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Soil water retention and plant growth response on the soil affected by continuous organic matter and plastic mulch application

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Soil water retention and plant growth response on the soil affected by continuous organic matter and plastic mulch application

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Abstract. Soil-water and plant growth interaction is a primary key to develop environmental plant production system. The objective of this research is to evaluate change in soil water retention characteristics and plant response as the effect of continuous organic matter and plastic mulch application. The experiment was conducted in the plastic house field with plot size of 5 m (length) x 1 m (width). The field had treatments of plastic mulch type (mesh and poly) and no mulch, nitrogen (0, 10 and 40 kg N ha⁻¹), and 2 ton ha⁻¹ organic matter (incorporated into all plots). Water retention measurement using sand box method for low suction and pressure plate apparatus was applied for high suction. Completely randomized block experimental design and Duncan-MRT were used to analysis the effect of treatment on the parameters. Soil organic carbon and nitrogen increased slightly in both mulch types, but C:N ratio decreased in poly mulch which had the lowest value during two planting season. Various change in soil water retention was shown in different mulch type with mesh mulch had the highest result on lower suction, and control was the lowest water retention on the high suction. Soil water availability was highest in mesh mulch type followed by control and poly mulch type. This study could conclude that continuous incorporation of organic matter and mesh-plastic mulch was useful in achieving environments to improve soil C:N ratio and soil water retention.

1. Introduction

Soil-water and plant growth interaction has become a crucial issue in soil-water and nutrient management to maintain sustainable plant productivity. Nutrient dissolution and movement process from rhizosphere to plant uptake could be well done supported by soil water. Therefore, soil water availability had to be criticized as the limitation factor to optimize crop production. Soil texture and organic matter in soil have been considered the key components that determine soil water retention [1]. Soil organic matter content and composition affect both soil structure and adsorption properties; so, water retention may be affected by changes in soil organic matter [2]. However, the effect of continuous crop residues incorporation is still under discussion, especially if change of soil water retention characteristics were taken into account.

Incorporation of organic matter had been put into practice as soil amendment in protect the soil from solar energy to reduce evaporation and aid in moisture retention to decrease soil water loss [3]. Several



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studies conclude that soil moisture, rather than temperature, has the most significant influence on soil organic matter [4]. Moreover, soil organic matter had been applied as an important factor to predict soil water retention characteristics [5, 6]. Combining method between organic matter incorporation and mulching is still an interesting challenge to be explored in order to improve of soil water loss prevention and characterized soil water retention. Mulch, itself could be act as barriers to movement of moisture out of the soil [3], ensure maintenance of a lower water content in soils from zone with high rainfall, reduce nutrient leaching, and increased yield [7]. In many cases, type and kind of mulch materials were most consider to be applied in crop production. Filipov [8] explained that the wide variety of plastic mulch has different properties: reflect, absorb or transmit sunlight, determine a specific microclimate around a crop plant and inside of high tunnels or greenhouses, is effective at reducing weed growth (except in the planting holes).

The most popular type of plastic mulch was polyethylene (PE) which has excellent tensile strength as the requirement for mechanical application of the plastic mulch and to resist tearing when exposed to strong win and foot traffic. Beside it, mulch color could be influence on the microclimate. In this study plastic mulch become consideration to be evaluate because there are wide variety of plastics have been used in the field, recently. Specially in Japan agriculture, growing plant in greenhouse or in “high plastic tunnels/house” field with plastic covering and mulching soil surface have been popular and usual practices. Nowadays, two types of black polyethylene *i.e.* high- density and low-density of polyethylene were most used mainly in the plastic house field. Low-density polyethylene type is called “mesh plastic” because this type has micro pore which has capacity to drain and evaporate water. The objective of this study is to evaluate change in soil water retention characteristics and plant growth response as affected by continuous incorporation of organic matter and plastic mulch. Better knowledge and considerable information from this study result could be applied as strategic technology within soil-water and nutrient management.

