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EFFECT OF LEGUMES LIVING MULCHES ON SOIL MOISTURE, WEED INFESTATION, GROWTH AND YIELD OF MAIZE (ZEA MAYS L.) DURING DRY SEASON

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Abstract

The experiment was conducted at the field of Department of Agronomy, Yezin Agricultural University, Myanmar to study the effect of green gram and cowpea living mulches on soil moisture, weed infestation, growth, and yield of maize, and to select the suitable living mulch in maize cultivation during dry season. The experiment was conducted by using randomized complete block design (RCB) with three replications. A total of seven treatments were comprised of control (no mulch) (T1), maize: green gram (1:1) (T2), maize: green gram (1:2) (T3), maize: green gram (1:3) (T4), maize: cowpea (1:1) (T5), maize: cowpea (1:2) (T6) and maize: cowpea (1:3) (T7). Soil moisture content and weed infestation were significantly different among the treatments. The maximum weed infestation was recorded from T1 (no mulch) at all sampling times. The minimum weed infestation was observed from maize: cowpea (1:2) (T6) followed by maize: cowpea (1:3) (T7) at 20 DAS and 80 DAS. At 40 DAS and 60 DAS, the minimum weed infestation was found in T7 followed by T6. In addition, the maximum weed control efficiency was found in T6 at 20 DAS and T7 followed by T6 at 40 DAS. The highest leaf area index was attained from T6 at maximum vegetative growth stage. The maximum crop growth rate was observed from maize: green gram (1:2) (T3) and maize: green gram (1:3) (T4) from vegetative growth stage to grain filling stage. However, the maximum grain yield was recorded from maize: cowpea ((1:2) (T6). According to the results, maize: cowpea ((1:2) (T6) is suitable for maize cultivation during dry season of the study area.

Keywords: cowpea, green gram, living mulches, maize, maize yield

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Introduction

Maize is a heavy nutrient feeder with adequate water requirement for growth especially from vegetative through flowering and grain filling stages (Dugje et al., 2014). Nowadays, climate change effects on maize production, food security and livelihoods of smallholder farmers in most of the developing countries. One of the climate smart agriculture practices, mulching can enhance agricultural production by alleviating adverse climate effects on maize productivity through improved soil moisture storage, water use efficiency, increased soil carbon and nutrient supply with the long-term resilience to climate change (Zizinga et al., 2022).

Mulch can be any material placed on the soil surface to avoid erosion, reduce weed growth, obtainable soil moisture (Awe, Reichert, Timm & Walter, 2014) and soil temperature both of which effect plant growth and yield and compensates for water limits, low temperatures (Lithourgidis, Dordas, Damalas & Vlachostergios, 2011). Moreover, mulches used as cover crops and live crops grown in between the rows of main crop provide different benefits in agro-ecologies through competition such as nitrogen fixation, erosion control, improving organic matter, nutrient recycling, pest and weed control, and improving soil organism (Khan et al., 2021). Legumes used in mulching practices like living mulches have the potential to form an important component in agro-ecosystems and can be a useful tool for weed suppression in sustainable agricultural systems with useful advantages such as improvement of soil structure, regulation of soil water content, reducing soil erosion, soil enrichment by nitrogen fixation (Kruidhof, Bastiaans & Kropff, 2008). Living mulches can be important for use as an ecological strategy to control weeds (Kestutis et al., 2012)

However, living mulches compete for nutrients and water with the main crop and this can reduce yields (Uchino, Iwama, Jitsuyama, Yudate & Nakamura, 2009). As a result, they may need to be mechanically or chemically killed (Kestutis et al., 2012). Despite the importance of living mulch in improving soil properties, there are contradictory reports in the literature on the effect of living mulches on the grain yield of main crops. Some studies have reported a decreased or no difference in the yield of main crops (Radicetti et al., 2018). Others have also reported an increase in crop yields (Bhaskar, Bellinder, DiTommaso & Walter, 2018). Moreover, quantitative data is also limited on the effect of legume living mulch on maize grain yield in Myanmar. Therefore, this experiment was carried out with the following objectives.

