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Effects of Cereal-Legume Intercropping and Mulching on Maize (*Zea Mays* L.) Productivity in Dry Season using Drip Irrigation in South-Sudanian Climatic Zone of Burkina Faso

Vinsoun Millogo [α], Michel Kéré [σ], Ouda Sanfo [ρ], Toundji Olivier Amoussou [ω], Timothy Harrigan [¥], Robert Burdick [§] & Ajit Srivastava [χ]

Abstract- The availability and sustainability of water in rural areas are significant challenges facing agricultural producers in the Sahelian zones. Maize-legume intercropping with a mulch cover for water conservation with drip irrigation is a promising production practice for conserving water, increasing productivity and improving soil health. A randomized complete block trial with 04 replications and 08 treatments was established in Sonsongona (11.2522°N, 4.4559°W), a village located west of Bobo-Dioulasso, Burkina Faso. Means separation by analysis of variance (ANOVA) was with RStudio 1.2.1335 software at the 5% threshold according to the Newman-Keuls test. The mulched treatments significantly affect soil moisture, maize growth, weed growth, and important maize yield attributes. Mulched maize plant height was not significantly greater than mulched treatments at 60 days after planting, but the average grain yield was 4,479.00 ± 39.70 kg/ha for maize + peanut + mulch compared to 3,288.00 ± 328.75 kg/ha for maize seeded without mulch or a legume. Overall, combined with legumes, mulching increased maize yield, conserved soil moisture, and helped control weeds. Combining mulch with legumes reduces weeding labor costs by controlling grass cover.

Keywords: drip irrigation, conservation agriculture, maize, day after planting (DAP) mulching, maize-legume intercropping, burkina faso.

Résumé- La disponibilité de l'eau agricole de manière durable est un l'un des challenges auquel fait face à la plupart des pays de la zone Sahélienne. En effet, parmi les défis à relever, il y a l'utilisation rationnelle de l'eau disponible à travers l'irrigation goutte à goutte et la gestion durable des sols à travers l'agriculture de conservation. C'est dans ce contexte que cette étude a été réalisée à Sonsongona à l'Ouest du pays avec pour objectif d'amélioration de la situation alimentaire des ménages vulnérables par la mise en place d'un système de culture de maïs en saison sèche en association avec des légumineuses adaptées au système d'irrigation goutte à goutte. Un essai en bloc complètement randomisé à quatre (04) répétitions et huit (08) traitements a été installé. Ce système d'irrigation goute-à-goute avec pompage solaire a été conçu et installé par l'équipe du consortium de la mécanisation agricole appropriée en 2017. Les données ont été soumises à l'analyse des variances (ANOVA) à l'aide du logiciel RStudio 1.2.1335. La comparaison des moyennes a été faite à l'aide du test Newman-Keuls au seuil de probabilité 5%. Les résultats ont montré que les traitements avec paille ont eu des effets significatif sur l'état d'humidité du sol, la croissance du maïs, le taux d'enherbement et sur certains composants du rendement du maïs. Les traitements avec paille engendraient, quant à elles, une bonne croissance, mais non significative en hauteur (Maïs + arachide + paille : 240,30 ± 8,68 cm ; Maïs + niébé + paille: 242,30 ± 8,10 cm ; Maïs + mung bean + paille : 242,30 ± 7,75 cm et Maïs + paille sans légumineuses : 242,20 ± 8,46 cm) et en diamètre (Maïs + arachide + paille : 3,58 ± 0,83 cm ; Maïs + niébé + paille : 2,76 ± 0,05 cm ; Maïs + mung bean + paille: 2,80 ± 0,13 cm et Maïs + paille sans légumineuses: 2,87 ± 0,13 cm) des plants de maïs au 60è JAS. Le rendement grain du maïs était de 4 479,00 ± 39,70 kg/ha pour Maïs + niébé + paille contre 3 288,00 ± 328,75 kg/ha. De façon générale, le paillage combiné aux légumineuses améliore l'état d'humidité du sol et permet de contrôler l'enherbement. La croissance des plants de maïs a été meilleure lorsque le paillage est combiné aux légumineuses. Le mung bean a un effet sur la croissance supérieure aux autres légumineuses. Les résultats ont montré une amélioration non significative du rendement du maïs. Le niébé a un effet sur le rendement supérieur aux autres légumineuses. La combinaison du paillage aux légumineuses permettrait de réduire le coût des travaux en contrôlant l'enherbement des parcelles et permettant ainsi de diversifier la production.

Mots clés: irrigation goutte à goutte, agriculture de conservation, maïs, jour après semi (JAS), paillage, association céréales-légumineuses, burkina faso.

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I. Introduction

Agricultural sector contribute to food security, economic growth and reduce poverty and food insecurity in sub-Saharan Africa. Agriculture

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accounts for more than 25% of GDP in African countries and is the primary source of income and employment for at least 65% of the African population (Heno et al., 2006). Agriculture contributes up to 30% of the regional GDP and employs more than 55% of the rural population (CEDEAO, 2015). In Burkina Faso, agriculture contributes 40% of the GDP and employs 86% of the active population (MAHRH, 2011). However, Burkina Faso faces chronic food insecurity because of adverse agro-climatic conditions and significant soil degradation leading to low crop yields. Agriculture is primarily a rainfed livestock-cropping system (Sonou, 2010). Demographic pressures and the subsequent loss of fallow land has further amplified this trend (Coulibaly, 2012). Therefore, increasing agricultural productivity is a significant challenge for Burkina Faso.

Irrigation can help to create additional household income beyond the rainy seasons by focusing on high-value cereals crops such as maize. Drip irrigation increases agricultural productivity by reducing the vulnerability of plants to water stress since the difficulties associated with irrigation are limited to the irrigation frequency and the insufficient subsoil water by capillary action (Tapsoba, 2016, Millogo et al., 2021). Among the current irrigation methods, drip irrigation appears to be the most efficient (Sonou, 2010; Millogo et al., 2021). It provides uniform distribution and efficient water use for the plant (Millogo et al., 2021). The efficiency of drip irrigation is 90% to 95% compared to 40% to 45% for gravity irrigation and 80% for sprinkler irrigation (Sonou, 2010).

Despite water management efforts, declining soil fertility remains another problem many farms face (Coulibaly et al., 2012a). Continuous land use leads to low carbon and declining soil organic stocks (Coulibaly et al., 2012a). This land utilization, combined with the transfer of nutrients for crops such as maize, is one factor that maximizes the risk of declining soil fertility with the significant consequence of lower crop yields.

Given the importance of legumes in nitrogen fixation, their association with cropping systems as alternatives to nitrogen fertilization appears to be a reasonable approach. According to Coulibaly et al. (2012a); Crasky et al. (2003), legume systems provide sustainable soil fertility management through atmospheric nitrogen (N) fixation. By improving the nitrogen status of the soil, legumes increase cereal yields (Azontondé, 1993; Rusimanhodji et al., 2012; Coulibaly et al., 2017a; Coulibaly et al., 2017b). The maize and legume association represents an alternative in managing risks and uncertainties for farmers faced with global changes (Coulibaly et al., 2017a).

Despite their importance in cropping systems, there is little evidence of their impact on dry season cereal production. For legumes to become an essential part of cropping systems, it is necessary to look at their effects on dry season cereal production. There is a need to investigate the intercropping and mulching effects on maize productivity in the dry season under drip irrigation. This study is aimed to sustainably intensify the cropping system productivity of smallholder farmers by establishing a drip irrigation system to grow crops and legumes during the dry season. The solar panel drip irrigation system was designed, implemented, and tested in 2018 by the USAID-funded Appropriate Scale Mechanization Consortium (ASMC) team. A paper was published on its water distribution and use efficiency (Millogo et al., 2021). The objectives of the study reported in this paper were to study effects of intercropping maize with legume combined with mulching on dry season maize yield and soil water parameters.

II. Materiel and Methods

a) *Overview of the study area*

This study was conducted at Sonsongona village (04°16' West longitude and 11°60' North latitude) of (Figure 1A), located 20 km from Bobo-Dioulasso city centrum nearby Bobo-Dioulasso-Banzon corridor. The village is part of the commune of Bobo-Dioulasso in the Houet province, which, together with the provinces of Tuy and Kénédougou, are the Hauts-Bassins Region. Sonsongona is located in the southern Sudanian climate with annual rainfall between 800 and 1200 mm. It is characterized by a dry season (November to April) during which the Harmattan blows and a rainy season (April to November) dominated by the monsoon. The inter-annual variability of rainfall ranges from 723.7 mm in 2017 to 1303.8 mm in 2018 with 51 and 70 rainy days, respectively (Figure 1B). The intra-annual variation is marked by a total annual rainfall of 1303.8 mm on 70 rainy days (Figure 1C). The soil at the study site is sandy loam on the surface and clayey at depth with an acid pH and low humus content (Table 1).The vegetation is a wooded savannah divided into three strata: woody, shrubby and herbaceous, with open forests on the shallows and along the river (Guinko and Fontès, 1995).