2. Materials and methods

The experiment was conducted in two plastic houses field with plot size of 5 m (length) x 1 m (width) of Tropical Agriculture Research Front (TARF) – Japan International Research Center for Agricultural Sciences (JIRCAS), Ishigaki, Okinawa Prefecture. Soil type is considered as Ultisols [9]. The experiments was set up using a completely randomized block design with treatment two types of plastic mulch (mesh and poly) and control (no mulch), nitrogen (0, 10, and 40 kg N ha⁻¹). Rose grass and Okra (*Abelmoschus esculentus*) was growth to evaluate plant growth response on incorporated soil by 2 ton ha⁻¹ of organic matter. Disturbed soil sample was collected for chemical properties analysis and undisturbed sample using ring cores sample (2.5 cm in height and 50 cm³ in volume) for water retention measurement.

The hanging water principle is applied on sand box method for low suction of pF 0.5 to 1.5. Measurement of high suction of pF: 2.0, 2.5, 3.0, 3.5, and 4.2 was using pressure plate apparatus. Measurement preparation was done by saturated all samples in the tray with tap water for 48 h. During this process, capillary raised was perform in all samples by adding water gradually into tray until around 5 mm below the core’s upper edge to exclude air trapped in soil. Fully saturated sample is then transferred to sand box chamber for low suction and pressure plate chamber for high suction measurement.

The water content at each suction step was calculated when equilibrium was attained at each suction. In sand box chamber, equilibrium was attained when water was stop to drain until the position of height suction reached. The equilibrium in pressure chamber was reached until no water move out from chamber drain pipe. After equilibrium in each suction, soil sample and then weighed as defined as wet mass. Dried mass sample was obtained after measurement of the pF 4.2, the cores were oven dried in temperature of 105 °C for 48 h and then weighed as defined as dried weighed. Water content calculation was done by gravimetric method and the results were converted to volumetric basis, since the amounts of water remaining in the soil at any equilibrium state is a function of the size and volume of water filled pores.

Total soil organic carbon and nitrogen content was analyzed using an Automatic High Sensitive NC Analyzer, Sumigraph NC-22F. Plant response was determined based on dry weight of plant biomass. The mean values of the results were analyzed using SPSS ver. 20. General linear regression further analyzed the amount of variance explained by the dependence of one variable on another where treatments relationship was implied. Significant differences tested with RMS-Duncan post-hoc test.

3. Results and discussion

3.1 Change in Soil Organic Matter, Nitrogen Content and C:N Ratio

Incorporation of organic matter into soil could be contribute to increase soil organic matter and nitrogen. Total soil organic matter, nitrogen content and C:N ratio in each treatment in the soil with continuous organic matter incorporation is shown in table 1. Slightly difference was found among treatment on soil organic matter, nitrogen content and C:N ratio. It showed for nitrogen increased in average only 0.001% and soil organic matter increased in average 0.07%. Nitrogen changed almost same in all treatment except in addition 40 kg N with increasing of 0.004% N, however in case of soil organic matter the highest value of 0.09% C was found in 10 kg N treatment. Change in C and N value had directly implication to C:N ratio. In respect to the effect of nitrogen and mulch on C:N ratio showed decreasing of C:N ratio during two planting season.

Table 1. Average of soil organic matter, nitrogen and C:N ratio on two planting season

Treatment	Soil N		Soil OM		C:N ratio	
	1 st (%)	2 nd (%)	1 st (%)	2 nd (%)	1 st season	2 nd season
Control	0.125 (0.034)	0.126 (0.028)	1.102 (0.20)	1.174 (0.287)	9.486 (0.382)	8.795 (0.588)
Mesh mulch	0.120 (0.027)	0.121 (0.022)	1.060 (0.17)	1.118 (0.214)	9.404 (0.382)	8.786 (0.420)
Poly mulch	0.125 (0.030)	0.126 (0.022)	1.080 (0.17)	1.156 (0.251)	9.315 (0.359)	8.629 (0.280)
0 kgN	0.118 (0.027)	0.119 (0.020)	1.054 (0.15)	1.106 (0.225)	9.458 (0.400)	8.893 (0.476)
10 kgN	0.132 (0.030)	0.130 (0.026)	1.131 (0.22)	1.220 (0.264)	9.279 (0.232)	8.696 (0.214)
40 kgN	0.120 (0.032)	0.124 (0.025)	1.056 (0.15)	1.122 (0.252)	9.468 (0.445)	8.621 (0.549)

(...) standard deviation

Nitrogen treatment in relation to C:N ratio for the first season of 40 kg N was the highest value, but it became the lowest in the second season. For mulch treatment was maintained the lowest value in poly mulch type during both the season. This result informed an important function of poly mulch type combine with high dose nitrogen in mineralization of organic matter when it applied into soil continuously. The organic matter could be higher value in poly mulch type as the maintaining of temperature conditions during all growth season. For mulch treatment was maintained the lowest value in poly mulch type during both the season.

