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Conservation Agriculture Improves Soil Fertility and Increases Maize Yields in Dryland Farming

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Abstract: In this experiment the soil fertility and maize yields under conventional and two conservation (1 and 2) systems were evaluated in dry farming area in Bali Province of Indonesia in May 2021. A split-plot design was arranged with the location as the main plot and the system (conventional and conservation) as the sub-plot, with four replications. In conventional system, intensive tillage, application of urea fertilizers was involved, but neither embedding plant residues nor rice straw mulches were used. In conservation 1 system, no tillage-no rice straw mulches were done but legume cover crop residues (*Pueraria javanica*) were embedded into the soil. In conservation 2, no tillage-but rice straw mulches were applied and legume cover crop residues were embedded into the soil. The legumes were planted between holes of maize and the base of the stems were cut a week before planting maize. The rice straw mulches were applied on the soil surface and maize of variety BISI 18 was used. Results indicated that conservation system could improve soil fertility of dryland farming through increasing the soil organic-C, available-P and K and microbe respiration at the two locations compared to the conventional one. The conservation system gave maize yields of 6.27 tones clean cobs/hectares harvested at 75 days after sowing although it was still 38.58% lower than that resulted from the conventional one.

***Key words**: Conservation tillage, legume cover crops, maize yields, dryland farming*

I. INTRODUCTION

Farming practice in dryland areas which is not followed aspects of soil conservation dan sustainability will not only threaten the sustainability of land resources but also threaten food security and increases human poverty (FAO, 2013). Dryland farmers who work on narrow land, low farm inputs and lack of information technology are vulnerable to unconservative and sustainable farming. Conservation agriculture is one alternative agricultural practice especially on dryland that can improve soil quality on degraded land so as to increase crop productivity, food availability, environmental quality (Derpsch et al., 2014; FAO, 2015). Model of conservation agriculture combines three components includes minimum soil cultivation, returning back plant residues as much to the soil, and crop rotation spatially or temporaly (FAO, 2015). This model is contrast to habits of famers, particularly in developing country, where soil cultivation becomes a mandatory stage to be done in each growing season. Although the components of conservation agriculture, which include no soil cultivation, mulching and crop rotation, has been known to farmers in Indonesia however integrating the three components in one agricultural package has not been widely practiced. Until now agricultural practices without conservation techniques can still be found as in shifting cultivation systems outside Java. Even in sedentary agricultural systems, the application of soil conservation techniques is not been considered an important part of agriculture.

Agricultural practices without following this conservation model will result in a rapid land degradation process caused by soil erosion, loss of soil organic, soil compaction and scarcity of water supply to irrigate crops. Land degradation can be interpreted as land damage that causes a decrease in soil quality that exceeds the standard citeria for land damage (Wahyunto and Dariah, 2014). The four components that make up the conservation agriculture system are conservation tillage, utilization of plant residues as mulch, regulation of planting patterns (rotation of intercropping), and integrated nutrient management (Lal, 2015). Cover crops can improve soil organic matter, nutrient cycles, and biological activity through increased carbon inputs and diversity (Reycosky, 2021). In addition to soil erosion, loss of soil organic matter, soil compaction, and scarcity of water supply result in less normal growth and eventually low crop yields. One type of crop that is cultivated in dry land in general is maize as a food source of carbohydrates in addition to other second crops. The implementation of a conservation agricultural system that is without tillage and involves incorporation of cover crops and straw mulch application is expected to improve soil fertility and increase maize yields in dry land (Nining-Wahyuningrum, 2015). Cover crops have been shown to reduce nitrogen and phosphorus losses (Ripley and Benning, 2017). The results of research by Nyamanggara et al. (2013) in Zimbabwe showed that conservation agriculture is proven to increase maize yields on dry land. This research aims to find strategies to improve soil fertility and increase maize yields while preventing soil damage in dry land. This research is very important to be carried out considering soil damage and nutrient losses and low yields of maize crops caused by conventional agricultural practices. In addition, conservation agriculture research in dry land is still very limited, especially in Indonesia. The potential success of this research will be assessed from the results obtained in the application of conservation farming systems at two experimental sites compared to conventional agriculture.

