Effect of tillage practices on moisture retention and maize (Zea mays L.) performance under rainfed conditions in Swaziland

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Abstract- *An experiment was conducted to determine the effect of tillage practices on moisture retention and maize performance under rainfed conditions in Swaziland. The five treatments were based on structure of seedbed and seed planting method. They were ; zero tillage where jab planter was used to directly seed (JAB), tractor drawn planter to directly seed without ploughing (TDSS), tractor drawn cultivator to loosen soil followed by planting with tractor planter (TDRDS), planting basics made by using hand hoe (PLB) and conventional tillage (CNT) which was used as a control. The treatments were replicated three times. The data collected included weather data, germination counts, plant height, moisture retention, total dry matter and dry grain yield. The results displayed a significant difference in terms of moisture retention for the majority of the periods where measurements were done ($p<0.05$). Conventional tillage retained the least moisture while JAB retained the most moisture. In terms of seed emergence, TDRDS had the highest emergence during the first seven days compared to the other treatments. Conventional tillage had the tallest plants (268.5 cm) compared to the other treatments at 21 days after planting. Conventional tillage also had the highest total dry matter (16.2 tons/ha) and planting basins had the lowest dry matter (12.6 tons/ha). TDRDS had the highest grain yield (9.9 tons/ha), and JAB had the lowest grain yield (9.1 tons/ha). The difference in mean total dry matter and mean grain yield was not significant ($p>0.05$).*

Keywords-Germination, maize, moisture, tillage, yields.

I. INTRODUCTION

Maize (*Zea mays*) is Swaziland's staple food crop and is produced by over 90% of small holder farmers on communal land [1]. The crop is grown mainly for subsistence purposes. While almost all homesteads in the communal land produce maize, the country has never reached self-sufficient levels in maize production [2]. As a mitigation strategy, the gaps in production are covered by imports from South Africa which is the neighbouring country.

Maize can be grown on a wide variety of soils, but performs best on well-drained, well-aerated, deep warm loams and silt loams containing adequate organic matter and well supplied with nutrients [3]. It can be grown successfully on soils with a pH range of 5.0 - 7.0, but a moderately acid environment of pH range 6.0 - 7.0 is optimum. Values outside this range may result in nutrient deficiency and mineral toxicity. Addition of lime is recommended for good yields on more acid soils.

Availability of moisture in the soil is fundamental for sustainable maize production as maize requires 450 to 600 mm of rainfall per unit area for optimum growth [4]. The crop evapotraspiration (ETc) for maize is between 1.09 mm/day and 5.50 mm/day, with average value being 3.33 mm/day [5]. Tillage is practiced to loosen the soil, forming a good medium to enhance uniform seed germination, weed management and incorporate crop residues [6]. Retaining permanent soil cover in minimum tillage can reduce water requirement for a crop by as much as 30% [7]. Subsoil tillage was reported to decrease water consumption by up to 8% and increase maize yield by up to 674 kg/ha compared to conventional tillage [8]. Tillage may result in high crop yields due to modification of soil's physical, chemical and biological properties [9]. The objective of the study was to determine the effect of tillage practices on moisture retention, and maize performance under rainfed conditions in Swaziland.

II. MATERIALS AND METHODS

2.1 Description of the study area and research design

The experiment was conducted at the Malkerns Research Station in Swaziland, located at 26.55543 ^{o}S, 31.16293 ^{o}E, at an altitude of 752 m above sea level. The area is in the semi-arid region of the country with long-term average annual rainfall ranging between 800 – 1000 mm. The soils are sandy clay loam with high mineral content. It was conducted between November 2016 and April 2017.

The experiment was Randomized Complete Block Design (RCBD), with five treatments that were replicated three times. The five treatments were based on the structure of seedbed and seed planting method. The treatments were; jab planter (JAB),

tractor drawn direct maize seeder (TDDS), tractor drawn tines cultivator & maize seeder (TDRDS), planting basins (PLB), and conventional tillage (CNT). In the JAB treatment, planting was done directly using hand held jab planter without cultivating the soil [10]. Planting was done using tractor drawn maize seeder without cultivating the soil for the TDRDS treatment. The double row direct maize seeder used was drawn by Landini Powerfarm tractor that weighted 3320 kg [11]. A tractor drawn tines cultivator was used to loosen the soil prior to planting using the tractor drawn direct maize seeder for the TDRDS treatments. Planting basins with diameter of 25 cm were made using a hand hoe. Seeds were planted by hand at the centre of each basin. The plots were cultivated using tractor drawn mould board plough in the conventional tillage. There after planting was done by hand. The conventional tillage treatment was used as a control.