3.2. Evaluation of Plant Response to the Applied Treatment

Biomass of pasture (rose grass) and okra was used to evaluate plant response in treatment of plastic mulch and nitrogen after two cropping seasons. Statistical analysis showed there is no significant effect among all treatments in biomass of rose grass (table 2). The highest result was performed in combination treatment of mesh plastic-mulch type and 40 kg ha⁻¹ N with biomass weight of 15.23 kg. However, on

single treatment of plastic mulch was shown poly mulch had the highest value of 12.83 kg in total average of biomass weight. In case of nitrogen was found biomass of 12.84 kg as the highest result came from treatment of 10 kg ha⁻¹ N. Even biomass yield on this first season was shown no significant among the treatment, but the possibility of nutrient support to the second planting season could be adapted.

Table 2. Biomass of rose grass and okra after two cropping season

Plant	Nitrogen		
	0	10	40
Rose grass	11.00±2.1	12.84±1.6	11.92±2.6
	10.56 ^{ns}	12.37 ^{ns}	12.83 ^{ns}
	Mulch		
	Control	Mesh	Poly
	10.56±2.3	12.50±1.9	13.16±1.6
	11.0 ^{ns}	11.93 ^{ns}	12.84 ^{ns}
Okra	Nitrogen		
	0	10	40
	4.73±2.2	3.75±1.9	4.71±2.1
	3.75 ^{ns}	4.71 ^{ns}	4.73 ^{ns}
	Mulch		
	Control	Mesh	Poly
2.55±0.5	3.82±0.9	6.81±1.2	
2.55*	3.82*	6.81*	

Value reported as mean, standard deviation and subset of Duncan-MR test

With regards to decreasing of C:N ratio, there is possibility additional nutrient from decomposition of organic matter. This expectation can be proven and explained based on the second cropping result. In the second cropping season with Okra as experiment plant was shown significant different in mulch treatment. The result in total average showed increasing of Okra production more than twice with application of poly mulch compare to control and mesh treatment. In the combination treatment, the highest value of 8.27 kg was found by poly mulch without nitrogen (0 kg N) application. In case of fertilizer, there is tendency of nitrogen treatment have no effect to increase biomass yield. General biomass yield evaluation between two house field has found that almost biomass yield in both house field has difference value range 10% - 26.5% (unpublished raw data). Comparing result tendency between single, combination treatment and total average could be generated explanation as the differences of environmental characteristic of two house field. However, increasing of yield is still need to be evaluated regarding on biomass yield using continuous incorporation of organic matter.

3.3. Soil Water Retention in Plastic Mulch and Nitrogen Treatments

Change of soil water retention for type of plastic mulch and nitrogen treatment with increasing of pressure suction is presented in figure 1. Mulch application has clear effect to water retention compare to none mulch or fertilizer treatment in both cropping season. Water retention of mesh mulch (46.8% and 13.3%) and 10 kg N ha⁻¹ (43.7% and 11.8%) in each low to high suction had high moisture content compare to other result for single treatment. Figure 2a and b show the different tendency of moisture content result in mulch and nitrogen treatment for the both cropping season. The highest water retention of 32.48 % could be retained by mesh type while none mulch (control) only 26.16 % vol. basis on the suction range of pF 0.5 to 4.2. Nitrogen treatment has no different moisture content in all evaluated suction with average value range of 28.23% to 30.26 % vol. basis. Water retention in combination treatment between mesh mulch and 10 kg N ha⁻¹ was shown the optimum moisture content with 47.4% in the low suction and 14.6% in the high suction.