Table 1: Physical and chemical property of the soil

Sable	Limon	Argile	Humus	pH
62,66	2166,	15,67	Faible	6,8

Source: (Yé, 2018; Millogo et al., 2021).

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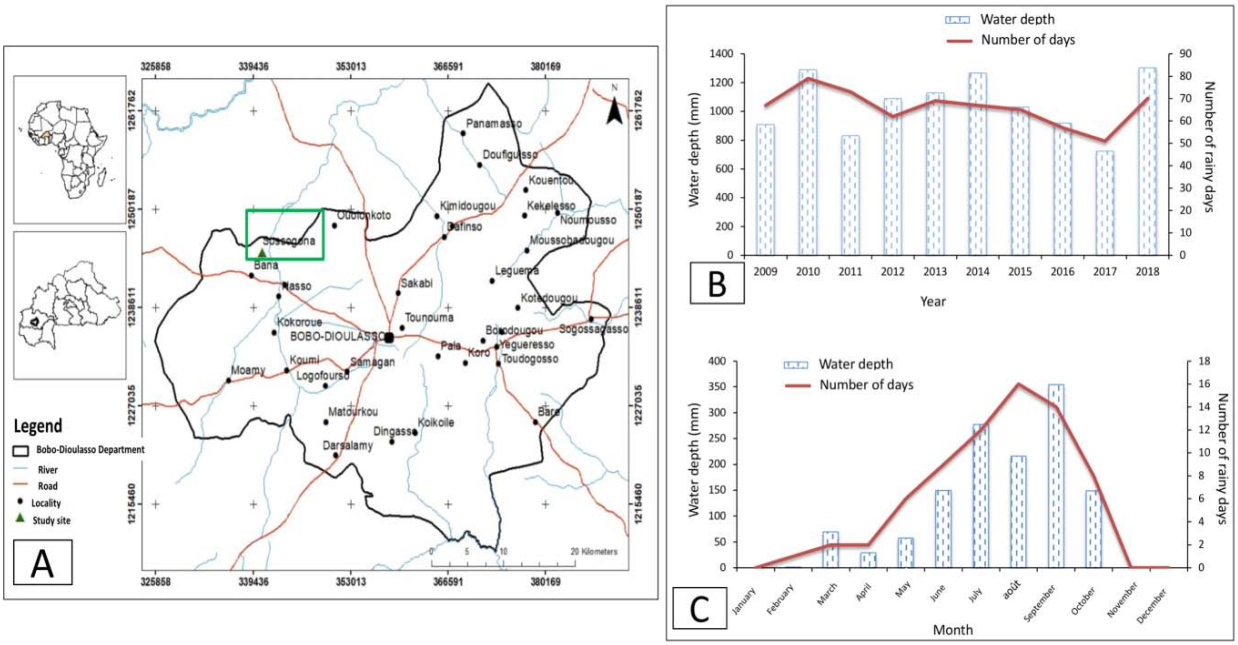


Figure 1: Map of the study site (A) with the variation in rainfall over the last ten years (B) and during the year 2018 (C)

b) Irrigation system description

The irrigation system used was an ASMC prototype design and implemented in 2017 to deliver water homogeneity (Millogo et al., 2021). Major components of the system included a well, a solar planel, a PS-200 HR 07 solar pump, a water tower with a capacity of 2000 L tower, and an irrigation kit consisting of ramps, valves, volumetric meters, emitter lines, and integrated emitters.

c) Technical and plant materials

The soil sampling equipment included: a hand auger, a metric square; a weighing scale; a bag; an oven; a hand hoe, a sprayer; a caliper; and metric measuring tape. The plant material consisted mainly of maize (*Zea mays*), cowpea (*Vigna unguiculata*), groundnut (*Arachis hypogeae*), and mung bean (*Vigna radiata*). The maize variety Streat Resistant N°21 (SR21) with an intermediate cycle (95 days) was used. Its planting-male flowering and planting-maturity cycles are 59 days after planting (DAP) and 95 days to seed, respectively. The height of the plant was 180 cm with an ear insertion height of 90 cm. This variety tolerates some common diseases such as helminthosporiasis, rust and is resistant to MSV (Maize Streat Virus). It is a white maizeed-toothed variety with a potential 5.1 t/ha (Sanou, 2009). This variety is suitable for areas with rainfall between 900 and 1200 mm of water per year. The cowpea was variety KVx442-3-25SH (Komcalé), a precocious and drought-tolerant variety with a potential yield of 1.5 to 2 tonnes/ha (CNS, 2014). The peanut variety Fleur11, was chosen because of its short cycle with a potential yield of 2.5 tons/ha (CNS, 2014). The mung bean was species *Vigna Radiata.*

d) Fertilization

We used both organic and mineral fertilizers. 320 g of NPK (14-23-14) and urea 320 g (46%) were used for mineral fertilizers in equal amounts in all plots (320 g). Mineral fertilizers were used under a special authorization to meet only farmer standard practices. For organic fertilization, cattle manure was incorporated before soil preparation (10 t/ha). Soil covering/mulching was with rice straw. The straw was applied at the rate of 3 tons/ha with a thickness of 5 cm.

e) Experimental Design

The experimental design was a randomized complete block with a total area of 637 m^2 (Figure 2). Two factors were considered in the study. The first factor was the crop associated with four levels (groundnut, cowpea, mung bean, and legume-free). The second factor was soil cover with two patterns (without mulch and with mulch). The trial consisted of 04 replicates and 08 treatments. Each plot was 16 m^2 (5.7 m × 2.8 m). The inter-block and inter-plot spacings were 1 m and 0.4 m, respectively. The treatments were: (i) MwRP: Maize + Peanut with Rice Straw, (ii) MfRP: Maize + Peanut without Straw, (iii) MwRC: Maize + Cowpea with Rice Straw, (iv) MfRC: Maize + Cowpea without Straw, (v) MwRMb: Maize + Mung bean with Rice Straw, (vi) MfRMb: Maize + Mung bean without straw, (vii) MwLf: Maize + Straw without legumes, (viii) MfLf: Maize without Straw without Legumes.

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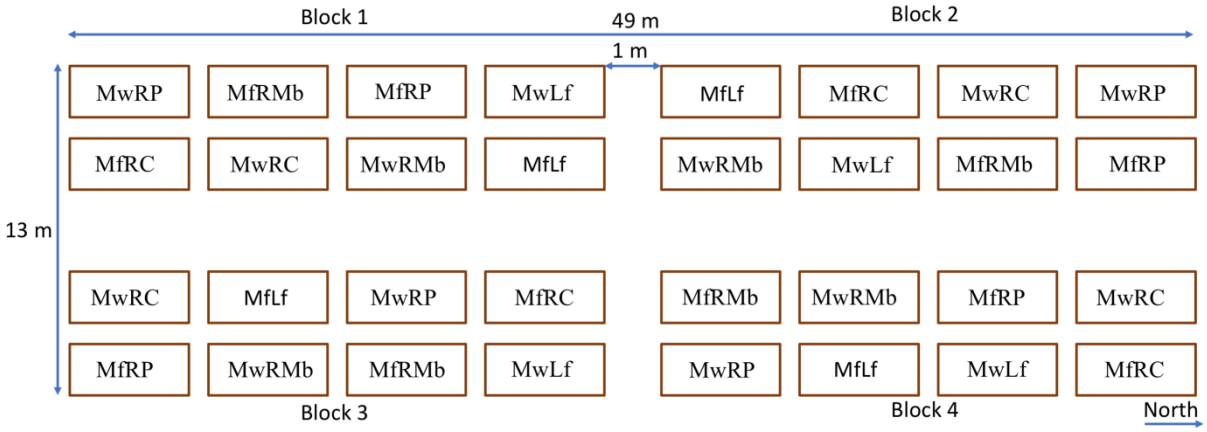


Figure 2: Illustration of the experimental design. MwRP: Maize with Rice straw combined with Peanut; MfRP: Maize free of rice Straw combined with Peanut; MwRC: Maize with Rice straw combined with Cowpea; MfRC: Maize free of Rice straw combined with Cowpea; MwRMb: Maize with Rice straw combined with Mung bean; MfRMb: Maize free of Rice straw combined with Mung bean; MwLf: Maize with Rice straw and Legume-free; MfLf: Maize free of rice straw and Legume-free

f) Implementation

Seedbed preparation consisted of ploughing to a depth of 15 to 20 cm, then crumbling with a hoe. The drip irrigation lines were installed was set up following the soil preparation. Planting operations were by hand. Maize was planted on February 13 at 0.8 m row spacing and 0.2 m inter-hills spacing at a seeding rate of two seeds per hill, followed by an emergence seedling thinning to one plant/hill. Cowpea, groundnut, and mung bean were planted two weeks after maize in the inter-row area at a rate of two seeds/hill for cowpea and mung bean and one seed/hill for groundnut. Cowpea and mung bean were planted at 40 cm spacings and groundnut at 20 cm spacings. Other operations such as weeding, fertilization, and irrigation were carried out jointly to maintain the crops. Hoe weeding was carried out on the 14th, 29th, and 44th day after planting (DAP) and manual weeding on the 60th DAP. Organic fertilization consisted of applying cattle manure before ploughing by spreading. The mineral fertilization, i.e., the application of chemical fertilizers, was carried out following the technical itinerary of maize. The NPK fertilizer (14-23-14) was applied at 200 kg/ha on the 15th DAP. Urea (46%) was applied in two fractions. The first dose of urea (100 kg/ha) was applied on the 30th DAP, and the second dose (50 kg/ha) was applied on the 45th DAP. The water was applied by drip irrigation to meet the water needs of the main crop, maize (60 to 65 m^3), according to Millogo et al. (2021).

g) Data collection and statistical analysis

For soil moisture determination, soil samples were taken for three strati of 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm. Soil sampling was done following the diagonal of each plot, and 03 specific locations were identified for these samples. For each stratus, a composite sample was taken and transported to the laboratory. Samples of 200 g wet weight were put in the oven at 105°C for 48 hours. Samples were collected on the 7th, 21st, 35^{th,} and 49th DAP. The soil moisture was determined after drying the samples in the oven. The moisture content was calculated using equation one below in Table 1.