Each plot measured 7 m by 6 m, with 6 rows of maize planted 0.90 m apart and 0.25 m between plants. A 5 m and 2 m alley was left between the treatments and replications respectively.

2.2 Planting and fertilizer application and agronomic practices

Soil samples were taken from the site before planting to determine the soil pH, nitrogen (N) and phosphorus (P) content. The results were used to determine fertilizer requirements. Compound basal fertilizer in the form of Nitrogen (N), Phosphorus (P) and Potassium at ratio of 2:3:2 (22) was applied at a rate of 400 Kg/ha at planting. This resulted in application of 25 kg/ha, 38 kg/ha and 25 kg/ha for N, P, and K respectively. Nitrogen in the form of Limestone Ammonium Nitrate (28% N) was applied some 35 days after planting as side top dressing at a rate of 28 kg/ha. Planting was done on the 3rd of November, 2016. A hybrid maize variety, SC 719 was used for the trial. The variety is moderately tolerant to heat and drought stress. It takes about 130 days to mature and has a potential yield of 10 tons/ha under optimum conditions. [12].

A combination of CLEAOUT 45 Plus and Dual Gold herbicide was applied to all the plots some 48 hours before planning. CLEAOUT 45 Plus is a non-selective, non-residual herbicide that is used to control herbaceous weeds in agricultural sites [13]. Dual Gold is a selective concentrate herbicide for pre-emergence control of annual grasses [14]. CLEAROUT 45 Plus herbicide and Dual Gold herbicide were mixed with 20 litres of water at a dose of 400 ml and 100 ml respectively. Bladex, a selective herbicide for control of weeds was applied some five weeks after planting at a concentration of 400 ml Bladex in 20 litres of water [15]. The herbicides were all applied using a knapsack sprayer. Bulldock 0,05 GR granular pesticide was used to control maize stock borer (*Buseola fusca*). About a gram of the pesticide was applied into each maize plant funnel some seven weeks after planting [16]. The experiment was rainfed and no irrigation was applied.

2.3 Data collection and analysis

Data collected from the field were; germination count, plant height, total dry matter and dry grain yield. The number of seeds that had emerged was counted in each plot for day 5 to day 9 after planting.. Plant height was measured for 10 plants in each plot using calibrated wooden pole sat 7, 9 and 21 weeks after planting. The same plants were used to measure height at all the periods. Five plants were sampled from each plot to determine the total dry matter produced. This was done at 140 days after planting when the crop was ready for harvesting. The plants were cut at the base and cut into pieces (stem, leaves, tassels and cobs). They were oven dried at 105 ^{o}C for 72 hours, and then weighed to determine the dry matter. Five cobs were randomly sampled from each plot. The grain was removed from the cobs when the moisture content was determined to be 12.5% using a hand held moisture meter [17]. The grain was weighted to determine grain yield from the five plants. The yield from the five plants was multiplied by 8000 to determine yield per ha, where the assumed plant population was 40000 per ha [18]. Moisture retention was determined in each plot during the period of November to December 2016 using soil moisture probe [19] between week 4 and week 9 after planting. The moisture retention was determined at 3 days interval.

Weather data (daily rainfall, minimum air temperature , maximum air temperature and soil temperature) were collected from the adjacent weather station at Malkerns Research Station.

The data collected during the course of the experiment were analysed using the Statistical Package for Social Sciences [20], whereby analysis of variance (ANOVA) was done in order to determine any significant differences between the treatments. The mean separation test was carried out using the Least Significant Difference (LSD).

III. RESULTS AND DISCUSSIONS

3.1 Soil analysis results and weather data

The soil pH was 5.11 in potassium chloride and in water it was 6.20 with an exchangeable acidity of 0.43% and delta pH of 1.09, meaning that there was a net positive charge in the soil. Available nitrogen was 0.14% and phosphorus 3.85 ppm. The

organic matter content of the soil was determined to be at 2.28%. Lime was not applied as the soil pH was at the required range. The mean air temperature for the duration of the experiment was optimum as it ranged between 17 ^{o}C and 29.9 ^{o}C (Table 1).

TABLE 1
MEAN AIR TEMPERATURE AND SOIL TEMPERATURE DATA AT MALKERNS

Month	Temperature (^{o}C)		
	Mean maximum air temperature	Mean minimum air temperature	Mean soil temperature at 30 cm depth
November	25.9	17.2	23.8
December	28.9	17.9	26.3
January	27.2	17.7	26.2
February	28.0	18.6	26.8
March	28.2	17.1	25.1

A total of 537 mm was received, and this was within the range of rainfall required by the maize crop. The rainfall was well spread, as there was at least 5 mm of rainfall received in each week, except during week 7 and week 21 (Fig 1).