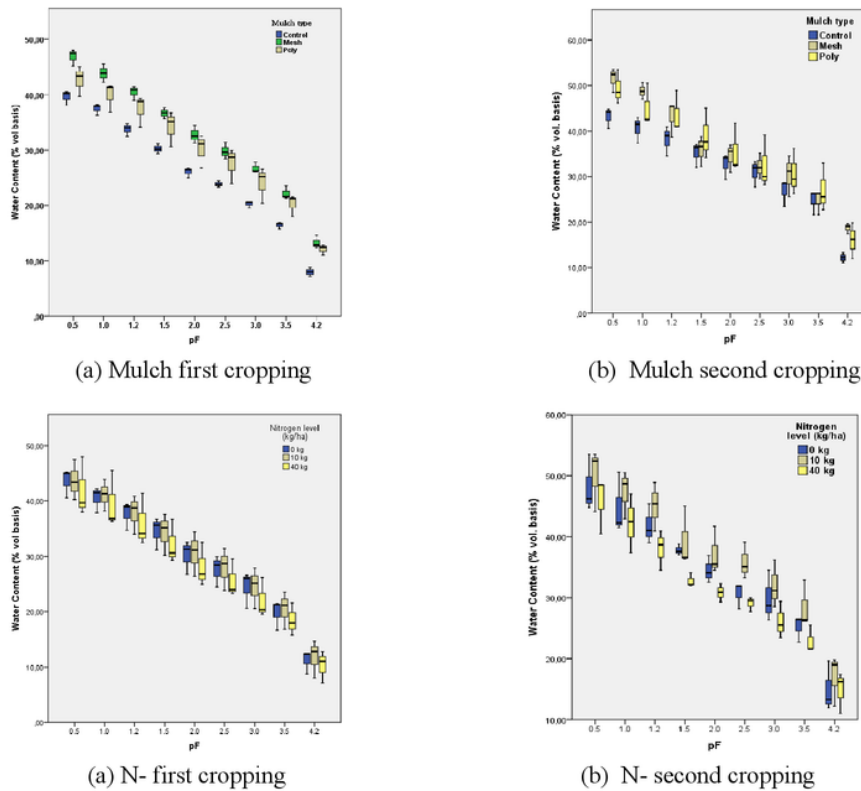


Figure 1. Soil water retention for mulch and nitrogen with increasing of pressure suction

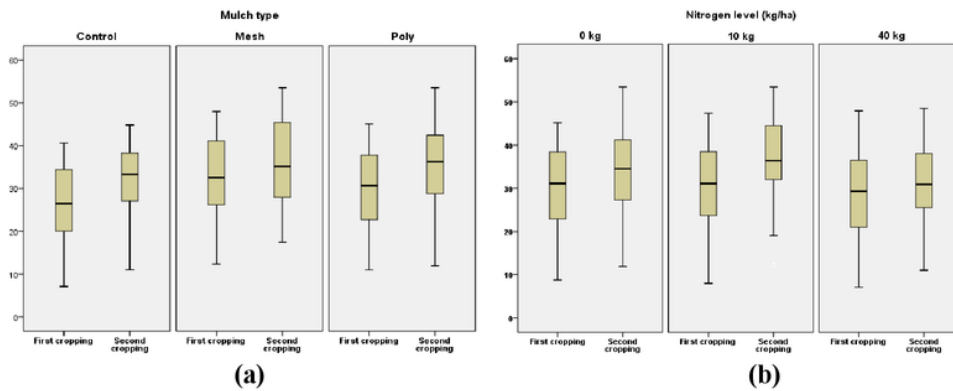


Figure 2. Water retention after two cropping season in treatment: (a) mulch type, and (b) nitrogen

4. Conclusion

The result of this study was confirmed the function organic matter incorporation into soil continuously in improving soil water retention and plant growth environment. The effect of plastic mulch and nitrogen

was not significant in soil organic matter, nitrogen, and C:N ratio. But there was tendency improving of these properties using poly mulch type combine with 40 kg N ha⁻¹. Water retention generally increased after twice addition of organic matter into soil. Moreover, application mesh mulch and 10 kg N ha⁻¹ had higher water retention as compared to non-nitrogen, 40 kg N ha⁻¹ or non-mulch and poly mulch. Future study are being need to investigate effect of different amount and type of organic matter incorporation to soil bio-physical characteristics.

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