plant height of maize obtained from mulch and tillage practices showed a significant ($P<0.05$) difference as presented in Table 3. The highest plant height was obtained on maize planted under deep tillage and mulch practice. The lowest plant height was obtained on maize planted under minimum tillage and no-mulch.

Maize planted under deep tillage and mulch has highest plant height due to decreased soil bulk density which increased proliferation of roots for the uptake of nutrients as well as moisture conservation by mulch. In support of the results of the study, [1] reported highest maize plant height under deep tillage. Similarly [2] indicated highest plant height of maize under mulching.

Table 3. Effect of tillage and mulch practices on maize plant height (cm)

Plant part	MN	DN	MM	DM	SEM
Maize	14.10^{c}	19.23^{b}	22.41^{b}	28.92^{a}	± 2.41

Means with several superscripts in the same row varied considerably (P <0.05). SEM is for Standard Error of Mean. MN stands for Minimum tillage + No Mulch, DN stands for Deep tillage + No Mulch, MM stands for Minimum tillage + Mulch, and DM stands for Deep tillage + Mulch

The forage legumes plant height obtained from tillage and mulch practices showed significant (*P*<0.05) difference as presented in Table 4. The highest plant height was obtained on soybean planted under deep tillage and mulch, followed by lablab and grazing vetch. The lowest plant height was obtained on lablab and grazing vetch planted under minimum tillage and no-mulch. Soybean planted under deep tillage and mulch obtained highest plant height probably because of trapped moisture under the mulch, favourable temperature in the root zone.

The fine soil texture may allow easy nutrients absorption and faster roots growth which resulted in accelerated forage growth. Similar results were obtained by [23] who indicated highest plant height on soybean under deep tillage. Similarly, [26] reported highest plant height on soybean under mulching compared to the control treatment.

Table 4. Effect of tillage and mulch practices on forage legumes plant height (cm)

Plant part	MN	DN	MM	DM	SEM
Grazing vetch	4.61^{c}	8.22^{b}	11.34^{a}	12.42^{a}	±1.44
Soybean	10.30^{b}	7.83^{c}	11.81^{ab}	14.53^{a}	± 2.22
Lablab	7.47^{b}	7.94^{b}	8.17^{b}	14.23^{a}	± 1.55

Means with several superscripts in the same row varied considerably (P <0.05). SEM is for Standard Error of Mean. MN stands for Minimum tillage + No Mulch, DN stands for Deep tillage + No Mulch, MM stands for Minimum tillage + Mulch, and DM stands for Deep tillage + Mulch

Maize leaf and stem lengths obtained from tillage and mulch practices showed no significant difference but root length under the same management showed a significant (*P*>0.05) difference as presented in Table 5. The highest leaf and stem lengths were obtained on maize planted under deep tillage and mulch. The lowest leaf and stem lengths were obtained on maize planted under minimum tillage and mulched plot. The highest root length was obtained on maize planted under deep tillage and mulch.

The lowest root length was obtained on maize planted under minimum tillage and no- mulch. Maize planted under deep tillage and mulch obtained the highest root length probably because tillage allowed easy roots penetration and easy nutrients abortion and mulch helped to conserve moisture for the plant to use. In support of the results, [27] reported the highest root length of cereal under deep tillage. Similarly, [34] reported the highest root length of cereal under deep tillage and mulch.

Table 5: Effect of tillage and mulch practices on vegetative length of maize (cm)

Vegetative length	MN	DN	MM	DM	SEM
Leaf length	35.00^{ab}	33.12^{b}	26.33^{b}	42.91^{a}	± 6.13
Stem length	65.03^{bc}	67.02^{b}	62.00^{c}	81.03^{a}	± 20.72
Roots length	6.12^{b}	7.50^{b}	15.32^{a}	16.83^{a}	± 2.23

Means with several superscripts in the same row varied considerably (P <0.05). SEM is for Standard Error of Mean. MN stands for Minimum tillage + No Mulch, DN stands for Deep tillage + No Mulch, MM stands for Minimum tillage + Mulch, and DM stands for Deep tillage + Mulch

The grazing vetch and soybean leaf length obtained from tillage and mulch practices showed some significant difference but, lablab leaf length under the same management showed no significant (*P*>0.05) difference as presented in Table 6. The highest leaf length was obtained on the lablab planted under deep tillage and mulch. The lowest leaf length was obtained on soybean planted under deep tillage and no-mulch followed by grazing vetch planted under minimum tillage and no-mulch. Lablab planted under deep tillage and mulch obtained highest leaf length probably because of conserved moisture and proper aeration for plant development while, retarding weed emergence by mulch. In support of the results, [26] and [31] reported an increase in leaf length of lablab under deep tillage and mulch compared to the control treatment.

The grazing vetch and soybean stem length from mulch and tillage practices showed significant difference whereas, lablab stem length under same management showed no significant difference as presented in Table 6. The highest stem length was obtained on grazing vetch planted under deep tillage and mulch. The lowest stem length was obtained on lablab both planted under deep tillage and no-mulch and minimum tillage and mulch.
Grazing vetch planted under mulch and deep tillage obtained highest stem length probably because mulch improved soil temperatures and tillage contributed by providing soil with fine texture for nutrients circulation. Similar results were obtained by [10] who observed high stem length of grazing vetch under deep tillage and mulch. The grazing vetch and lablab root length from mulch and tillage practices showed significant difference but, soybean root length under same management had no significant (*P*<0.05) difference as presented in Table 6.