Objectives

1. To study the effect of green gram and cowpea living mulches on soil moisture, weed infestation, growth and yield of maize
2. To select the suitable living mulch in maize cultivation during dry season

Materials and methods

Experimental sites and design

The experiment was conducted at the field of Department of Agronomy, Yezin Agricultural University (YAU) in Myanmar during 2023-2024 dry season (from October 2023 to February 2024). The soil type of study area was loamy sand. The experimental area was (1075) m^2. Individual plot size was 7 m x 5 m with 1 m distance between plots. Spacing of maize was 75 cm × 23 cm. The maize variety, CP 808 was used as the tested variety. The experiment was carried out in a Randomized Complete Block Design with three replications. Green gram and cowpea were used as living mulches. There were seven treatments: control (no mulch) (T1), maize: green gram (1:1) (T2), maize: green gram (1:2) (T3), maize: green gram (1:3) (T4), maize: cowpea (1:1) (T5), maize: cowpea (1:2) (T6) and maize: cowpea (1:3) (T7). Living mulches was sown drilling between maize rows after maize sowing on same day. Living mulch was applied with the seed rate of 10 kg ha^{-1} for each plot. To minimize competition of maize and living mulches for resource utilization during the crop development period, living mulches were cut 4 times based on plant height of living mulch with the average height was over 30 cm. They were cut by leaving 10-15 cm from the ground level. After cutting, the green masses of legume living mulches were covered between maize rows.

Crop management

Land was prepared by two ploughing, two harrowing and leveling. According to the guidelines of Department of Agricultural Research (DAR), as basal, the fertilizer was applied with the rate of 56.81 kg N ha^{-1}, 55.58 kg P_2O_5 ha^{-1} and 37.05 kg K_2O ha^{-1}. At 20 days and 40 days after sowing of maize, 28.41 kg N ha^{-1} and 18.53 kg K_2O ha^{-1} were applied as top dressings. Pesticides were sprayed 5 times as necessary throughout the growing season of crop.

Data collection

The soil moisture content was measured at 1 DAI (days after irrigation), 3 DAI, 7 DAI and 14 DAI intervals in every irrigation time.

Weed infestation was measured at 20 days after sowing (DAS), 40 DAS, 60 DAS and 80 DAS by placing 1 m^2 quadrats randomly twice in the middle of each plot along the diagonal. To determine weed infestation, the weeds were pulled out from each 1 m^2 quadrats, and then counted and determined weed density and weed dry weight. After that, the collected weeds were oven dried at 70°C for 72 hours to obtain total weed weight as weed dry weight (gm^{-2}) (Demjanova et al., 2009). The plots of all treatments were weeded out twice at 20 DAS and 40 DAS after counting weed infestation to avoid crop failure.

Weed control efficiency (WCE) was also determined by formula, Amare, Sharma & Zewdie (2014):

$$\mathrm{WCE} = \frac{\mathrm{WDC} - \mathrm{WDT}}{\mathrm{WDC}} \times 100$$

Where: WCE = Weed control efficiency, WDC = Weeds dry mass from control plot (untreated), WDT = Weeds dry mass from treated plot

Plant height was measured from randomly selected and marked five plants in each plot at ten days intervals starting from 21 days after sowing (DAS) to 71 DAS. The nine plants virtually with the same size were marked, and from three of those selected plants, the leaves area was measured at maximum growth stage, the next three plants at tasseling stage and the last three plants at grain filling stage. And then, the leaves were dried and measured for their dry weight. Leaf area index was calculated by the formula described by Watson (1956). Crop growth rate was measured in $gm^{-2}day^{-1}$ by the formula, Hunt (1978).

$$\text{Lead area index (LAI)} = \frac{\text{Sum of the leaf area of all leaves (cm}^2\text{)}}{\text{Ground area of field where the leaves have been collected (cm}^2\text{)}}$$

(Watson, 1956)

$$\text{Crop growth rate (CGR)} = \frac{\text{Total dry matter at second sampling} - \text{Total dry matter at first sampling}}{\text{Time between second and first sampling} \times \text{Ground area}}$$

(Hunt, 1978)

Yield of maize was measured from harvest area at the center of each plot. Then, the total grain yield from each plot was weight and converted to ton ha^{-1}.

$$\text{Grain yield (ton ha}^{-1}\text{)} = \frac{(100 - \text{moisture})(\text{Field weight (kg)} \times \text{shelling} \times 10000\ \text{m}^2)}{85 \times \text{harvested area (m}^2\text{)} \times 1000}$$

(Centro International De Mejoramiento De Maiz Y Trigo [CIMMYT], 1985)

Where, 85 = adjusted factor of grain moisture to 15%

10,000 sq. meter = conversion factor to an area of one hectare of a plot

Shelling % was measured from seed dry weight adjusted at 15% moisture and ear dry weight described by the formula.

$$\text{Shelling \%} = \frac{\text{Seed dry weight}}{\text{Ear dry weight}} \times 100$$

(CIMMYT, 1985)

