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The Effect of Soil Management on the Availability of Soil Moisture and Maize Production in Dryland

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Abstract Objective of this study was to identify effects of soil management on the availability of soil moisture, growth and yield of maize. This study was carried out-under randomized complete block design, consisting four soil management treatments, which were grouped into six replications. The soil management treatments are P0M0 = control (no-tillage and no-straw mulch); P1M0 = soil tillage and no-straw mulch; P0M1 = no-tillage with straw mulch thickness of 10 cm; P1M1 = soil tillage with straw mulch thickness of 10 cm. Results showed that soil tillage with straw mulches could maintain the availability of soil moisture in the depth of 20 cm up to 60 cm, as well as provide a significant improvement of maize growth and grain yield.

Keywords Soil Management, Mulches, Soil Moisture, Soil Tillage

1. Introduction

The agricultural sector in the Jeneponto district is major source of livelihood with a great farming land potential. Data of BPS Jeneponto[23] showed that area of irrigated sawah covers 15,670.49 ha with rice planting twice a year, and drylands covers 42,669.92 ha, which is dominated by Vertisols and Ultisols. Drylands suggest a higher potential than the other lands in producing food products, it also produces other product such, as plantation like banana, coconut, cashew, kapok and animal husbandry like cow, horse, buffalo and goat.

Drylands farming is farming where the soil moisture becomes the limiting factor for the crop to grow and to produce in some parts of time in a year[29, 34]. Dryland management include soil and water conservation technologies, skills and resources to cope the availability of water in dry season, water surplus in rainy season, and for use of water available in management of sustainable agriculture[42]. The soil moisture to function as essential nutrient for plant life and soil organism, a nutrient solvent and nutrient transport, and as a soil temperatures buffer[74]. Water function as main component of plant protoplasm, solvents inorganic materials which will be distributed to parts of plants, as a reagent in photosynthesis process and hydrolytic processes in the decomposition of starch into glucose, as a stabilizer in cell turgor for the continuation of cell enlargement, as well plant temperature regulator[10, 38, 49,50].

Effort to maintain soil moisture can be made by mulches and soil tillage for evaporation rate controlling. Straw mulch in soil surface can reduce evapotranspiration, reducing air temperature and soil temperature[35, 40, 59, 77, 80]. Soil tillage increases soil porosity in the soil surface[47], increase water infiltration[60], increase root penetration[57], and improve soil aeration[12]. Soil tillage can storage more rain water[71]. Implementation mulch and soil tillage, effective for soil water use efficiency[7].

Research Lal[52] showed use of mulch increased average yield of 2,33 Mg ha^{-1} to 2,59 Mg ha^{-1} during first growing season, and from 0,69 Mg ha^{-1} to 0,79 Mg ha^{-1} during second cropping season. Mulches increased maize yield by 17%[44], straw mulch increased 52.11% higher than in control[67], 60,5% higher than in control[20], increase maize yield and biomass 0,24 t ha^{-1} and 1,57 t ha^{-1}[79]. Interaction of soil tillage and straw mulch improve soil porosity[85]. Soil tillage increased porosity and decrease soil bulk density[15]. Soil tillage increases the cob weight of maize and grain yield compared to no-tillage[5].

The availability of improving of ground water through conservation technique can be a solution in dryland farming, selection of conservation provides an opportunity to increase production in the dryland. This study was aimed to identify effects of soil management on the availability of soil moisture, growth, and yield of maize.

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2. Methods

This research was carried out in the regency of Jeneponto, South Sulawesi. Geographically located between in 5°23'12" – 5°42'1,2" south and 119°29'12'' – 119°56'44,9" east[24]. Research locations was in kecamatan Bangkala Barat Kelurahan Bulu Jaya. The research was carried out from May 2011 to September 2011. The soil sample analysis was carried out in the Laboratory of Soil Department Agricultural Faculty of Hasanuddin University and Laboratory of Soil Department, Agricultural Faculty Brawijaya University (Table 1). The soil on the research location was dominated by vertisols[23].

This experiment was carried out-under randomized complete block design, consisting four soil management treatments, which were grouped into six replications. The management treatments are P0M0 = control (no-tillage and no-straw mulch), P1M0 = soil tillage and no-straw mulch, P0M1 = no-tillage with straw mulch thickness of 10 cm dan P1M1 = soil tillage with straw mulch thickness of 10 cm.