Rice straw cover was evaluated in a 1 m^2 sample placed randomly on the diagonal of each plot. It was estimated as a percentage at the 14th, 29^{th,} and 44th DAP. The parameter was assessed using a visual rating scale ranging from 1 (no cover) to 9 (complete cover) as described by Marnotte (1984). Measurement of growth parameters of maize plants included plant height and crown diameter. Plant height was measured on 06 randomly selected plants (Kouelo et al., 2017) in the plot at the 15th, 30th, 45th, and 60th DAP. This height was measured from the collar to the ligule of the last well-developed leaf of the plant. The collar diameter was measured on six randomly selected plants (Kouelo et al., 2017) for height measurements using a caliper at the 15th, 30th, 45^{th,} and 60th DAP.

Several maize yield components were measured at maturity: 1,000-grain weight, grain yield, number of grains/ears (calculated from the number of radius/ear and the number of grains/radius), number of ears, straw yield, and stalk weight. All the plots' maize plants were cut at the crown level at 124 DAP for the measurements. The ears were harvested, then dried and shelled by hand. The seeds were weighed using an electronic balance. The values were extrapolated to the hectare (kg/ha) according to formula number 2 (Table 1). After shelling, the stalks were weighed and extrapolated to one hectare using formula number 3 (Table 1). The weight of 1,000 grains was by manually counting 1,000 grains and then weighing using an electronic scale. The number of ears of maize was by direct counting of all the ears of maize in the plot and

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then extrapolated to the hectare according to formula number 4 (Table 1). After drying, six ears were randomly selected for counting the number of rows per ear and the number of grains per row used to determine the number of grains per ear. The number of grains per ear was by formula 5 (Table 1). The straw was weighed on a scale to obtain the different fresh weights. Samples of 100 g were taken and dried in an oven at 105°C for 72 hours to determine dry weights. The total straw production was determined by formula 6 (Table 1). All values were extrapolated to represent kg/ha according to formula number 7 (Table 1). The data were then subjected to an analysis of variance (ANOVA) using RStudio 1.2.1335. The separation of the means was made at the 5% threshold according to the Newman-Keuls test.

Table 2: Formulas used for the various calculations

Number	Computation formulae
1	Moisture Content (%) = (((wet weight-container weight)-(dry weight-container weight))/(dry weight-container weight))×100
2	Yield (kg/ha) = ((Pu ×10000))/(10 (m^2) ×1000) Where, Pu: grain weight of the useful parcel in grams; 10000: the surface area of one hectare in m^2 , 10 m^2 the surface area of the useful parcel, 1000: the equivalent of one kilogram in grams
3	Stalk weight (kg/ha) = ((WRuP×10000))/(10 (m^2) ×1000) Where, WRuP: Weight of the Rafles of the Useful Plot, 10000: the surface area of one hectare in m2 , 10 m^2 the surface area of the useful plot, 1000: the equivalent of one kilogram in grams
4	Number of ears/ha = ((NEPu ×10000))/(10 (m^2)) Where, NEuP: number of ears of the useful plot, 10000: the surface area of one hectare in m^2 , 10 m^2 the surface area of the useful plot
5	Number of grains/ears = (number of grain/radius)×(number of radius/ear)
6	DW (g) = DWS/FWS×TFW Where, DW: dry weight; DWS: dry weight of the sample; FWS: fresh weight of the sample; TFW: total fresh weight
7	Straw yield (kg/ha) = (WS ×10000)/10 (m2) ×1000 Where, WS: the weight in grams of the straw of the useful plot, 10000: the surface area of one hectare in m^2 , 10 m^2 the surface area of the useful plot, 1000: the equivalent of one kilogram in grams

III. Results

a) Effects of mulching and legumes on soil moisture

The effects of mulching and legumes on soil moisture content (Figure 3) showed that moisture content varied from one treatment to another depending on the measurement depth and production period. At the 7th DAP (Figure 3A), soil weight moisture varied in the overlying horizons from 11.25 ± 2.69% (MfLf) to 13.38 ± 2.35% (MwRC). In the middle and deep horizons, the same trends were observed. All mulched land plots (MwRP, MwRC, MwRMb, MWLF) had improved soil moisture compared to bare soil (MfLf). At this level, no significant difference was detected among treatments.

From the 21st DAP (Figure 3B), better moisture levels are with the MwRP (16.00 ± 0.41%) and MwRC (16.00 ± 0.54%) treatments in the overlying horizons. At this level, all treatments with mulch (MwRP, MwRC, MwRMb, MWLF) had better moisture content than treatments without mulch (MfRP, MfRC, MfRMb, and MfLf). These moisture levels varied significantly between treatments ($p < 0.05$). Treatments (MfRP, MfRC, MfRMb) had no significant effect on soil moisture compared to bare soil (MfLf). In the medium and deep horizons, the different treatments did not significantly affect soil moisture levels.

At the 35th DAP (Figure 3C), the moisture content ranged from 15.00 ± 0.5% (MfLf) to 18.12 ± 1.14% (MwRMb) and the moisture content did not vary significantly between treatments. The greatest moisture levels were in the mulched plots. The moisture content in plots under legume cover (MFRP, MFRC, and MfRMb) was greater compared to plots under mulch alone (MWLF) and without mulch (MfLf). The combination of mulch and legumes (MwRP, MwRC, and MwRMb) improved soil moisture compared to bare soil (M) or legumes alone (MfRP, MfRC, and MfRMb).

The greatest moisture levels were on the 49th DAP (Figure 3D) in the surface zones with the combined legume and mulch treatments (MwRP, MwRC, and MwRMb). Legumes (MfRP, MfRC, and MfRMb) improved soil moisture compared to simple mulch (MWLF) and bare soil (MfLf) at these same depths. In the middle and deep horizons, no significant difference was found. However, the effect of mulching and

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legumes on moisture remains better than on bare soil. In fact, there is no significant difference between the differents horizons but the soil moisture is better on mulchning and legumes treatments than bare soil.