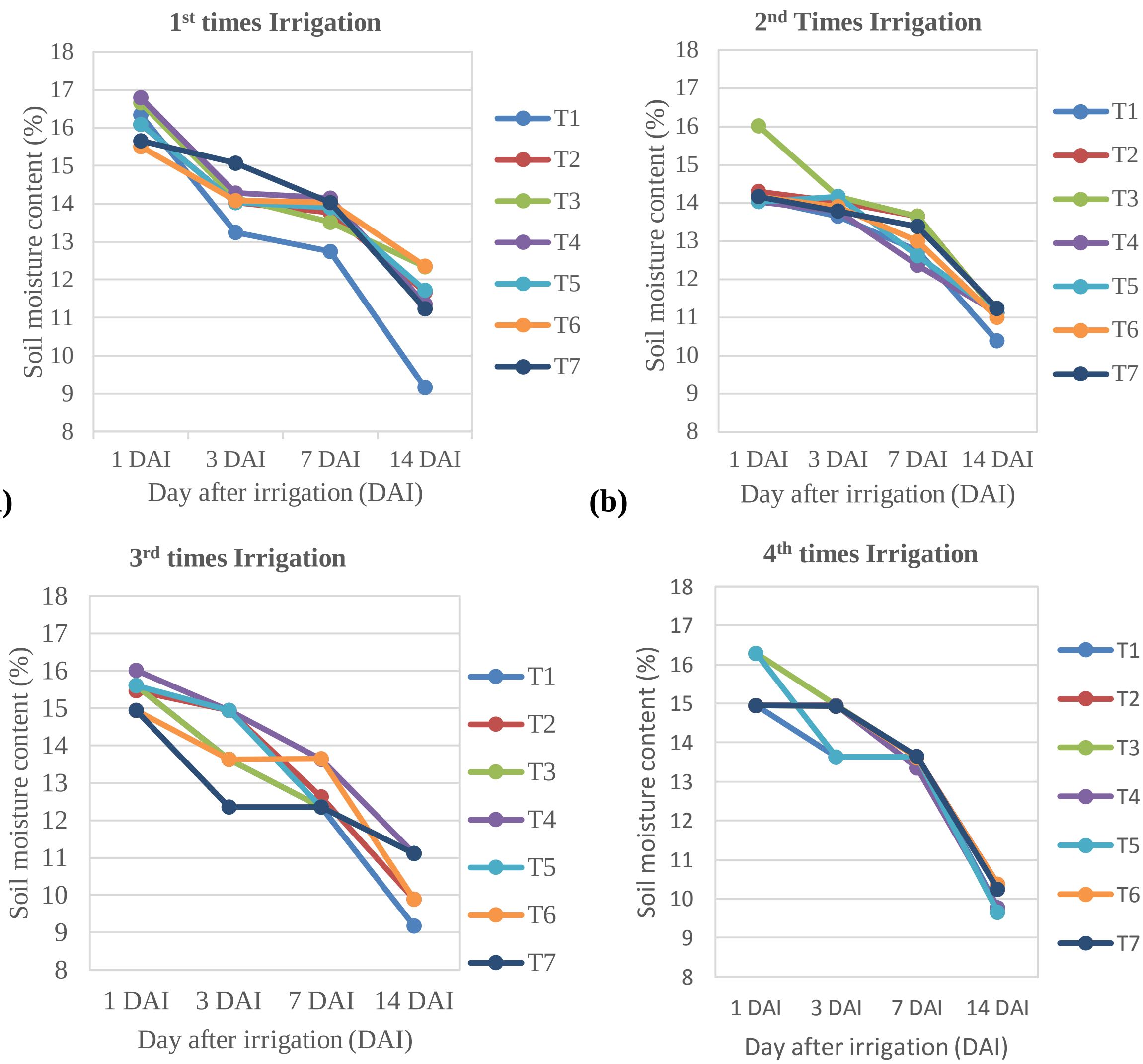
Data analysis

The data were analyzed for analysis of variance (ANOVA) by using Statistix (version 8.0) and treatment means were compared at 5% level of least significant difference (LSD) test (Gomez & Gomez, 1984).