Table 1. Parameter, method, and time of observation

Parameter	Method	Observation Time
Soil moisture in rooting zone	Gravimetric[2]	Planting, vegetative phase, generative phase, harvesting
Rain water addition	Ombrometer[68]	During the rain
Root penetrating resistance	Penetrometer DAIKI[51]	During vegetative phase
Crop height	Measured from the lowest trunk to the growing point[81]	Every ten days
Number of leaf	Only on leaf perfectly opened which was measured[81]	Every ten days
Weight of dry matter	All produced dry matter which was measured[81]	Harvesting
Weight of maize cob	Weighing produced maize cob[81]	Harvesting
Weight of maize kernel	Weighing produced maize cob and kernel[81]	Harvesting

To see effect treatments which had been done, result of observations carried out analyzes of variance. To evaluate differences between treatments performed Tukey Test ($\alpha = 0.05$)[37].

3. Results and Discussions

3.1. Availability of Soil Moisture

Soil moisture conditions at each soil depth is presented in Figure 1. Soil moisture was observed on the depth of 10 cm, 20 cm, 30 cm, 40 cm, 50 cm, and 60 cm. Different soil managements affect soil water storage[39]. Soil moisture are also affected by soil texture[33], soil porosity[62, 78] and soil bulk density[78].

Based on the soil sample analysis, greater bulk density with increasing soil depth, porosity decreases with soil depth. This causes soil moisture at the depth of 30-60 cm relatively constant. In contrast to the depth of 10-30 cm, due to soil tillage[32, 65] and mulching application[54], soil bulk density getting lower but soil porosity increase. Soil tillage increased soil evaporation and induced the soil surface to become dry[39]. Reducing soil tillage causes soil water storage increases[61].

The availability of soil moisture in every growth stages of the maize would improve growth and yield of maize. When the maize entered flowering time, the crop experienced moisture stress, especially on the control and non mulches treatments. The most decreasing yield of maize occurred whenever the crops were lacking of water during the flowering period[9, 21, 53, 58].