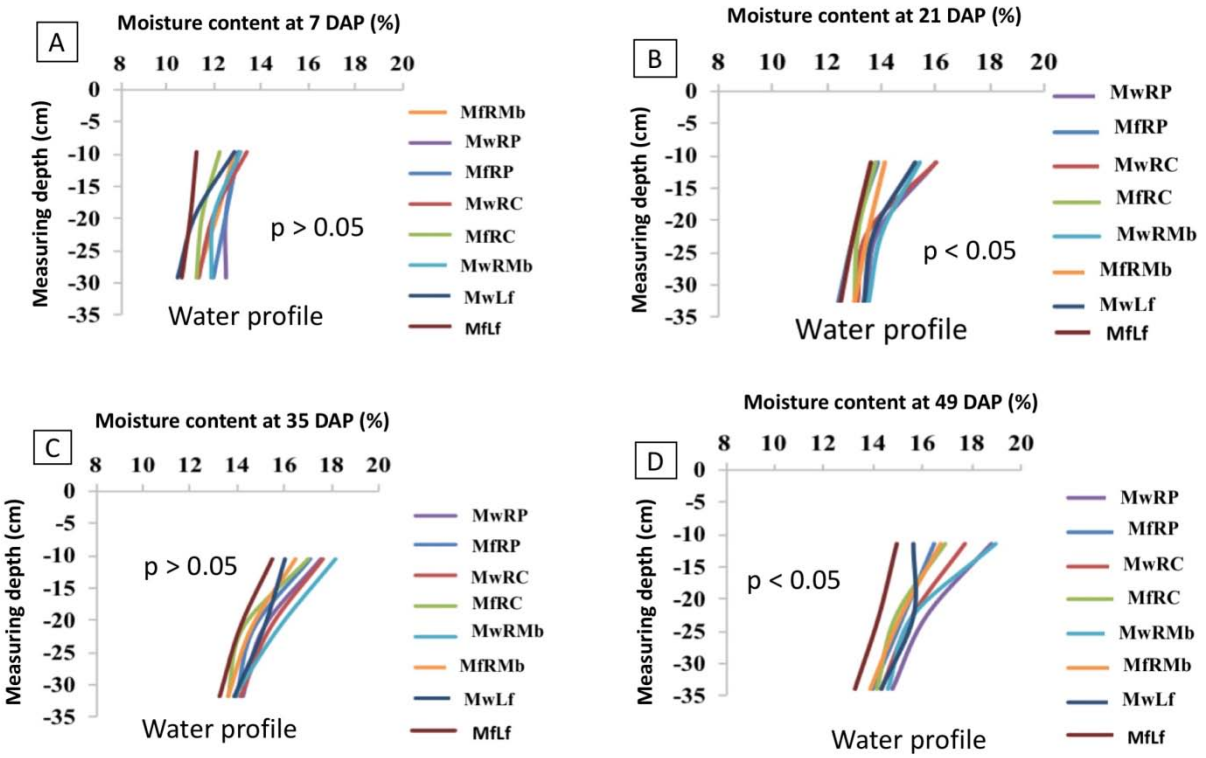


Figure 3: Effect of legumes and mulching on soil moisture status. MwRP: Maize with Rice straw combined with Peanut; MfRP: Maize free of rice Straw combined with Peanut; MwRC: Maize with Rice straw combined with Cowpea; MfRC: Maize free of Rice straw combined with Cowpea; MwRMb: Maize with Rice straw combined with Mung bean; MfRMb: Maize free of Rice straw combined with Mung bean; MwLf: Maize with Rice straw and Legume-free; MfLf: Maize free of rice straw and Legume-free

b) Effects of mulching and legumes on grass cover

The specific and combined effects of mulch and legumes on plot grass cover differed between treatments and between assessment periods (Table 2). A significant difference ($p < 0.05$) was detected among no mulching and mulching treatments. In fact, the assessment of the straw cover rate at 14 DAP showed that the highest value was with the MwRP treatment (22.5 ± 3.23%) and the lowest value with the MfRMb treatment (15.00 ± 00%). At this level, all the plots that were mulched (MPAb: 22.5 ± 3.23%, MwRC: 20.00 ± 3.53%, MwRMb: 18.75 ± 2.39%, and MWLF: 18.75 ± 1.25%) had a higher grass cover rate than the plots without mulching (MfRP, MfRC, MfRMb, and MfLf).

As in the 14th DAP, data on grass cover rates also differed between treatments. The MwRC treatment resulted in the highest grass cover rate (24.16 ± 3.40%), and the lowest value was with the MWLF treatment (17.50 ± 1.44%). At this level, treatments combining legume-mulch (MwRP: 22.66 ± 3.53%, MwRC: 24.16 ± 4.40% and MwRMb: 23.75 ± 3.15%) gave higher values compared to simple mulching (MWLF: 17.50 ± 1.44%). However, bare soil (MfLf: 20.00 ± 2.89%) had a higher grass cover rate than plots with legume only (MfRP: 18.75 ± 2.39%, MFRC: 18.75 ± 3.75% and MfRMb: 17.50 ± 2.50%). No significant differences were detected among different treatments.

At the 42nd DAP, the grass cover rate also differed from one treatment to another. The highest value was with the MfRMb treatment (32.50 ± 3.88%), and the lowest value was with the MfRP treatment (22.91 ± 4.73%). Peanut in combination with mulch had a better effect on the grass cover rate (MwRP: 25.83 ± 6.25%) compared to the other combinations (MwRC: 29.58 ± 1.57%) and MwRMb (28.75 ± 6.71). At this stage, weed control is essential regardless of the treatment. No significant difference was found between treatments.

On the 56th DAP, the grass cover rate varied according to treatments. Significant differences were detected among mulching and no mulching treatments. The effect on the grass cover rate is much greater with the MwRMb treatment (17.5 ± 1.44%) than with the MfLf treatment (27.50 ± 5.81%). At this production stage, all treatments combining legumes with mulch significantly affected the weed cover (MwRP: 18.75 ± 1.25%, MwRC: 20.00 ± 2.04%, and MwRMb: 17.5 ± 1.44%). Similarly, legumes associated solely with maize had an effect on

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weed cover (MfRP: 21.25 ± 1.25%, MfRC: 23.75 ± 3.15% and MfRMb: 22.50 ± 1.44%) compared to mulch (MWLF: 26.25 ± 1.25%) and bare soil (M: 27.50 ± 5.81%).

Table 3: Combined effects of mulching and legumes on weed growth

Weed growth					
Treatments		14 DAP	28 DAP	42 DAP	56 DAP
MwRP	M	22.50[a]	21.66[a]	25.83[a]	18.75[c]
	SE	3.23	3.53	6.25	1.25
MfRP	M	17.50[a]	18.75[a]	22.91[a]	21.25[b]
	SE	2.5	2.39	4.73	1.25
MwRC	M	20.00[a]	24.16[a]	29.58[a]	20.00[c]
	SE	3.53	3.4	1.57	2.04
MfRC	M	18.75[a]	18.75[a]	25.41[a]	23.75[b]
	SE	2.39	3.75	3.75	3.15
MwRMb	M	18.75[a]	23.75[a]	28.75[a]	17.50[c]
	SE	2.39	3.15	6.71	1.44
MfRMb	M	15.00[a]	17.50[a]	32.50[a]	22.50[b]
	SE	-	2.5	3.88	1.44
MWLF	M	18.75[a]	17.50[a]	26.66[a]	26.25[a]
	SE	1.25	1.44	2.63	1.25
MfLf	M	17.50[a]	20.00[a]	29.91[a]	27.50[a]
	SE	2.5	2.89	5.81	5.81
Freedom Degree		7	7	7	7
p-value		0.618	0.631	0.882	0.005
Significance		NS	NS	NS	**

*M: mean; ES: standard error; NS: non-significant ($p > 0.05$), **: $p < 0.01$. Numbers with the same superscript in the same column were not statistically different at the 5% threshold. MwRP: Maize with Rice straw combined with Peanut; MfRP: Maize free of rice Straw combined with Peanut; MwRC: Maize with Rice straw combined with Cowpea; MfRC: Maize free of Rice straw combined with Cowpea; MwRMb: Maize with Rice straw combined with Mung bean; MfRMb: Maize free of Rice straw combined with Mung bean; MwLf: Maize with Rice straw and Legume-free; MfLf: Maize free of rice straw and Legume-free*

c) *Effects of mulching and legumes on maize height growth*

The specific and combined effects of mulch and legumes on maize plant height growth are presented in Table 3. The height varied from one treatment to another. At 15th DAP, the average height of maize plants ranged from 4.72 ± 0.11 cm (MfRP) to 5.69 ± 0.06 cm (MwRP). The greatest growth was with the MwRMb treatment (5.52 ± 0.28 cm). All treatments with mulching improved maize height (MwRMb: 5.52 ± 0.28 cm, MwRP: 5.69 ± 0.06 cm, MwRC: 5.64 ± 0.45 cm and MWLF: 5.27 ± 0.25 cm) compared to treatments without mulch (MfRP: 4.72 ± 0.11 cm, MfRMb: 4.70 ± 0.21 cm and M: 4.95 ± 0.25 cm) except for the MfRC treatment (5.34 ± 0.28 cm). However, there were no significant differences between treatments.

At 30th DAR, the height also ranged from 21.71 ± 0.89 cm (MfRC) to 26.88 ± 1.10 cm (MwRP), although no significant difference between treatments was detected. At this stage of growth, the greatest growth was when the soil was covered with straw mulch. All crops under mulch had more growth (MwRP: 26.88 ± 1.10 cm, MwRC: 24.29 ± 1.10 cm, MwRMb: 24.75 ± 0.97 cm and MWLF: 24.36 ± 1.93 cm) compared to crops not mulched (MfRP: 22.35 ± 0.46 cm; MfRC: 21.71 ± 0.89; MfRMb: 21.94 ± 0.89 cm and M: 22.12 ± 1.00 cm).

At the 45th DAP, although no significant differences were detected, maize plant height growth varied among treatments. The most growth was with the MwRMb treatment (97.17 ± 7.77 cm), and the least growth was with the MfLf treatment (76.33 ± 6.31 cm). As at 30th DAP, maize plants had good growth on the mulched plots (MwRP: 95.12 ± 5.12 cm, MwRC: 88.29 ± 5.40 cm, MwRMb: 97.17 ± 7.77 cm and MWLF: 93.29 ± 7.08 cm) compared to unmulched plots (MFRP: 81.54

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± 4.10 cm, MfRC: 82.25 ± 4.74 cm, MfRMb: 79.21 ± 1.18 cm and MfLf: 76.33 ± 6.31 cm). Combining legumes with maize did not significantly affect maize growth, but maize tended to be taller when mulched than in bare soil (MfLf: 76.33 ± 6.31 cm).