Results and Discussion

Soil moisture

The soil moisture content was measured at 1 DAI (days after irrigation), 3 DAI, 7 DAI and 14 DAI intervals after every irrigation time (Figure 1). There was significantly different in soil moisture content among the different living mulches at first times irrigation of 14 DAI. The minimum soil moisture content was obtained from control (9.17%) and the maximum soil moisture content was found in T6 (12.36%) followed by T3 (12.35%). However, at second- and third-times irrigation, there was significantly different at 7 DAI among the treatments. At fourth times irrigation, there were significantly different at all sampling times. The minimum soil moisture content was recorded from T3 and T5 followed by T1 and T4. The maximum soil moisture content was observed from T6 followed by T7. However, living mulches could not retain soil moisture significantly after 3 DAI. Because the living mulches could not cover the soil surface due to the poor growth and development of living mulches during dry season.



T1 = control (no mulch), T2 = maize: green gram (1:1), T3 = maize: green gram (1:2),
T4 = maize: green gram (1:3), T5 = maize: cowpea (1:1), T6 = maize: cowpea (1:2),
T7 = maize: cowpea (1:3)

Figure 1. Soil moisture content as affected by legume living mulches in maize at Yezin during dry season

Weed density

There was significantly different in weed density among the different living mulches at 40 DAS (days after sowing), 60 DAS and 80 DAS (Table 1). The minimum weed density was observed from control at all sampling times and the maximum weed density was found in T7 followed by T6 and T4 at 40 DAS, in T4 followed by T7 and T6 at 60 DAS and in T7 followed by

T6 and T3 at 80 DAS respectively. Broughton (2010) reported that the addition of living mulches is a viable method for weed suppression.

Table 1. Weed density as affected by living mulches in Yezin during dry season

Treatments	Weed density (units m^{-2})			
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**
T1 (Control, no mulch)	463.67	207.17 a	203.67 a	138.50 a
T2 (Maize 1: Green Gram 1)	366.33	108.33 b	105.33 b	89.17 b
T3 (Maize 1: Green Gram 2)	371.67	96.83 bc	59.67 c	59.83 c
T4 (Maize 1: Green Gram 3)	363.67	88.83 c	51.17 c	68.67 bc
T5 (Maize 1: Cowpea 1)	389.50	95.17 bc	99.99 b	72.50 bc
T6 (Maize 1: Cowpea 2)	343.67	83.50 c	54.33 c	55.00 c
T7 (Maize 1: Cowpea 3)	363.50	83.00 c	52.33 c	50.33 c
$LSD_{0.05}$	135.33	17.07	26.83	26.43
Pr>F	ns	**	**	**
CV%	20	8.81	16.85	19.48

* and **: significant at 5 and 1 % level, ns = no significant

Weed dry weight

Weed dry weight was significantly different among the different living mulches at all sampling times (Table 2). The minimum weed dry weight was observed from T6 followed by T7 at 20 DAS and 80 DAS. At 40 DAS and 60 DAS, the minimum weed dry weight was found in T7 followed by T6. The maximum weed dry weight was recorded from T1 at all sampling times. As a results, living mulches' green masses may cover ground to suppress the weeds. Teasdale (1998) stated that living mulches that provide dense ground cover early in the growing season can prevent weed establishment.

Table 2. Weed dry weight as affected by living mulches in Yezin during dry season

Treatments	Weed dry weight (gm^{-2})			
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**
T1 (Control, no mulch)	47.18 a	25.25 a	28.17 a	11.08 a
T2 (Maize 1: Green Gram 1)	24.58 b	19.97 b	14.05 b	5.25 f
T3 (Maize 1: Green Gram 2)	22.81 b	12.41 cd	6.75 c	6.17 c
T4 (Maize 1: Green Gram 3)	22.43 b	11.25 cde	6.21 c	6.08 d
T5 (Maize 1: Cowpea 1)	26.38 b	14.99 c	12.84 b	8.83 b
T6 (Maize 1: Cowpea 2)	16.64 b	8.74 de	6.47 c	3.08 g
T7 (Maize 1: Cowpea 3)	20.96 b	7.63 e	6.10 c	5.42 e
$LSD_{0.05}$	14.16	3.81	2.95	0.05
Pr>F	*	**	**	**
CV%	30.78	14.94	14.41	0.46

Weed control efficiency

Weed control efficiency were highly significant different among the treatments at all sampling times (Table 3). The minimum weed control efficiency was observed in T5 at 20 DAS and 80 DAS and in T2 at 40 DAS and 60 DAS. The maximum weed control efficiency was found in T6 at 20 DAS. After that, the higher weed control efficiency was found in T7 followed by T6 at 40 DAS and followed by T4 at 60 DAS. At 80 DAS, the highest weed control efficiency was given from T6. Living mulches may suppress weeds by competing for water, light, and nutrients. Living mulches have provided excellent control without adversely affecting the yield of corn, soybean, summer squash, spring cabbage, tomatoes, and snap bean (Ilnicki & Enache, 1992).