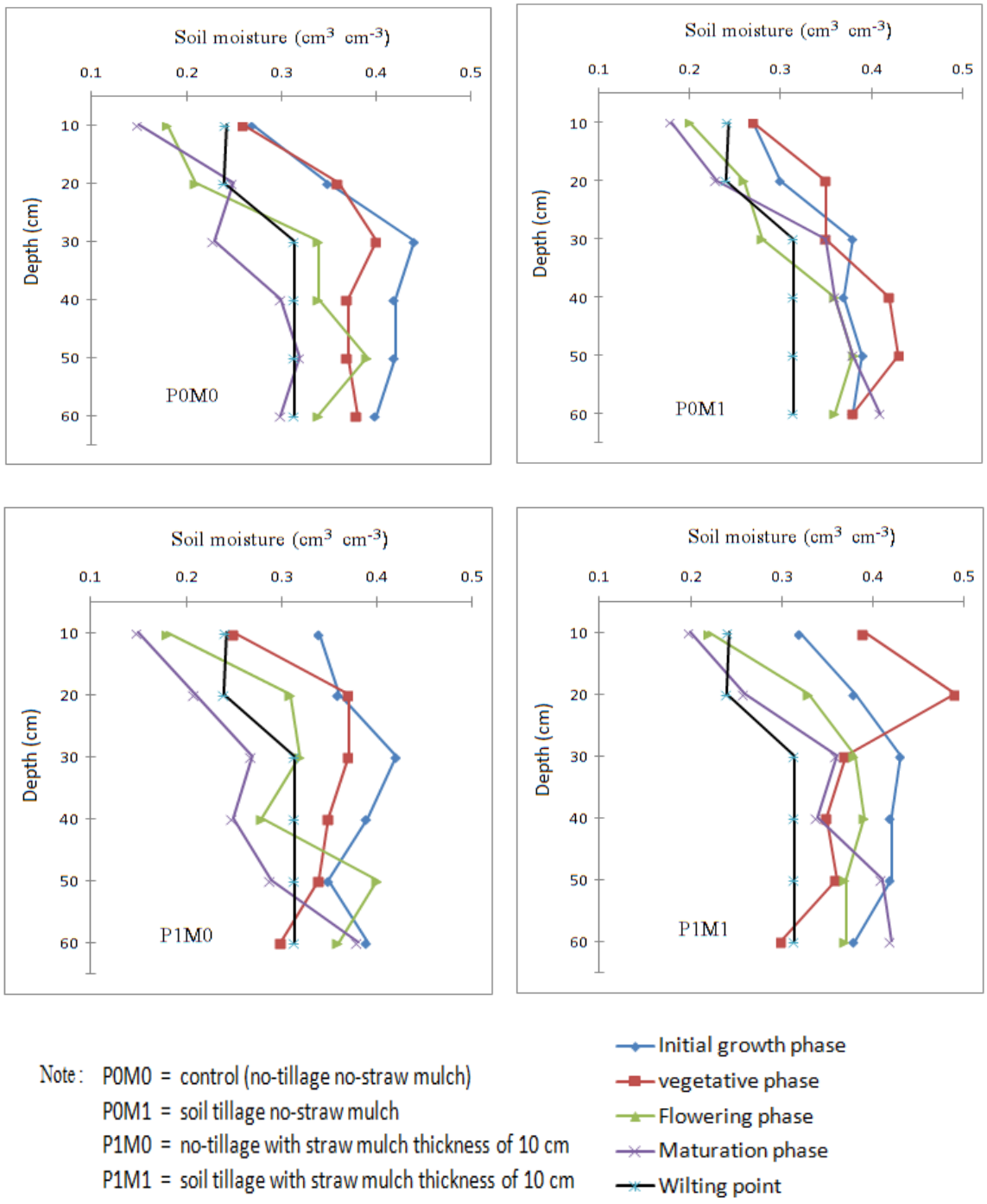

Figure 1. Soil moisture at the different soil management treatments during the maize growing season

3.2. Soil Retention

Penetrometer retention is often used as an indicator of soil resistance to root extension[36]. Soil retention reflects the easy or difficulty the soil penetrated by plant roots[51].

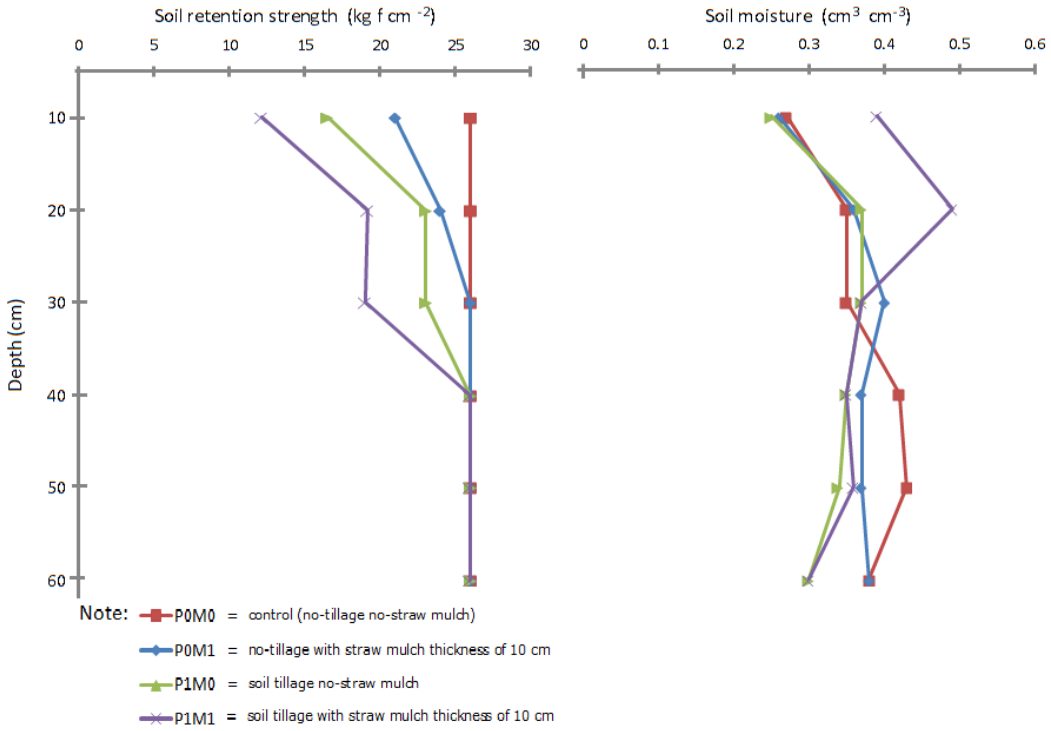

Figure 2. Soil retention and the moisture at the vegetative phase of maize

Figure 2 showed the soil retention is increases with along depth, although soil moisture is still available in the depth that. In the vegetative phase, the soil retention has reached more than 12 kg cm^{-2}. The penetration retention associated with root ability to penetrate the soil for get water and nutrients[88].