At 60th DAP, the average height of the maize plants ranged from 215.40 ± 8.42 cm (MfLf) to 242.30 ± 8.10 cm (MwRC) and 242.30 ± 7.75 cm (MwRMb). Mulching lead to greater growth (MwRP: 240.30 ± 8.86 cm, MwRC: 242.30 ± 8.10 cm, MwRMb: 242.30 ± 7.75 cm and MWLF: 242.20 ± 8.46 cm) than unmulched (MfRP: 220.60 ± 2.58 cm, MfRC: 223.60 ± 10.48 cm, MfRMb: 223.50 ± 6.34 cm and MfLf: 215.40 ± 8.42 cm). However, legumes (MfRP: 220.60 ± 2.58 cm, MfRC: 223.60 ± 10.48 cm, MfRMb: 223.50 ± 6.34 cm) had a significant effect on maize plant growth compared to bare soil (M: 215.40 ± 8.42 cm). In combination with mulch, cowpea (MwRC: 242.30 ± 8.10 cm) and mung bean (MwRMb: 242.30 ± 7.75 cm) gave a better effect on growth. However, no significant differences were detected.

Table 4: Combined effects of mulching and legumes on maize height growth

Treatments		Maize height (cm)			
		15 DAP	30 DAP	45 DAP	60 DAP
MwRP	M	5.69[a]	26.88[a]	95.12[a]	240.30[a]
	SE	0.06	1.1	5.12	8.86
MfRP	M	4.72[a]	22.35[b]	81.54[a]	220.60[a]
	SE	0.11	0.46	4.1	2.58
MwRC	M	5.64[a]	24.29[a]	88.29[a]	242.30[a]
	SE	0.45	1.1	5.4	8.1
MfRC	M	5.34[a]	21.71[b]	82.25[a]	223.60[a]
	SE	0.4	0.89	4.74	10.48
MwRMb	M	5.52[a]	24.75[a]	97.17[a]	242.30[a]
	SE	0.28	0.98	7.77	7.75
MfRMb	M	4.70[a]	21.94[b]	79.21[a]	223.50[a]
	SE	0.21	0.89	1.18	6.34
MWLF	M	5.27[a]	24.36[a]	93.29[a]	242.20[a]
	SE	0.25	1.93	7.08	8.46
MfLf	M	4.95[a]	22.12[b]	76.33[a]	215.40[a]
	SE	0.25	1	6.31	8.42
Freedom Degree		7	7	7	7
p-value		0.1	0.034	0.093	0.172
Significance		NS	*	NS	NS

*M: mean; ES: standard error; NS: non-significant ($p > 0.05$), *: $p < 0.05$. Numbers with the same superscript in the same column are not statistically different at the 5% threshold. MwRP: Maize with Rice straw combined with Peanut; MfRP: Maize free of rice Straw combined with Peanut; MwRC: Maize with Rice straw combined with Cowpea; MfRC: Maize free of Rice straw combined with Cowpea; MwRMb: Maize with Rice straw combined with Mung bean; MfRMb: Maize free of Rice straw combined with Mung bean; MwLf: Maize with Rice straw and Legume-free; MfLf: Maize free of rice straw and Legume-free*

d) Effects of mulching and legumes on maize plant diameter

The specific and combined effects of mulch and legumes on maize plant diameter growth are presented in Table 4. The values varied depending on the stage of growth. At the 15th DAP, maize plant diameter values ranged from 0.46 ± 0.05 cm (MfRC) to 0.58 ± 0.04 cm (MWLF). The largest maize plant diameter tended to be in the mulched plots (MwRP: 0.53 ± 0.03 cm, MwRC: 0.48 ± 0.04 cm, MwRMb: 0.49 ± 0.05 cm and MWLF: 0.58 ± 0.04 cm). However, no significant difference was detected.

At 30 DAP, plant diameter varied significantly ($p < 0.001$) from 1.90 ± 0.09 cm (MfLf) to 2.45 ± 0.10 cm (MWLF). The greatest plant diameter was with the MWLF treatment: 2.45 ± 0.10 cm. All plots mulched plots resulted in more growth (MwRP: 2.41 ± 0.01 cm, MwRC: 2.25 ± 0.08 cm, MwRMb : 2.31 ± 0.15 cm and

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MWLF: 2.45 ± 0.10 cm) compared to plots without mulch (MfRP: 1.97 ± 0.09 cm, MfRC: 2.03 ± 0.05 cm, MfRMb: 1.93 ± 0.06 cm and M: 1.90 ± 0.09 cm). However, legumes had asignificant effect on maize plant diameter growth compared to bare soil (MfLf: 1.90 ± 0.09 cm).

At the 45th DAP, plant diameter did not vary significantly among treatments. The largest diameter was with the MwRMb treatment (3.09 ± 0.10 cm), and the smallest diameter was with the MfRC treatment (1.78 ± 0.09 cm). When the soil was mulched, there was greater growth (MwRP: 2.95 ± 0.12 cm, MwRC: 3.03 ± 0.10 cm, MwRMb: 3.09 ± 0.10 cm and MWLF: 2.96 ± 0.50 cm) relative to the unmulched soil (MfRP: 2.90 ± 0.13 cm, MfRC: 1.78 ± 0.09 cm, MfRMb: 2.94 ± 0.50 cm and MfLf: 2.77 ± 0.08 cm). At this stage of growth, the presence of legumes influenced plant diameter (MfRP: 2.90 ± 0.13 cm, MfRC: 2.78 ± 0.09 cm, and MfRMb: 2.94 ± 0.15 cm) compared to pure maize (MfLf: 2.77 ± 0.08 cm). At the 60th DAP, no significant difference was detected among treatments.

Table 5: Effects of mulching and legumes on maize diameter growth

Collar diameter (cm)					
Treatments		15 DAP	30 DAP	45 DAP	60 DAP
MwRP	M	0.53[a]	2.41[a]	2.95[a]	3.58[a]
	SE	0.03	0.01	0.12	0.83
MfRP	M	0.45[a]	1.97[b]	2.90[a]	2.58[a]
	SE	0.03	0.09	0.13	0.05
MwRC	M	0.48[a]	2.25[a]	3.03[a]	2.76[a]
	SE	0.04	0.08	0.1	0.05
MfRC	M	0.46[a]	2.03[b]	2.78[a]	2.48[a]
	SE	0.05	0.05	0.09	0.11
MwRMb	M	0.49[a]	2.31[a]	3.09[a]	2.80[a]
	SE	0.05	0.15	0.1	0.13
MfRMb	M	0.46[a]	1.93[b]	2.94[a]	2.73[a]
	SE	0.02	0.06	0.15	0.18
MWLF	M	0.58[a]	2.45[a]	2.96[a]	2.87[a]
	SE	0.04	0.1	0.5	0.13
MfLf	M	0.47[a]	1.90[b]	2.77[a]	3.45[a]
	SE	0.04	0.09	0.08	0.83
Freedom Degree		7	7	7	7
p-value		0.447	0	0.392	0.546
Significance		NS	***	NS	NS

*M: mean; ES: standard error; NS: non-significant ($p > 0.05$), ***: $p < 0.001$. Numbers with the same superscript in the same column are not statistically different at the 5% threshold. MwRP: Maize with Rice straw combined with Peanut; MfRP: Maize free of rice Straw combined with Peanut; MwRC: Maize with Rice straw combined with Cowpea; MfRC: Maize free of Rice straw combined with Cowpea; MwRMb: Maize with Rice straw combined with Mung bean; MfRMb: Maize free of Rice straw combined with Mung bean; MwLf: Maize with Rice straw and Legume-free; MfLf: Maize free of rice straw and Legume-free.*

e) *Effects of mulching and legumes on maize grain and biomass*

The effects of mulching and legumes on yield components are shown in Table 5. The different components were similar. Maize stalk weights ranged from 738.50 ± 148.83 kg/ha to 1,054.00 ± 23.47 kg/ha. The best weight of stalks was with the MwRMb treatment (1,054.00 ± 23.47 kg/ha). All mulch treatments improved maize stalk weight (MwRP: 927.80 ± 81.39 kg/ha, MwRC: 941.50 ± 32.59 kg/ha, MwRMb: 1,054.00 ± 23.47 kg/ha and MWLF: 1,015.20 ± 65.35 kg) compared to treatments without mulch (MfRP:

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869.00 ± 26.11 kg/ha, MfRC: 750.00 ± 107.74 kg/ha, MfRMb: 738.50 ± 148.83 kg/ha and M: 920.50 ± 18.77). Legumes did not improve stalk weight ($p > 0.05$).

For the number of ears per hectare, values ranged from 26,000.00 ± 3,135.82 ears/ha (MfRC) to 38,500.00 ± 1,658.51 ears/ha (MwRMb). Here, no difference was detected among treatments. Table 5 showed that 1,000 grains weight ranged from 287.80 ± 1.89 kg (MfRMb and MfLf) to 303.50 ± 8.92 kg/ha (MwRMb). The greatest 1,000 grains weight was with the mung bean-mulch treatment (MwRMb: 303.50 ± 8.92 kg/ha). No significant difference was detected among treatments for 1,000 grain weight.