Table 3. Weed control efficiency as affected by living mulches in Yezin during dry season

Treatments	Weed Control Efficiency (%)			
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**
T1 (Control, no mulch)	0.00 b	0.00 e	0.00 c	0.00 g
T2 (Maize 1: Green Gram 1)	44.69 a	20.77 d	50.01 b	52.63 b
T3 (Maize 1: Green Gram 2)	46.40 a	50.97 bc	76.13 a	44.36 e
T4 (Maize 1: Green Gram 3)	49.50 a	55.76 ab	78.15 a	45.11 d
T5 (Maize 1: Cowpea 1)	38.83 a	40.35 c	54.22 b	20.30 f
T6 (Maize 1: Cowpea 2)	61.73 a	65.19 ab	77.16 a	72.18 a
T7 (Maize 1: Cowpea 3)	49.38 a	70.17 a	78.49 a	51.13 c
$LSD_{0.05}$	24.64	15.26	0.46	6.62
Pr>F	**	**	**	**
CV%	33.38	19.80	0.64	6.29

* and **: significant at 5 and 1 % level, ns = no significant

Plant height

In all mulches, plant heights increased continuously from 21 DAS to 71 DAS (Figure 2). Plant heights were not significantly different among the treatments. However, the maximum plant height was achieved from T5 at data collected times except at 51 DAS. The minimum plant height was from T7 at 21 DAS, T4 at 31 DAS, T3 at 41, 51 and 61 DAS and T4 at 71 DAS respectively. This may be the ratio of green gram may be the highest competition with the maize. Therefore, the lowest plant height was found in T4 (maize 1: green gram 3).

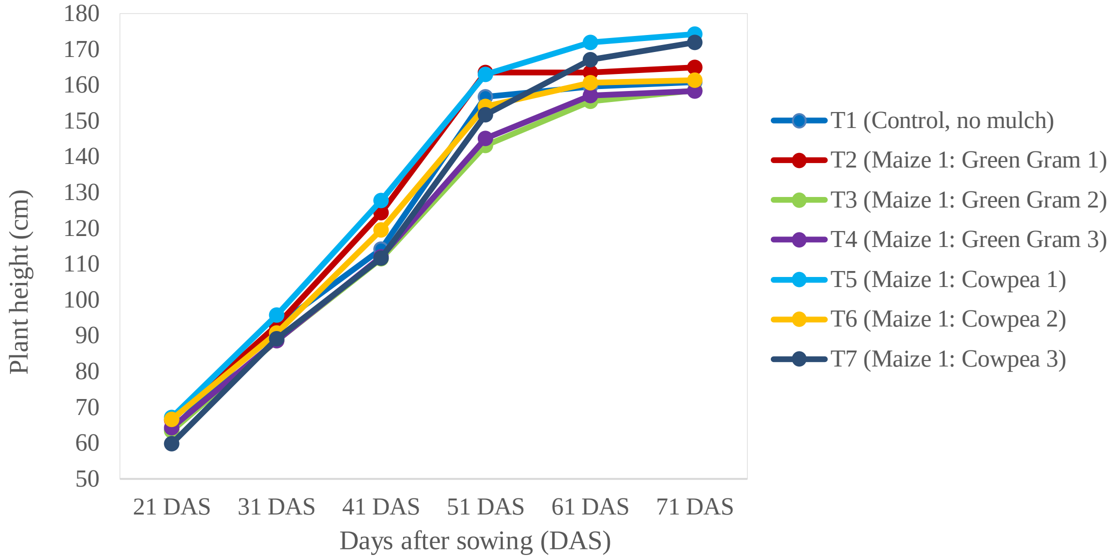


Figure 2. Mean plant height of maize as affected by living mulches in Yezin during dry season

Leaf area index (LAI)

The LAI value of maize at all living mulches treatments was not significantly different at all sampling times (Figure 3). At maximum vegetative growth stage, the maximum LAI value was recorded in T6 while the minimum LAI value was obtained from T4. After that, the maximum LAI value was obtained from T3 followed by T5 at tasseling stage and grain filling stage whereas the minimum LAI value was obtained from T4 and T7.