There are differences in soil retention between each soil management treatments, of which 25 kg f cm^{-2} is the highest value limit penetromener. Soil tillage, soil tillage with straw mulch thickness of 10 cm showed strength at 0-30 cm respectively from 16,5-23 kgf cm^{-2} and 12,17-19 kgf cm^{-2} lower than in the no-tillage 21-26 kgf cm^{-2}. Soil retention at a depth of 40-60 cm the same for all treatments, this is because soil tillage is only reached a depth of 30 cm. Soil tillage causes soil resistance is lower than in the no-tillage[6, 63]. Soil tillage make soil crumb thereby increasing soil porosity[65]. Elder and Lal[32] stated that soil porosity greater at soil tillage. Different pore sizes affect infiltration and soil penetration strength[46]. Soil with high porosity has a lower soil retention[25]. Straw mulch can reduce soil bulk density and increases soil porosity[54]. Mulching lowering soil strength on soil tillage to 7,29 kgf cm^{-2} and mulch to 4,73 kgf cm^{-2} – 5,9 kgf cm^{-2}[65]. The penetrometer resistance which was more than 16,3 kgf cm^{-2}[82], 20,39 kgf cm^{-2}[19], soil strength over 8.16 kgf cm-2 can slow root extension[17]. Plants root development is impeded when the soil resistance force of more than 12 – 15 kg cm^{-2}, for maize the maximum root penetration is 11–13 kg cm^{-2} and palawija between 5 – 8 kg cm^{-2}[83].

The control treatment, even though the soil moisture availability was sufficient on the depth of 10-60 cm, due the soil retention was high, then roots are constrained to explore the soil deeper. Growth and root elongation is limited by the soil strength[18]. The depth of root system had an effective impact on the taking water and nutrients from the deeper soil[57]. According to Mackill[55] the root mechanism to drought stress is magnitude root penetration at hard soil layers increase the absorption of water in the soil deeper layers.

The soil moisture availability on the control treatment is caused by the presence of crust which functions as mulch. On the soil with high clay, like vertisol, there is generally crust on the soil surface which acts as a mulch. Results of research by Schwartz[76] stated that a crust on the soil surface can reduce gas diffusion so that suppress evaporation.

Treatment soil tillage with mulch could reduce the soil retention. It enabled the root to penetrate deeper to get water and nutrients. Mulching reduces soil strength due to increased soil moisture[84]. Soil tillage improves soil quality through reduced soil strength[31]. Soil tillage increased the pore space on the soil surface which was just worked on, even though the infiltration amount would get lower over time[47].

3.3. Crop Growth and Production

Height of crop and number of leaf are presented in Table 2, and yield outcome are presented in Table 3.

The result of the research showed that the best height crop and number of leaf were obtained on soil tillage with mulch treatment, and statistically different from control treatment. This is because soil tillage can increase water infiltration and improve soil air arrangement, so the crop can grow well[87]. It was also supported by straw mulch

that could reduce evapotranspiration, lower the air and soil temperature, so moisture was available more for crops[40].

Table 2. The loss of moisture, height of crop, and number of leaf at the end of the research

Treatments	Moisture usage (mm)	Crop height (cm)	Number of leaf (strand)
P0M0	203.32	38.9 a	5.0 a
P0M1	223.35	120.1 b	8.6 bc
P1M0	222.35	118.1 b	7.5 b
P1M1	231.80	127.4 b	9.6 c
LSD 5 %		19.21*	1.83*

Note: * Number which is followed by different letter is significantly different (p=0.05)

The control treatment, the maize growth impeded suspected due root was unable to penetrate the soil to get water, so the crop experienced water stress. The growth parameter and maize yield components significantly reduced due to soil moisture deficits and delayed flowering due to water stress[1]. Pirdashti[66] reported that water stress at the vegetative phase of rice significantly reduced plant height.

The research result of soil tillage and mulch on the yield and the weight of dry matter are shown in Table 3.