Grain yield varied among treatments. The greatest grain yield was with the MwRP treatment (4,479.00 ± 39.70 kg/ha), and the lowest yield was with the MfLf treatment (3,288.00 ± 328.75 kg/ha). All mulch treatments improved grain yield (MwRP: 4,479.00 ± 39.70 kg/ha, MwRC: 4,385.00 ± 61.94 kg/ha, MwRMb: 4,435.00 ± 447.32 kg/ha and MWLF: 4,105.00 ± 267.98 kg/ha) compared to treatments without mulch (MfRP: 3,884.00 ± 58.95 kg, MfRC: 3,430.00 ± 491.59 kg/ha, MfRMb: 3,735.00 ± 641.86 kg/ha and MfLf: 3,288.00 ± 328.75 kg/ha). Treatments combining legumes (MfRP, MfRC, and MfRMb) also improved this parameter compared to bare soil (MfLf). The analysis of variance did not reveal significant differences among treatments.

The highest amount of dry matter was with the MWLF treatment (7,026.00 ± 1,084.00 kg/ha), and the lowest value was with the MfRMb treatment (4,316.00 ± 447.50 kg/ha) with no significant difference detected among treatments (Table 5). The number of grains per ear ranged from 518.00 ± 12.32 grains/ear (MfRP) to 600.10 ± 10.80 grains/ear (MwRMb). All treatments combining legume-mulching improved the number of grains/ear (MwRP: 597.50 ± 19.51 grains/hair, MwRC: 574.70 ± 13.40 grains/ear and MwRMb: 600.10 ± 10.80 grains/ear) compared to simple mulching (MWLF: 557.00 ± 19.28 grains/ear) and bare soil (M: 564.60 ± 30.75 grains/ear). Legumes with maize (MfRP: 518.00 ± 12.32 grains/ha, MFRC: 535.60 ± 21.57 grains/ha and MfRMb: 525.40 ± 14.96 grains/ha) did not significantly ($p > 0.05$) improve grain count compared to mulching alone (MWLF: 557.00 ± 19.28 grains/ha) and bare soil (M: 564.60 ± 30.75 grains/ha).

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Table 6: Yields and yield components as a function of mulching and legumes

Treatments		Stalk weight (kg/ha)	Number of ears/ha	Thousand Grains Weight(g)	Total Grain Weight (kg/ha)	Straw yield (kg/ha)	Number of grains/ears
MwRP	M	927.80[a]	29,500.00[a]	298.20[a]	4,479.00[a]	5,988.00[a]	597.50[a]
	ES	81.39	2,101.59	6.43	39.7	935.7	19.51
MfRP	M	869.00[a]	31,500.00[a]	288.80[a]	3,884.00[a]	4,535.00[a]	518.00[c]
	ES	26.11	1,892.97	3.2	58.95	489.51	12.32
MwRC	M	941.50[a]	32,750.00[a]	293.20[a]	4,385.00[a]	5,772.00[a]	574.70[a]
	ES	32.59	3,119.16	6.42	61.94	241.95	13.4
MfRC	M	750.00[a]	26,000.00[a]	297.50[a]	3,430.00[a]	5,464.00[a]	535.60[c]
	ES	107.74	3,135.82	6.03	491.59	468.26	21.57
MwRMb	M	1 054.00[a]	38,500.00[a]	303.50[a]	4,435.00[a]	5,064.00[a]	600.10[a]
	ES	23.47	1,658.31	8.92	447.32	623.81	10.8
MfRMb	M	738.50[a]	28,750.00[a]	287.80[a]	3,735.00[a]	4,316.00[a]	525.40[c]
	ES	148.83	4,385.11	1.89	641.86	447.5	14.96
MWLF	M	1 015.20[a]	36,250.00[a]	298.20[a]	4,105.00[a]	7,026.00[a]	564.60[b]
	ES	65.35	1,652.02	2.69	267.98	1,084.00	19.28
MfLf	M	920.50[a]	31,750.00[a]	287.80[a]	3,288.00[a]	5,330.00[a]	527.00[c]
	ES	18.77	2,780.14	1.89	328.75	455.07	30.75
Freedom Degree		7	7	7	7	7	7
p-value		0.064	0.074	0.357	0.175	0.143	0.036
Significance		NS	NS	NS	NS	NS	*

*M: mean; ES: standard error; NS: non-significant ($p > 0.05$), *: $p < 0.05$. Numbers with the same superscript in the same column are not statistically different at the 5% threshold. MwRP: Maize with Rice straw combined with Peanut; MfRP: Maize free of rice Straw combined with Peanut; MwRC: Maize with Rice straw combined with Cowpea; MfRC: Maize free of Rice straw combined with Cowpea; MwRMb: Maize with Rice straw combined with Mung bean; MfRMb: Maize free of Rice straw combined with Mung bean; MwLf: Maize with Rice straw and Legume-free; MfLf: Maize free of rice straw and Legume-free*

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IV. Discussion

a) Effects of mulching and legumes on soil moisture

Mulching improved soil moisture status compared to bare soil at the 21st DAP of maize. Mulching protects the soil from direct sunlight, which reduces water loss by evaporation. These results are similar to results from previous studies (Bougoum, 2012; Kohio, 2015; Doumbia, 2016). However, by the 35th DAP, mulching did not have a significant effect on soil moisture. We noticed a progressive loss of mulch cover due to its decomposition. The straw deteriorated throughout the growing season and its impact on soil moisture diminished.

Concerning the effect of legumes on soil moisture, the results revealed that legumes tended to increase soil moisture compared to soil without cover crops at the 49th DAP of maize. Legumes as cover crops protect the soil from direct sunlight, thereby reducing evaporation from the soil surface. Balboné (2013) found that they increased soil moisture levels when legumes were combined as cover crops. In addition, Coulibaly (2012) reported that biomass production of legumes protects the soil, thereby reducing evaporation from the soil surface. Salez (1988) also pointed out that legume covers reduce the risk of erosion and improve soil moisture. Our results indicate that the effect of legumes varies with the crop species, likely by the fraction of soil cover provided by the legumes. The results confirm those by Balboné (2013), who reported that the effect of cover crops on soil moisture depended on the percent of soil covered and the stage of crop development. In our work, the impact of legumes on soil moisture status was significant at 56 DAP. During this period, cowpea and groundnut reached their maximum surface coverage, which was 99.92% and 89.91%, respectively.

Mulching effects on soil moisture was more pronounced when combined with cover crops such as legumes. Legumes increase the amount of biomass covering the soil. Our results agree with those of Bougoum (2012). Similarly, Doumbia (2016) highlighted that soil moisture content increased with the amount of biomass used.

b) Effects of mulching and legumes on weed growth

The evolution of the weed growth rate differs from one treatment to another. A non-significant difference was detected among treatments regarding the effect of mulching on the rate of grassing. But the rate was higher on the straw plots than on the bare soil. This could be explained by a lack of straw covering the soil, which favored weed development due to moisture. Fredon (2012) indicated that in weed control with mulch, the thickness of the mulch is essential and must be adapted to the materials used. In addition to this component, localized irrigation reduces the amount of weed control by reducing the amount of water available for weeds. Since the moisture content was improved on straw soils, this encouraged weed development. Results overall showed that legumes reduced weed development at 56th DAP of maize. These results could be explained by the ground cover of legumes smothering the weeds. In addition to this aspect, the high biomass production of legumes limits the germination and development of weeds. These results are consistent with those by Espoir et al. (2013), who indicated that when soybean (*Glycine max*) was used as a cover crop, it reduced weed development. Hien (2004) found that the effect of cowpea on weeds was most pronounced at 50th DAP maize. Dao (2014) confirmed these results and reported that the rate of weed growth was low in the maize-cowpea association compared to a pure maize crop. However, we found that weed cover was higher in legume crops than in pure crops from the beginning of production. Mulching using legumes depends on their stage of development (Balboné, 2013).

Similarly, Pamba et al. (2018) had shown that the installation of Mucuna (*Mucuna pruriens* L.) limited the development of weeds such as *Cynodon dactylon*, *Digitaria* sp., and *Imperata cylindrica*. These authors attributed the effect of mucuna to its shading, which was detrimental to weed development. By the 44th DAP, legumes had no significant effect on weed development. The soil moisture content increased, which would enhance weed development. Indeed, Pama et al. (2018) showed that weed control by association is essential in areas with low rainfall.