2. EXPERIMENTAL

This experiment was conducted in dryland farming areas at the village of Penatih (Kodya Denpasar) and of Sukawati (Gianyar regency) from May to October 2021.

2.1. Materials

The materials used in this experiment were maize seeds of variety BISI 18, seeds of legume cover crops *Pueraria javanica*, NPK fertilizers, pesticides dry rice straws and dryland areas at two locations. Cultivation tools were used in this experiment as well.

2.2. Operational

The experiment was designed as split-plot, in which location (Penatih and Sukawati) was assigned as the main plot and management system (Conventional, Conservation 1 and Conservation 2) as the subplot. Treatment of Conventional included 2 times soil cultivation, clean weeding, no LCC, no straw mulch); Conservation 1 included No soil cultivation, weeds were cut and spread on soil surface, LCC seeds of 8 kg/ha were sown and were cut at 30 DAS then incorporated into the soil before planting maize; Conservation 2 included the same activities as Conservation 1 and applied the straw mulch at 20 tones/ha. The experiment was replicated four times. Nitrogen (Urea) fertilizer (200kg/ha) was only given to the Conventional, while P and K fertilizers were applied to all treatments. The variables of growth included leaf area index and leaf chlorophyll content and yields of maize were observed and measured. Soil physical, chemical and biological properties of previous and after experiment were laboratory analyzed. Data collected were statistically analyzed using ANOVA (Gomez and Gomez, 2007) in Co-Stat and M-statC computer software. Mean comparation was calculated based on 5% DMRT and 5% LSD.

3. RESULTS AND DISCUSSION

Maize was unfortunately harvested at75 Das at the time of cob ripening, (normally harvested at 100 Das), due to insect attact. Results of statistical analysis showed that individual the effect of location and management system was significant ($P<0.05$) on all variables observed. However, the interaction effects of location and management system were not significant ($P\geq0,05$) on those variables. Legume cover crops showed good growth and resulted in not significantly different fresh weight at the two locations (Table 1). Soil C-organic content at Penatih was higher than that at Sukawati, although the content was actually considered low (<2%) (Fig.1a), however by embedding LCC residues at treatments of Conservation 1 and Conservation 2 the C-organic content was increased. Meanwhile soil total-N at both locations were still low until the end of experiment (Fig.2a) even though at Conservation1 and Conservation 2 treatments (Fig.2 b). Soil available-P at both locations were classified high (Fig.3a) and addition of LCC residues increased the available-P especially at Penatih (Fig 3.b). Although the soil available-K at Penatih was higher than at Sukawati (Fig 4a), the addition of LCC residues did not significantly increase the available-K content (Fig. 4b). Incorporation LCC residues did not significantly decrease the soil bulk density at the two locations That may be due to the relatively low rate of LCC seeds applied (8 kg/ha resulting LCC fresh weigh t of 0.909-1.904 tones/ha (Table 1) was not adequate to lower the soi density. In addition, that was probably also due to legume cover crop gave lower effects on soil bulk density compared to grasses or cereals (Blanco-Canqui, 2019). Originally at both locations, microbe population were not significantly different (Fig. 6a) but after the addition of LCC, the population of microbes were increased both in Conservation 1 and Conservation 2 treatments (Fig. 6b). The roles of LCC residues in increasing microbe respiration was significant in Conservation 1 and even more in Conservation 2 treatments (Fig. 7b).