The highest root length was obtained on grazing vetch planted under deep tillage and mulch. The lowest root length was obtained on lablab planted under deep tillage and no-mulch followed by, grazing vetch planted under minimum and no-mulch. Grazing vetch planted under deep tillage and mulch had highest root length probably because tillage provided crops with good soil texture for roots penetration and easy nutrients absorption and mulch helped to conserve moisture for plant development and growth. In line with the results, [35] and [32] reported highest root length on grazing vetch under mulch.

Table 6. Effect of tillage and mulch practices on vegetative length of forage legumes (cm)

Vegetative length	MN	DN	MM	DM	SEM
Grazing vetch					
Leaf length	1.42^{c}	5.07^{b}	5.19^{b}	7.39^{a}	± 0.66
Stem length	24.20^{c}	30.71^{c}	49.00^{b}	79.01^{a}	± 5.01
Root length	3.43^{d}	6.38^{b}	4.89^{c}	11.30^{a}	± 1.00
Soybean					
Leaf length	3.57^{b}	3.32^{b}	6.34^{a}	5.17^{a}	± 0.89
Stem length	12.91^{c}	18.91^{b}	17.02^{b}	35.00^{a}	± 2.23
Root length	7.24^{bc}	5.52^{c}	9.62^{a}	10.90^{a}	± 2.15
Lablab					
Leaf length	5.17^{b}	3.27^{b}	3.59^{b}	20.90^{a}	± 8.03
Stem length	16.30^{a}	12.81^{b}	12.80^{b}	17.93^{a}	± 2.12
Root length	6.68^{b}	3.72^{c}	4.42^{c}	10.71^{a}	± 1.17

Means with several superscripts in the same row varied considerably ($P < 0.05$). SEM is for Standard Error of Mean. MN stands for Minimum tillage + No Mulch, DN stands for Deep tillage + No Mulch, MM stands for Minimum tillage + Mulch, and DM stands for Deep tillage + Mulch

Correlation between all maize growth parameters was not significant as shown in Table 7. Maize height had a positive correlation with density, leaf length and stem length. Weak negative correlation was observed between maize height and root length. Leaf length had a positive but not significant correlation with stem length and root length. Stem length had a positive correlation with root length. Positive correlation came as a result of good soil fertility which gave plant a chance to have good nutrients from the soil and resulted in to good growth.

In contrast, [33] and [21] reported that among all morphological characteristics of maize, there was high, positive and significant correlation observed. In agreement of the results, [18] observed positive correlations between morphological characteristics and very little weak negative correlation.

Table 7. Correlation between growth indices of maize

Maize	Height	Leaf length	Stem length	Root length
Height	1.00	0.15	0.53	-0.99
Leaf length	0.15	1.00	0.04	0.12
Stem length	0.53	0.04	1.00	0.38
Root length	-0.09	0.12	0.38	1.00

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

Table 8 presented the correlation between growth parameters of selected forage legumes. Grazing vetch height had a positive and significant correlation with leaf length and root length while correlation with stem length was positive but not significant. Leaf length had a significant and positive correlation with stem and root length. Stem length had a significant and positive correlation with root length. Soybean showed no significant relationship between all its growth parameters but had a positive correlation between each.
Lablab height had a positive but not significant correlation with root length while with stem length had a significant and positive correlation. Weak negative correlation was observed

between height and leaf length of lablab. Leaf length had a positive and no significant correlation with stem and root length.

Stem length of lablab had a significant and positive correlation with root length. Moderate soil temperature contributed to positive correlation as it allowed good microorganism environment for them to perform microbial activities in helping plant's development. In contrast, [17] reported that an increase in one of the parameter let to an increase in to another. This resulted in to significant correlation and positive relationship among growth parameters in soybean. Similarly, [4] and [11] observed positive and significant correlation between lablab growth parameters.
In support of the results, [16] observed similar results. It was observed that soybean had positive correlation between its growth parameters and not significantly correlated. Similarly, [24] observed positive correlation in number of growth parameters of lablab and very little weak negative correlation among the parameters not significant to each other. [12] and [3] observed highly positive and significant correlation between grazing vetch growth parameters.

Table 8: Correlation between growth indices of selected forage legumes

Legume Forage	Height	Leaf length	Stem length	Root length
Grazing vetch				
Height	1.00	0.69*	0.56	0.68*
Leaf length	0.69*	1.00	0.61*	0.72**
Stem length	0.56	0.61*	1.00	0.85**
Root length	0.68*	0.72**	0.85**	1.00
Soybean				
Height	1.00	0.18	0.56	0.48
Leaf length	0.18	1.00	0.49	0.06
Stem length	0.56	0.49	1.00	0.17
Root length	0.48	0.56	0.17	1.00
Lablab				
Height	1.00	-0.04	0.64*	0.23
Leaf length	-0.04	1.00	0.42	0.43
Stem length	-0.04	1.00	0.42	0.43
Root length	0.64*	0.42	1.00	0.64*

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

4. Conclusion and Recommendations

In this study, tillage depth and mulch practices have shown a significant effect on the growth of cereal maize, soybean, lablab, and grazing vetch. The use of deep tillage with mulch produced better growth indices of cereal maize and forage legumes compared to deep tillage with no mulch, minimum tillage with mulch, and minimum tillage with no mulch. Among growth features, maize indicated a low correlation relationship whereas, legume crops produced a high correlation relationship between their growth indices. The combination of deep tillage and mulching showed the potential to improve the growth of maize and selected forage legumes as a source of fodder, therefore, this practice could be recommended as an effective agronomic strategy for smallholders during land preparation.

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