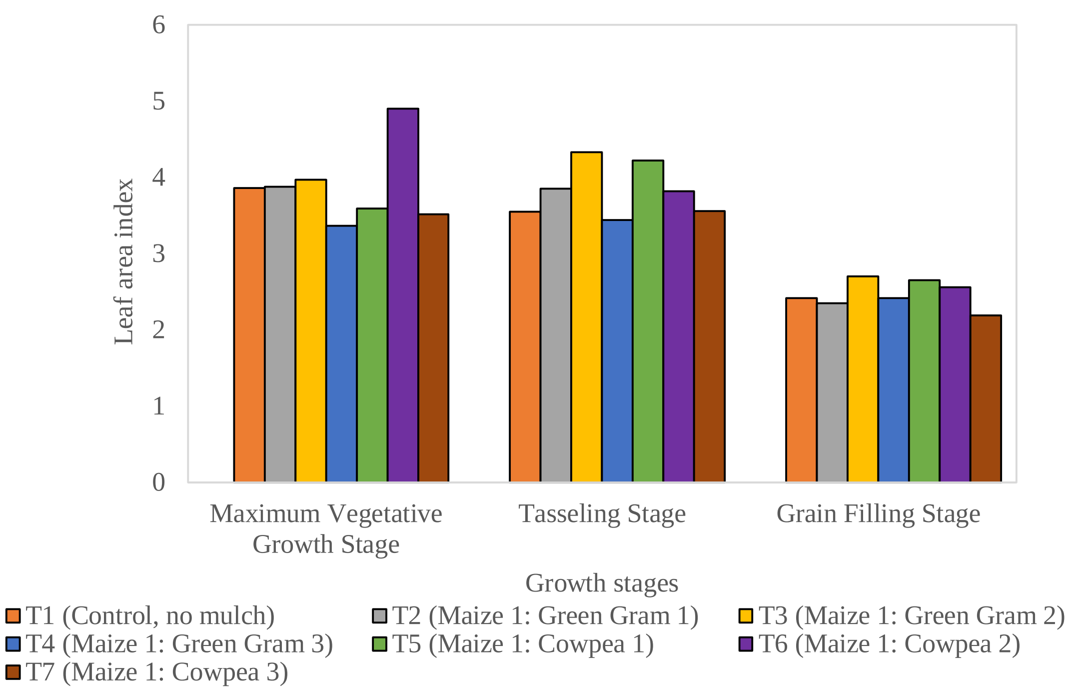


Figure 3. Leaf area index of maize as affected by living mulches during dry season

Crop growth rate (CGR)

Crop growth rate (CGR) was significantly different among different living mulches (Figure 4). The highest CGR value was observed from T3 with mean value of (43.25 $gm^{-2}day^{-1}$) followed by T1, T6, T5 and T4 from maximum vegetative growth stage to tasseling stage. The minimum CGR was obtained from T4. From tasseling stage to grain filling stage, the better CGR (32.39 $gm^{-2}day^{-1}$) was observed from T4 followed by T7, T6 and T5 respectively whereas the least CGR value (16.94 $gm^{-2}day^{-1}$) was recorded in no mulch (T1).