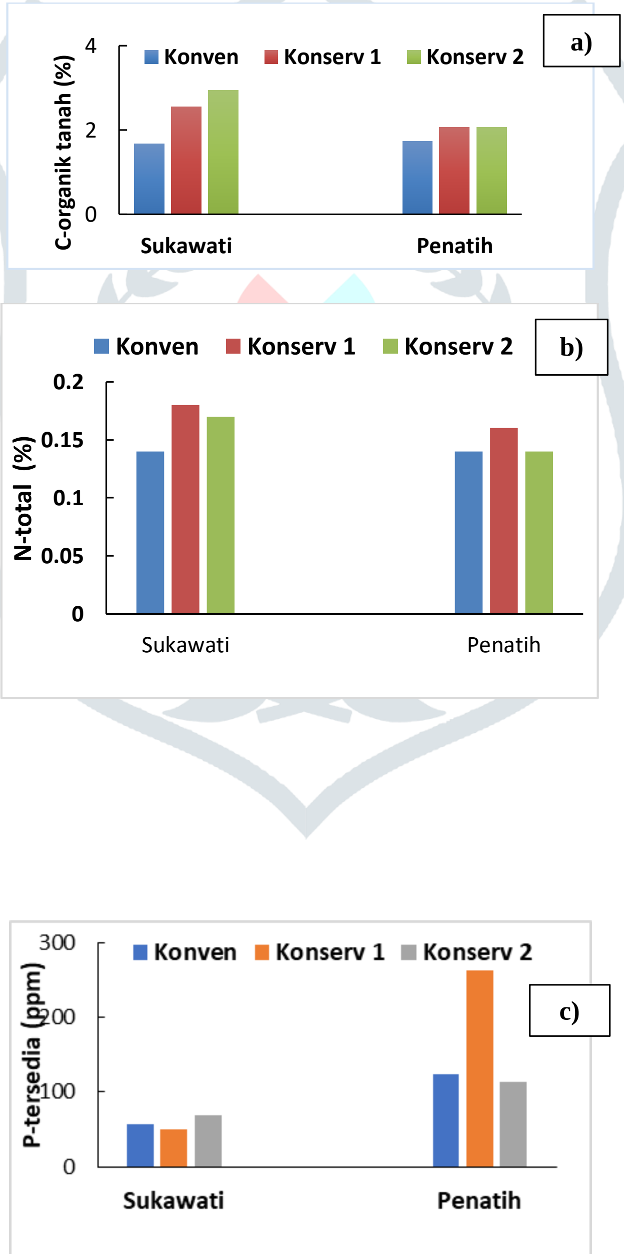
Maize yields (represented by fresh weight of cobs without petals in tones/ha) was significantly affected ($P<0.05$) by location and management system, however there was no interaction effect $P\geq0.05$) of the two subplot treatments. The yield of maize was 53.16% higher at Penatih than at Sukawati (Fig. 7a), which was resulted from the 44.05% higher fresh weight of maize per cob (Fig.8a) and from 5.92 cm longer cob (Fig. 9a). The higher maize yields were supported as well by the dry and fresh weights of maize biological parts (Fig. 3a and 4a), which was may cause by higher plant height and leaf number (Table 1). Besides that, higher chlorophyll content (Fig.5a) and leaf area index at Penatih also resulted in higher maize yields. Higher photosynthates resulted from higher chlorophyll content, leaf area index and leaf number could result in the earlier reproductive organs formation (such as flowers and cobs) (Table 1) and in higher maize grain filling. The better vegetative of maize growth of maize at Penatih than at Sukawati was resulted from better soil fertility particularly organic-C, available P and K (Fig. 1 a, c, d). In addition, microbe population was also higher at Penatih (Fig. 2a) although the microbe respiration was not different (Fig. 2b). As reported by Nining-Wahyuningrum (2015) after decomposition cover crops provide organic materials for the soil in order to increase its fertility through providing nutrients and increasing population and activities of microbes. The application of LCC did not result in increasing oil nitrogen content at both location and at both conservation treatments (Fig. 1b). This may be due to the relatively lower rates (8 kg/ha) of LCC seeds applied. The soil available-P at both locations and also in both Conservation treatments were classified high (Fig. 1c). The incorporation of LCC residues in two Conservation treatments resulted in increasing soil available-P for the plants although still in the forms of soi particles bounded (Lounbury, 2017). Hallama et al. (2020) and Soltangheisi et al. (2020) concluded that planting cover crops had potential in nutrient cycle in agricultural system, increasing P nutrient and crop yields as well. Incorporating LCC resulted in higher soil available-K in both Conservation treatments (Fig. 2d).