Table 3. Weight of kernel+cob, kernel and dry matter

Treatments	Kernel+cob (kg ha^{-1})	Kernel (kg ha^{-1})	Dry matter (kg ha^{-1})
P0M0	1057.00 a	837.50 a	2218.50 a
P0M1	7754.00 b	5981.00 b	5582.00 ab
P1M0	5768.33 b	4755.50 b	4988.33 ab
P1M1	9148.50 b	6074.33 b	7194.83 b
LSD 5%	3537.85*	2806.26*	3881.16*

Note: * Number which is followed by different letter is significantly different (p=0.05)

Statistically, treatments which were being tried were significantly different from the control. The highest weight of kernel+cob, kernel and dry matter was on treatment soil tillage with mulch, statistically it was significantly different from the control treatment. The production increase on tillage with mulch reached 80% compared to control treatments. A research which was carried out by Sharma[77] showed that the use of legume mulch caused an impact on the productivity of maize for 5,6-8,8% compared to treatment without mulch. Mulching or the use of lines with mulch increased the production of maize significantly[43]. An increase on peanut production of 18% happened with 5 tons ha^{-1} of mulch[71], use straw mulch of 5 ton ha^{-1} increased soybean production for 153%[4], production increase of 26-36%[16] increase on plum of 9.33 ton ha^{-1} with the control yield of 4.1 ton ha^{-1}[70].

The addition of mulch is one way of overcoming drought because the mulch can reduce the rate of evapotranspiration, water usage efficiency, soil water conservation, reduce evaporation and run off, supply organic materials, maintain soil aggregation and soil porosity, and weed control[8, 14, 16, 28, 72, 75]. The maximum soil temperature under straw mulch on the depth of 5 cm is 10^{o}C lower, and the minimum temperature is 1.9^{o}C higher than on soil without mulch[56, 73].

Statistically, treatment mulch and soil tillage treatment were not significantly different from tillage with mulch treatment, but the growth was not as good as soil tillage with mulch due to the limited ability of root in obtaining water and nutrient in the deepest soil layer. This was mainly happen on the vegetative phase when the crop needs high of water and nutrient. According to Aqil[9], the decrease of maize production happens when the crops experience water stress in flowering phase and during pollination period.

Combination of soil tillage and mulching shows a better production because mulch can reduce evaporation[40], while tillage increases infiltration of rainwater and reduce of soil retention[31]. Ar-Riza[11], stated that mulching and minimum soil tillage can create a good soil condition for improve aeration and decrease soil density. In dryland area, shallow soil tillage can help the growth of plants so that reduce the risk caused by dry season[86]. Tillage increased yield 36% greater than the no-tillage[31]. During dry season, soil tillage could double the production compared to treatment no-tillage[30]. Soil tillage tends to increase yield, but it needs more worker[16].

3.4. Production and Soil Moisture Absorption

The response of production of crops toward soil moisture is shown on Figure 3. Almost every plant processes affected directly and indirectly by the availability of water in the soil[50]. Water deficit causes a decrease in maize yield potential of 50-60%[13], decrease of 40% when water deficit in the flowering phase[26], yield decrease of 40% in tasselling phase and yield decrease of 66-93% when water deficit in ear formation[27].

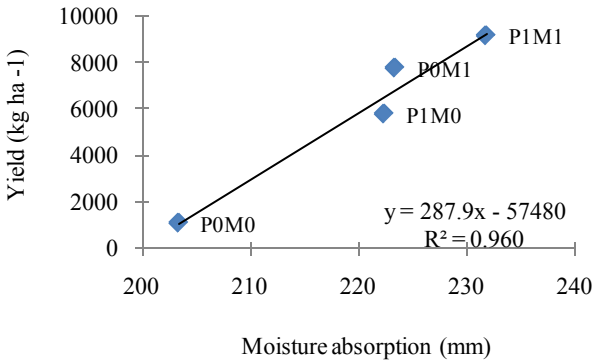

Figure 3. relation between soil moisture absorption and maize grain yield

Linear relationship between absorption of soil moisture by results significant at p = 5%, increase of soil moisture is absorbed by 1 mm can increase yield 287.97 kg. Water absorption by maize can increase grain yield, this is in line with research by Kang[45] which showed there was an increase of maize of 51,19 kg ha^{-1} each 1 mm of water absorption, increased yield 42,6 kg ha^{-1} each 1 mm of water absorption[89], increased yield 6,4 kg ha^{-1} each 1 mm of

water absorption[3], increased yield 31,05 kg ha^{-1} each 1 mm of water absorption[22], increased yield 16,6 t ha^{-1} each 1 mm of water absorption[64]. Research Prijono[69] showed there was an increase of mungbean yield of 13 to 27% from average. Increased yield of mungbean for 5 kg ha^{-1} mm^{-1}[48], an increase on mungbean yield of 100 kg ha^{-1} if there is an increase of root distribution in the depth of 7-13 cm[41].

4. Conclusions

Application of straw mulches and soil tillage can maintain the availability of soil moisture at a depth of 20 cm to 60 cm, reducing soil retention strength during the vegetative stage up to 10-30%, and improve crop growth and grain yield of maize.

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