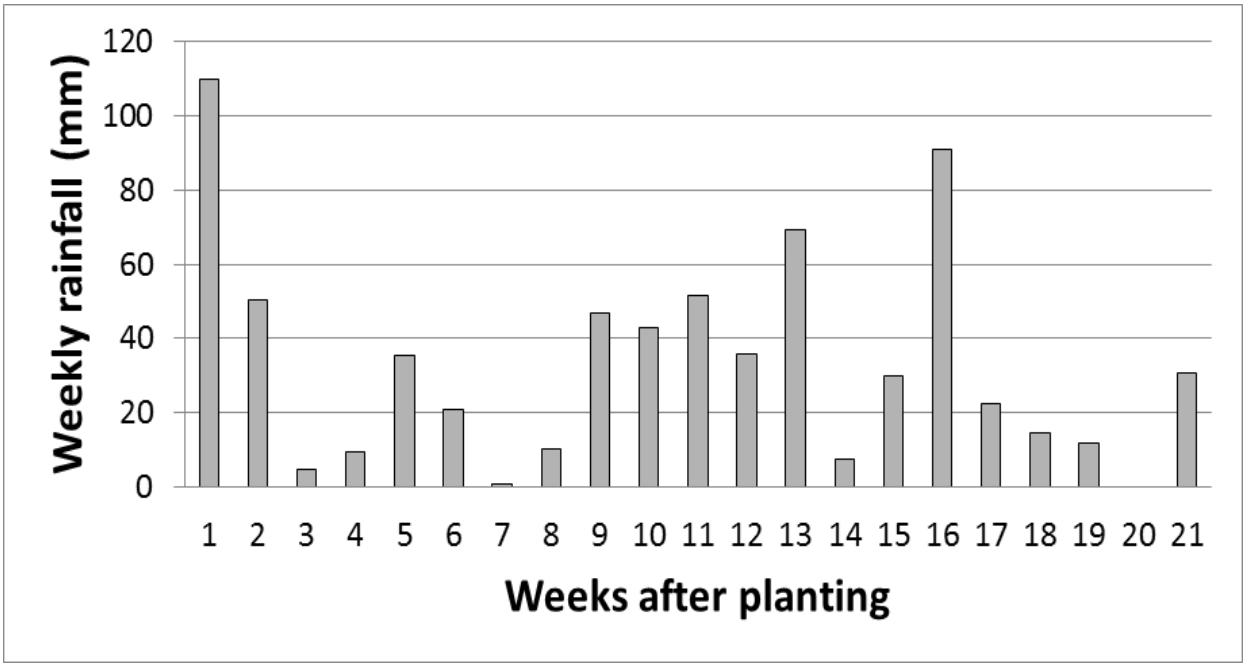

FIGURE 1: WEEKLY RAINFALL RECEIVED DURING THE PERIOD OF EXPERIMENT

3.2 Soil moisture suction

Conventional tillage (CNT) conserved the least moisture compared to all the other treatments as shown by the higher soil moisture suction in more or less all the periods (Table 2). The soil suction under CNT was significantly higher than all the treatments during period 1 ($P<0.05$), except for PLB. The moisture suction was measured during the 4th week after planting when cumulative rainfall of less than 15 mm had fallen within 14 days, and thus the moisture in the soil had been depleted. On the other hand, the soil suctions were lower and not significant different for all the treatments during periods 2, 3 and 9. These periods coincided with the weeks when there were high rainfalls and the soil moisture contents were high. The increases in soil moisture retention under conservation tillage were due to decreases in evaporation [21]. Similar results were found in an experiment for selected cowpea varieties where zero tillage conserved about 30% more moisture compared to conventional tillage [22].

TABLE 2
MEAN SOIL SUCTION FOR DIFFERENT PERIODS (P).

	Mean soil suction during different periods (Centibars)*								
Treatment	**P 1**	**P 2**	**P 3**	**P 4**	**P 5**	**P 6**	**P7**	**P 8**	**P 9**
JAB	18.3^{ab}	4.0	10	33.0^{abc}	3.7^{a}	13.0^{a}	23.0^{a}	27.7^{a}	4.0
TDDS	21.3^{cd}	2.7	8	25.7^{ade}	7.0^{b}	14.0^{b}	28.0	35.0	2.7
TDRDS	24.0^{efg}	2.7	9	15.0^{bdfg}	6.7^{c}	14.7	25.7	29.7	2.7
PLB	31.7^{aceg}	3.3	8.3	29.3^{fh}	4.3^{d}	17.3	25.3	30.3	3.0
CNT	33.7^{bdf}	4.7	8.7	45.0^{cegh}	13.7^{abcd}	20.7^{ab}	34.0^{a}	39.3^{a}	4.7

Parameters on same column with same symbol indicate that their means were significant different.