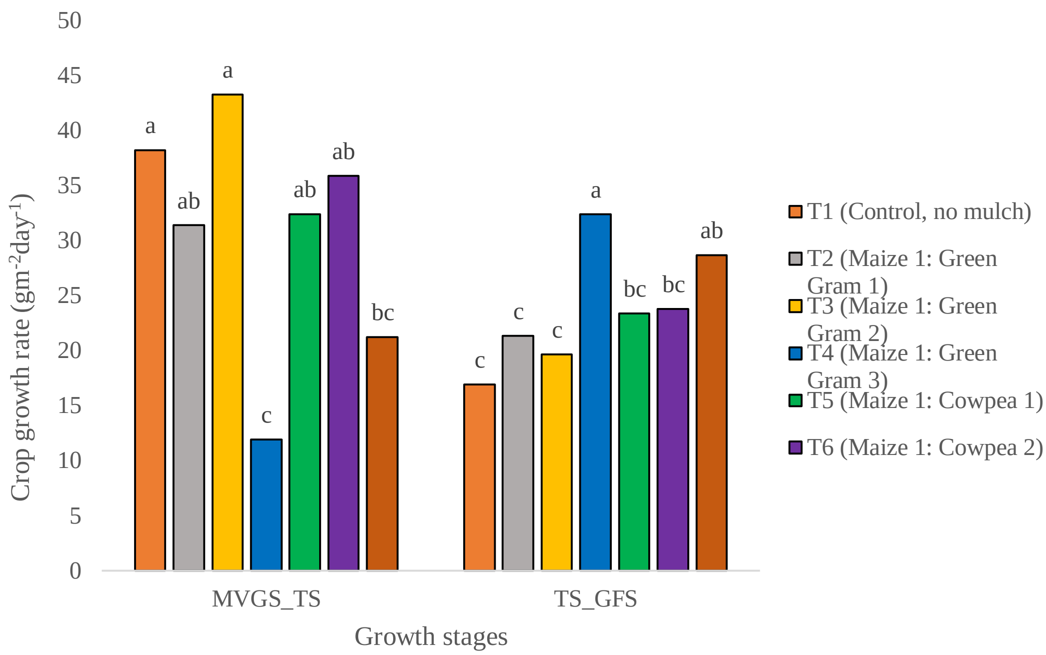


Figure 4. Crop growth rate of maize as affected by living mulches during dry season (MVGS = maximum vegetative growth stage, TS = Tasseling stage, GFS = grain filling stage)

Yield of maize

Grain yield of maize was significantly different among the treatments during dry season (Figure 5). The maximum grain yield was observed from T6 (7 ton ha^{-1}) followed by T2, T7 whereas the minimum grain yield was obtained from T1 (4.9 ton ha^{-1}). The difference in grain yield of maize in living mulches plots could be due to the result of enhanced soil nutrients (e.g. nitrogen), which is associated with legume plants like green gram and cowpea. Radicetti et al. (2018) reported that better crop nitrogen status and estimated a higher total nitrogen uptake and improved yield in living-mulch plots are higher than in no-mulch plots.

T1 = control (no mulch), T2 = maize: green gram (1:1), T3 = maize: green gram (1:2), T4 = maize: green gram (1:3), T5 = maize: cowpea (1:1), T6 = maize: cowpea (1:2), T7 = maize: cowpea (1:3)

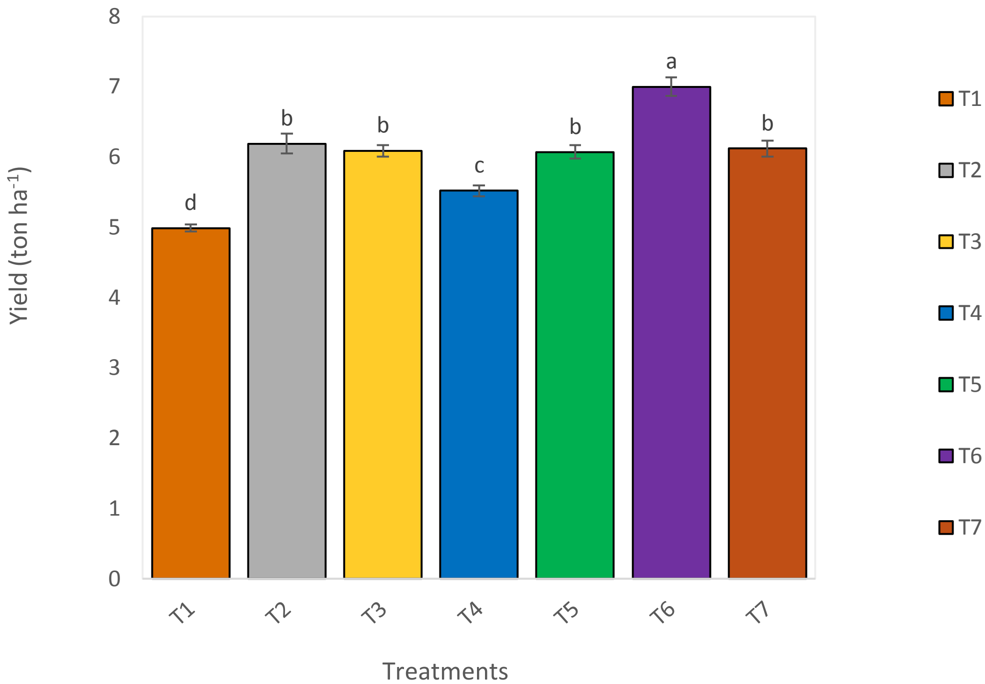
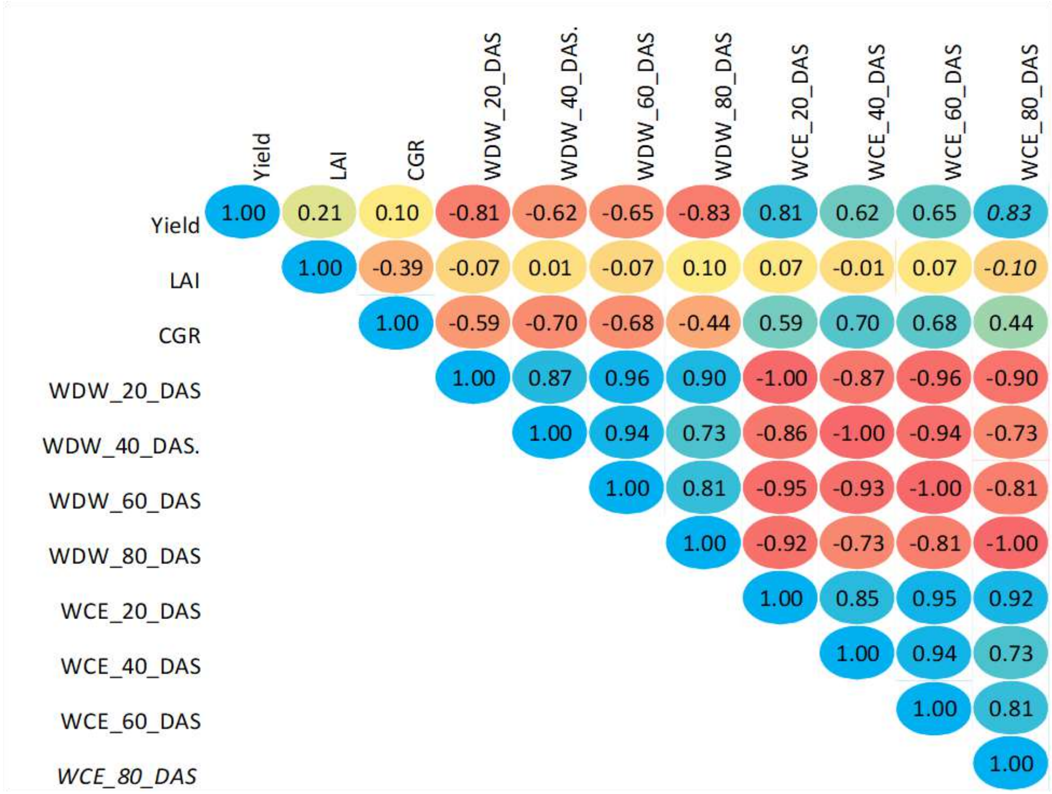