When combining mulch with legumes, it generally reduced the weed cover at 56th DAP for maize. Legumes increased the amount of biomass available on the soil surface, making it possible to cover the soil well. These results align with Bybee et al. (2018), who showed that crop association could reduce the amount of grass on land plots. Lawane et al. (2010) reported similar results by combining cowpea with cereals to control Striga (*Striga hermontica*).

c) Effects of mulching and legumes on maize growth

The most significant growth was under mulch. Mulching improves soil moisture, mineralization and increases the water available to the plants. Minengu et al. (2015) found similar results for maize plant growth on different cropping systems. Thus, for these authors, soil cover with *Sytholantes guineensis* associated with maize improves the cereal's growth in height and diameter. In contrast, Kouelo et al. (2017) found that mulching had no significant effect on maize crown diameter. According to Azontondé (1993), legumes protect soil and increase earthworm activity, improving soil structure. Improved soil structure allows good rooting and promotes soil colonization by the surface roots of maize plants. In intercropping system, maize makes better use of nitrogen fertilization (Mvondo, 1986). When organic manure is applied, cover crops improve the

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nitrogen status of the soil (Balboné, 2013). Atmospheric nitrogen fixation also improves the nitrogen status of the soil (Barikissou, 2012). The improved growth of maize plants in combined legume and mulch treatments is partially explained by the recycling of leached nutrients (Espoir et al., 2013).

Maize grew slowly on plots without mulch because of the rapid drying and moisture loss from unmulched plots, which increases soil strength and slows down the plant root development and slowing mineralization. The unmulched treatments had the lowest growth in plant diameter and height because of the reduced capacity of bare, legume-free soil to promote plant development. This reflects the importance of legume and straw cover.

Moreover, for the diameter at the collar, the difference in mulch combined with legumes was more pronounced from the 30th DAP onwards due to mulch deterioration and nutrient mineralization, leading to improved soil structure, resulting in better water infiltration. However, there was no detectable difference among treatments combining legumes with mulch and the mulch control alone. The nitrogen status of the soil improved plant growth. The application of urea on the 30th DAP, improved the available nitrogen on plots without legumes. After this stage, there was no significant difference between treatments combining legumes with mulching and mulching alone. Overall, all maize plants showed good vegetative development. The drip irrigation system applied sufficient water, as explained by Millogo et al. (2021). Devroc et al. (1982) reported that excess water leads to reduced growth and delayed development of maize plants regardless of the stage at which it occurs.

d) Effects of mulching and legumes on corn yield components

The grain yields were below the variety's genetic potential, estimated at 5.1 t/ha (Sanou, 2009). This low level of performance could be attributed to external factors. Because the experiment was not conducted in a controlled environment, it is subject to climatic conditions that influence maize productivity. Some authors, especially Durburcq et al. (1983), have found a correlation between air temperature and female-flower initiation. This period corresponds to the ear placement and determines the potential for grain production. The high trend in the average number of grains per ear with mulch compared to bare soil would be due to the decomposition of the straw, which enriches the soil and improves its structure. Mulching creates favorable conditions for maize development by improving soil moisture.

However, mulching and legumes did not have a significant effect on grain yield. This could be explained by the fact that there is no water stress in drip irrigation, and secondly, the effect of legumes on soil fertility is long-term. Our results vary from Kouelo et al. (2017), who found that maize grain yield increased from 1,020.5 kg/ha without cover to 2,138.17 kg/ha with cover. These results are also contrary to Roose (2015), who reported that reducing evaporation from the soil surface through straw mulch led to increased crop yields. Our work was under a drip irrigation system. Like Roose (2015), Masvaya et al. (2017) found that mulching combined with organic fertilization increased yield after two years of production. These authors pointed out that straw mineralization increases the amount of nitrogen available in the soil.

Mulching tends to increase straw yield. This work showed an increase in soil moisture and an improvement in soil carbon content due to straw mineralization. These results are in line with those by Bougoum (2012), whereby the effect of mulching was more pronounced in monoculture than in intercropping. Results when including legumes were better than the control because of the improved nitrogen status of the soil from legumes. Legumes also cover the soil cover and increase soil moisture. Our findings are consistent with Salez (1988), who found that more efficient legume resources naturally lead to higher yields.

The results are also in line with Lawane et al. (2010), who pointed out that legumes associated with cereals such as sorghum and millet gave better yields than pure crops. Similar results were reported by Azontondé (1993), stating that the maize-mucuna association increased maize yield. According to Azontondé (1993), the yield increases from 0.2 t/ha in pure culture to 2.8 t/ha in associated culture. Similarly, Pama et al (2018) found that mucuna cover improved maize yields. Mucuna limited the development of weeds, which reduced the competition between maize and weeds. Our results are consistent with Coulibalily et al. (2017a, 2017b), who reported that the crop association increased maize grain yield and that this increase was continuous.

The high associated crop yields are explained by the planting date of the legume, which minimized competition during early growth. According to Fayaud (2012), early growth determines the effectiveness of crop association. Our results agree with Bougoum (2012) that mulching combined with crop association contributed to an increase in sorghum yield of 33 to 72%. Gbakatchetche et al. (2010) also reported that mulching the soil with pigeon pea (*Cajanus cajan* L.) residues increases maize yield.

V. Conclusion

A 3 t/ha rice straw mulch conserved soil moisture in an ASMC drip irrigation system. Mulching improved maize plant growth and the number of grains per ear. However, inadequate mulching favored weed growth the soil was not completely covered. Legumes

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did not significantly affect maize growth but had a significant positive effect on soil moisture. The effect of legumes on soil moisture depended upon the legume species used. Peanut and mung bean was more effective than cowpea. Like mulching, legumes tend to promote weed growth at the beginning of production, but as the crops develop, they reduce the rate of weed growth. The combination of cropping and mulching thus reduces grass cover and improves soil moisture during the dry season. Simply mulching or mulching in combination with legumes tends to improve maize growth parameters. Thus, legumes in combination with mulching partially improve the growth parameters of maize.

Mulching alone or in association with legumes did not significantly improve maize yield under drip irrigation. Additionally, some legumes had more noticeable effects with straw. Legumes combined with mulch did not increase maize yield in the dry season. Due to the high yield of maize which could reach 3 to 4 t/ha compared to on-farm yields, maize production could be recommended under a drip irrigation system in Burkina Faso, especially for seed production in case of natural disaster. This work can facilitate interaction between producers and researchers searching for new technologies for changing agriculture. This technology would reduce the operational costs of weed control. In the context of food insecurity due to the scarcity of rainfall linked to climate change, these results show how it would be possible to diversify production during the dry season in a sustainable manner.

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References Références Referencias

1. Balbone I., 2013. Effets des cultures sur la couverture et les paramètres du sol pour la durabilité des systèmes de culture : cas des sols ferrugineux tropicaux de la station de recherche de Farako-Bâ. Mémoire de Master en gestion intégrée de la fertilité des sols. Institut du Développement Rural. Université Polytechnique de Bobo-Dioulasso. Bobo-Dioulasso, Burkina Faso. 39 p.
2. Barikissou E., 2012. Elaboration d'un protocole in vitro de contournement des barrières d'incompatibilité génétique entre *Phaseolus coccineus* L. et *Phaseolus vulgaris* L. Thèse de doctorat, Option Sciences Agronomiques et Ingénieries Biologiques. Communauté Française de Belgique, Académie Universitaire Wallonie-Europe. Université de Liège Gembloux, *Agro Bio Tech*. 141 p.
3. Bougoum H., 2012. Analyse des effets spécifiques et combinés des principes de l'agriculture de conservation sur la conduite et les performances technico-économiques des parcelles de Sorgho (*Sorghumbicolor* (L.) Moench. Mémoire d'Ingénieur. Institut du Développement Rural. Université Polytechnique de Bobo-Dioulasso. Bobo-Dioulasso, Burkina Faso 65 p.
4. Bybee K. A. F. et Ryan M. R. 2018. Advancing intercropping research and practices in industrialized agricultural landscapes. *Agriculture* 8: 80.
5. CEDEAO, 2015. L'agriculture et l'alimentation en Afrique de l'Ouest : mutations, performances et politiques agricoles. Abuja, Nigéria. 138 p.
6. CNS (Comité National des Semences), 2014. Catalogue des espèces et variétés agricoles du Burkina Faso. Ministère de la Recherche Scientifique et de l'Innovation. Burkina Faso. 81 p.
7. Coulibaly D., Ba A., Dembele B. et Sossoko F., 2017a. Développement des systèmes de productions innovantes d'association maïs/légumineuses dans la zone subhumide du Mali. *Agronomie Africaine Sp* 29(1): 1-10.
8. Coulibaly K., 2012. Analyse des facteurs de variabilité des performances agronomiques et économiques des cultures et de l'évolution de la fertilité des sols dans les systèmes agropastoraux en milieu soudanien du Burkina Faso : approche expérimentale chez et par les paysans. Thèse de doctorat. Option Système de production végétale, Institut du Développement Rural, Université Polytechnique de Bobo-Dioulasso. Bobo-Dioulasso, Burkina Faso. 140 p.
9. Coulibaly K., Gomgnimbou A. P. K., Traore M., Nacro H. B. et Sedogo M. P., 2017b. Effets des associations maïs-légumineuses sur le rendement du maïs (*Zea mays L.*) et la fertilité d'un sol ferrugineux tropical à l'ouest du Burkina Faso. *Afrique Science* 13(6) : 226-235.
10. Coulibaly K., Vall E., Autfray P. et Sedogo P.M., 2012b. Performance technico-économique des associations maïs/niébé et maïs/mucuna en situation réelle de culture au Burkina Faso : potentiel et contraintes. *Tropicultura*, 30, 3,147-154.
11. Coulibaly K., Vall E., Autfray P., Bacye B., Somda I, Nacro H.B. et Sedogo M.P., 2012a. Co-conception d'itinéraires techniques de culture pure du niébé (*Vigna unguiculata* L.Walp) et du mucuna (*Mucuna deeringiana* Bor(t), Merril) dans la zone cotonnières Ouest du Burkina Faso : intérêts et limites. *Journal*

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of agriculture and Environment for International Development. JAEID, 106(2):139-155.