3.3 Maize performance parameters and yield

The maximum germination count was reached some 9 days after germination, with counts ranging from 83.3% (under TDDS) to 87.1% under JAB (Table 3). The differences in means germination counts were not significant ($p>0.05$) for all treatments at 9 days after planting. On the other hand, the germination counts were significantly higher ($p<0.05$) for treatment TDRDS compared to all the other treatments at 5 days and 7 days after planting. Emergence of seedling is influenced by moisture, aeration and degree of compaction of the soils. The tractor drawn ripper loosened the soil, thus making it easier for the seedlings to emerge. The clods above the seed were pulverized by the cultivator with small weight [23].

TABLE 3
MAIZE SEEDING EMERGENCE FOR DIFFERENT TREATMENTS

Treatment	**Seed emergence (%). ***		
	5 days after planting	**7 days after planting**	**9 days after planting**
JAB	56.1^{a}	68.5^{a}	87.1
TDDS	52.0^{b}	69.5^{b}	83.3
TDRDS	61.1^{abcd}	75.6^{abcd}	84.4
PLB	56.0^{c}	68.3^{c}	82.7
CNT	57.6^{c}	72.6^{d}	85.7

Parameters on same column with same symbol indicate that their means were significant different.

The maize plants were significantly higher for CNT compared to JAB, TDRDS and PLB ($p<0.05$) at 7 weeks after planting (Table 4). However the plants were higher for PLB at 9 weeks after planting. At 21 weeks after planting the plants for CNT were higher than in all the other treatments, but the difference in mean height were not significant ($p>0.05$). Similar results were observed in a study done in Turkey where plants under conventional tillage were higher than those under no till [24]. In a study done in Ghana there was no significance in difference for mean height between different tillage treatments, even though the shorted plant was found in the no tillage treatment [25]. The great plant height under conventional tillage may be attributed to better soil aeration and more uniform distribution of nutrients in soil profile [26].

TABLE 4
PLANT HEIGHT FOR DIFFERENT TREATMENTS

Treatment	**Plant height (cm). ***		
	7 weeks after planting	**9 weeks after planting**	**21weeks after planting**
JAB	109.7^{ab}	194.4^{abc}	260.3
TDDS	120.5^{aceg}	183.8^{adef}	265.4
TDRDS	112.1_{cdef}	179.4^{bdh}	248.0
PLB	111.7^{dgh}	208.2^{ehi}	266.0
CNT	122.0^{bfh}	193.8^{cfi}	268.5

Parameters on same column with same symbol indicate that their means were significant different.

Conventional tillage produced the highest total dry matter at 16.2 tons/ha, while PLB produced the least dry matter at 12.6 tons/ha (Table 5). The difference in mean dry matter production for the different treatments was not significant ($p>0.05$). On the other hand TDRDS had the highest mean grain yield, at 9.9 tons/ha. The lowest grain yield was realized under PLB

where the yield was 9.0 tons/ha. The difference in grain yield for all the treatments was not significant ($p>0.05$). Similar results were realized in Pakistan where the highest dry matter yield was harvested from plants grown under deep tillage, followed by the plants grown under conservation tillage, while the plants grown in zero tillage plots gave the lowest dry matter yield [27]. The same pattern was observed on grain production. A combination of mouldboard plough and disc plough produced the highest grain yield, and no-tillage produced the lowest grain yield in a study conducted in Iran [28].

TABLE 5
TOTAL DRY MATTER AND GRAIN YIELD FOR DIFFERENT TREATMENTS

Treatment	Total dry matter at harvest (tons/ha)	Grain yield (tons/ha)
JAB	14.5	9.1
TDDS	13.8	9.6
TDRDS	15.3	9.9
PLB	12.6	9.0
CNT	16.2	9.6

IV. CONCLUSIONS

The study examined the effect of tillage practices on moisture retention and maize performance under rainfed conditions. Based on the results it can be concluded that the farming season during which the experiment was undertaken received adequate rainfall, as the total received was within the range of rainwater requirement for maize crop. The rains were well spread, and there were no cases of long periods without effective rainfall. CNT conserved the least moisture, as reflected by the higher soil suction values. On the other hand JAB conserved the most moisture. The difference in seed emergence was not significant for the different treatments. However, more seed emergence under TDRDS during the first seven days after planting. It was followed by CNT. CNT produced the tallest plants at 21 days after planting, even though the differences in plant height were not significant. CNT produced the highest dry matter, and PLB produced the least dry matter. PLB also produced the least grain yield. TDRDS produced the highest grain yield, even though the difference in grain yield for the treatments was not significant.

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