Figure 5. Yield of maize as affected by living mulches during dry season

Correlation analysis of weed infestation, growth and yield of maize

The results of correlation of yield and weed infestation of maize during dry season, 2023-2024 was shown in Figure 6. The blue color showed positive correlation coefficient value and the red color was negative correlation coefficient value. Crop growth rate was positively correlated with weed control efficiency and negatively correlated with weed dry weight at all sampling times. Weed control efficiency was negatively and significantly correlated with weed dry weight at all sampling times. Yield was positively correlated with weed control efficiency at all sampling times and specifically at 20 DAS. It could be suggested that the higher weed control efficiency, the higher yield can be achieved. In addition, yield was negatively correlated with weed dry weight. Especially, yield was negatively correlated with weed dry weight at 20 DAS. This indicated that the higher weed infestation can result the lower maize grain yield.



WDW = Weed dry weight, WCE = Weed control efficiency, DAS = Days after sowing of maize, blue color represents positive correlation, red color represents negative correlation and color intensity indicate the value of correlation coefficient

Figure 6. Association of weed infestation, growth and yield of maize in Yezin during dry season, 2023-2024

Conclusion

According to the experiment, cowpea living mulches is suitable with the ratio of maize: cowpea (1:2) instead of no mulching in maize cultivation. Cowpea living mulch in maize cultivation may have the potential to suppress growth and biomass of weeds compared to the control. Moreover, living mulch plots had increased maize grain yield compared to the control. However, living mulches were not suitable for the places where irrigation is not suitable for maize cultivation during dry season. Based on the results, growing living mulches in maize during dry season required more water than the normal growing conditions.

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Appendix 1. Living mulches' (LM) green masses weight at cutting times

Treatment	Plant Number	LM weight (g)			
		1st time (21 DAS)	2nd time (35 DAS)	3rd time (47 DAS)	4th time (35 DAS)
T1 (Control, no mulch)					
T2 (Maize 1: Green Gram 1)	798	1560	1634	1326	1230
T3 (Maize 1: Green Gram 2)	750	1620	1542	1128	1320
T4 (Maize 1: Green Gram 3)	770	1680	1558	954	720
T5 (Maize 1: Cowpea 1)	298	4562	4482	2543	2100
T6 (Maize 1: Cowpea 2)	310	4731	4691	2682	2420
T7 (Maize 1: Cowpea 3)	305	4480	4362	1968	2103

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