12. Crasky R.J., Douthwaite B., Manyong V. M., Snaguiga N., Schulz S., Van Lauwe B., Diels J. et Keatinge J. D. H., 2003. Amélioration de la gestion des sols par l'introduction de légumineuses dans les systèmes céréaliers des svanes africaines. *Cahiers Agricultures*, 12 : 227-233.
13. Dao L., 2014. Effets de different modes d'associations sur la productivité du maïs (Zea mays) et du niébé (Vigna unguiculanta L. Walp) en milieu contrôlé. Mémoire d'Ingénieur. Option agronomie, Institut du Développement Rural. Université Polytechnique de Bobo-Dioulasso, Bobo-Dioulasso Burkina Faso. 40 p.
14. Doumbia S. 2016. Effet de l'agriculture de conservation sur les flux hydriques, la fertilité du sol et les rendements des cultures en station à l'ouest du Burkina Faso. Mémoire d'Ingénieur. Option agronomie, Institut du Développement Rural. Université Polytechnique de Bobo-Dioulasso, Bobo-Dioulasso. 58 p.
15. Dudurcq J. B., Bonhomme R. et Derieux M., 1983. Durée des phases végétative et reproductrice chez le maïs. Influence du génotype et du milieu. *Agronomie, EDP Science*, 3(10) : 941-946.
16. Espoir M. B., Sylvain M., K. Katcho et N. G. Mushagalusa, 2013. Efficience des techniques de gestion de l'eau et de la fertilité des sols sur le rendement du maïs dans les régions semi-arides : cas de la plaine de la Ruzizi (Sud-Kivu, République Démocratique du Congo). Vertigo. La revue électronique en sciences de l'environnement. URL: http://journals.openeditions.org/vertigo/13922 consulté le 30 Janvier 2019
17. FREDON (Federation Regionale de Defense contre les Organismes Nuisibles), 2012. Utilisation de paillis pour la maitrise des adventices sur massifs arbustifs. Rapport d'étude. France.12 p.
18. Gbakatchetche H., Sanogo S., Camara M., Bouret A. et Keli J Z. 2010. Effet du paillage par des residus de pois d'angole (*Cajanus cajan* L.) sur le rendement du riz (*Oryza sativa*) pluvial en zone forestière de la Côte d'Ivoire. *Agronomie Africaine*. 22 (2) : 131-137.
19. Fontes J. et Guinko S., 1995. Carte de la végétation et de l'occupation du sol du Burkina Faso: notice explicative. Ministère de la coopération Française. 53 pages.
20. Heno J. et Branante C., 2006. Soil nutrient mining in Africa. IEDC. Report final. Agricultural production and soil ntient minig in Africa. 13 p.
21. Hien E., 2004. Dynamique du carbone dans un acrisol ferrique du Centre-Ouest du Burkina Faso: influence des pratiques culturales sur le stock et la qualité de la matière organique. Thèse de doctorat, Ecole Nationale supérieure Agronomique de Montpellier, France, 137 p.
22. INSD, 2007. Résultats préliminaires du recensement général de la population et de l'habitation (RGPH) de 2006 du Burkina Faso. Ouagadougou, Burkina Faso. 51 p.
23. Kohio B. E., 2015. Effet de différents niveaux de paillage sur la fertilité du sol, le flux hydrique et les rendements des cultures en milieu contrôlé. Mémoire d'Ingénieur. Institut des Sciences de l'Environnement et du Développement Rural. Centre Universitaire Polytechnique de Dédougou. Université de Ouagadougou. Burkina Faso 61 p.
24. Kouelo A.F., Hougnandan P., Azontonde A., Benmansour M., Bekou J. et Akplo T., 2017. Effet des pratiques de l'agriculture de conservation sur la croissance et les composantes du rendement du maïs dans le bassin versant de Lokogba au Bénin. *Agronomie Africaine* 29 (1) : 65-78.
25. Lawane G., Pabame S., Lendzemo V., Gnokreo F., Djimasbeye N., Ndoutamiala G., 2010. Efficacité de l'association des céréales et du niébé pour la production des grains et la lutte contre le Striga hermonthica (Del.). L. SEINY-BOUKAR, P. BOUMARD. Savanes africaines en développement: innover pour durer, Apr 2009. Garoua, Cameroun. CIRAD, 8 p.
26. MAHRH, 2011. Document guide de la révolution verte. Ouagadougou, Burkina Faso Septembre, 98 p.
27. Marnotte P., 1984. Influence des facteurs agroécologiques sur le développement des mauvaises herbes en climat tropical humide. 7 ème coll. Int. Ecol. Biol. et Syst. Des Mauvaises herbes. COLUMA-EWRS Paris France, 183-189.
28. Masvaya E. N., Nyanmangara J., Deschemaeker K. and Giller K. E., 2017. Tillage, mulch and fertilizer impact on soil nitrigens availability and maize production in semi-aride Zimbabwe. *Soil and Tillage Reseach* 168 : 125-132.
29. Millogo V, Kéré M, Yé D.V, Amoussou T.O, B R, Harrigan T and Srivastava A., 2021. Assessment of Water distribution Efficiency Using Solar Powered Drip Irrigation System Convenient for West Burkina Faso Small Scale Farming. Irrigation and Drainage Systems Engineering, Volume 10:9.
30. Minengu J.D.D, Mobambo P. et Mergeai G., 2015. Etude des possibilités de production de Jatropha curcas L. dans un couvert permanent de Stylosanthes guineensis (Aublet) Swartz en association avec (Zea mays L.) et le soja (Glycine max (L.) Merr.) dans les conditions du plateau de Batéké à Kinshasa. *Tropicultura*, 33 (4) : 309-321.
31. Mvondo Nkodo, 1986. Etude des principales caractéristiques de l'association culturale maïs (*Zea mays* L.)-Soja (*Glycine max*. L. Merrill) dans les conditions écologique de Dschang. Dschang:

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Institut de la Recherche Agronomique; Mémoire de fin d'étude. Agronomie, option: production végétales.68 p.
32. Pamba M., Muwa J. C. et Mwengi I. 2018. Etude des possibilités de production du maïs (Zea mays L.) et de soja (Glycine max L. (Merr)) sur couverture de Mucuna pruriens (L.) DC dans les conditions écologiques de Kikwit en République Démocratique du Congo. Révue Africaine d'Environement et d'Agriculture. 1 (1): 30-35.
33. RGA, 2010. Direction de la prospective et des statiques agricoles et alimentaires.
34. Roose E., 2015. Potentiel du paillage pour réduire et restaurer la productivité des sols tropicaux : une revue en Afrique francophone. IRD Editions. Institut de Recherche pour le Développement Montpellier, France.
35. Rusinamhodji L., Corbeels M., Nyamangaro J. et Giller K.E., 2012. Maize-grain legume intercroping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in Central Mozambique, *Field crop Res*., 136:12-22.
36. Salez P.1988. Compréhension et amélioration des systèmes de cultures associées céréales-légumineuses auCameroun. Thèse de doctorat. Ecole Nationale Supérieure Agronomique de Montpellier. Fance. 191 p.
37. Sanou J., 2009: Variétés de maïs vulgarisées au Burkina Faso, actualisation 2009. INERA/CT, 2 p.
38. Sonou M. 2010 : Capitalisation d'expériences sur le développement de la petite irrigation privée pour des productions à haute valeur ajoutée en Afrique de l'Ouest: rapport final; 140 p.
39. Tapsoba K. P., 2016. Contribution des cultures maraichères à la situation alimentaire au Burkina Faso : cas de Bobo-Dioulasso, Ouagadougou et Ouahigouya. Mémoire d'ingénieur. Option sociologie et économie rurale. Institut du Développement Rural. Université polytechnique de Bobo-Dioulasso. Bobo-Dioulasso, Burkina Faso. 46 p.
40. Yé D. V, 2018. Conception, installation et évaluation d'un système d'irrigation goutte à goutte pour la production de légumes dans le village de Sonssogona. Mémoire d'Ingénieur. Option agronomie. Institut du développement Rural. Université Nazi BONI. Bobo-Dioulasso, Burkina Faso. 56 p.

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