Meanwhile, microbe respiration increased by incorporating LCC residues in the two Conservation treatments (Fig 2b), indicated increas microbe activities which resulted in favorable soil condition (Kim et al., 2020 and Muhammad, 2021). The diversity of microbes is important in maintaining soil fertility and healthy in order to increase crop growth and development and finally their yields (Kocira et al., 2020). In contrast to that reported by Nyamanggara et al. (2013) in Zimbabwe, incorporating LCC residues in both Conservation treatments in the present experiment, could not increase maize yields in both locations. The maize yields in Conventional was 38,58% higher than that in both Conservation treatments, and there was no significant different in yields between Conversation treatments (Fig. 7b). That higher yield was due to higher cob fresh weight (Fig. 8b) and longer cobs (Fig. 9b) in Conventional treatment. Higher chlorophyll content (Fig. 5b) and leaf area index (Fig.6b) in Conventional treatment may also contribute to the higher yields in Conventional treatment. Wider leaf surface and higher chlorophyll content provide much contribution to better photosynthesis process in producing much more assimilates to be translocated to the maize cobs particularly those derived from earlier flowering (Table 1).

Table 1. The effects of location and management system on fresh weight of LCC, maize plant height, leaf number, time of flowering and time of cob appearing

Treatment	Fresh weight of LCC (g/plot)	Maize plant height (cm)	Maize leaf number (leaf)	Time of flowering (das)	Time of cob appearing (das)
Location					
Sukawati	203.67[a]	152.98[b]	13.01[b]	55.0[a]	58.0[a]
Penatih	426.40[a]	223.34[a]	15.03[a]	49.0[b]	52.0[b]
5% LSD	268.376	52.690	1.518	2.579	4.630
Managemenet system					
SM1	0[b]	221.63[a]	14.90[a]	50.0[b]	52.0[a]
SM2	488.75[a]	176.23[a]	13.72[a]	52.0[ab]	55.0[a]
SM3	459.35[a]	166.62[a]	13.45[a]	54.0[a]	57,0[a]
5% LSD	76.141	78.505	1.650	3.050	5.773

Notes: Figures followed by the same letter (s) in the same variable coloumn and treatment are not significantly different at 5% DMRT AND 5% LSD.



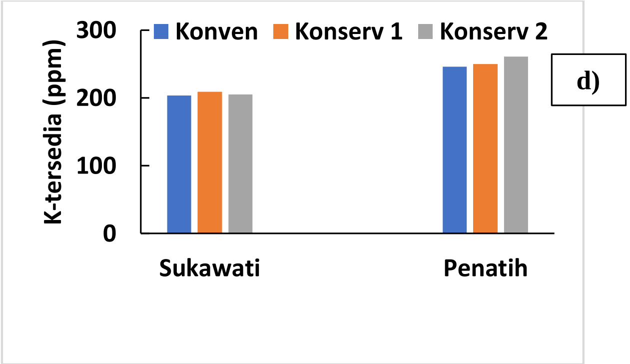
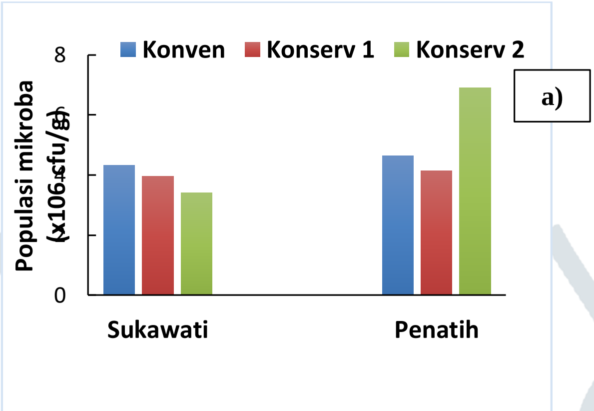


Figure 1 a) Soil organic-C, b) Soil total N, c) Soil available-P, d) Soil available-K at three management systems at Sukawati and Penatih locations



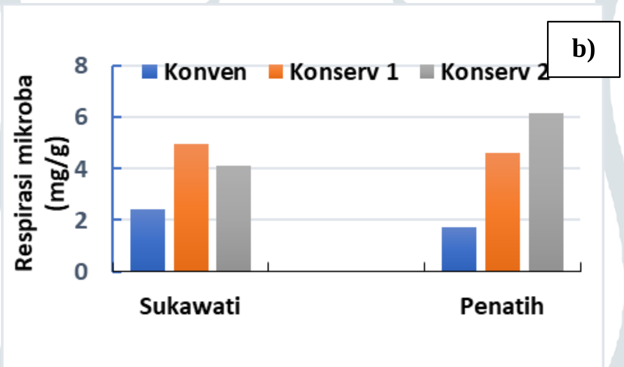
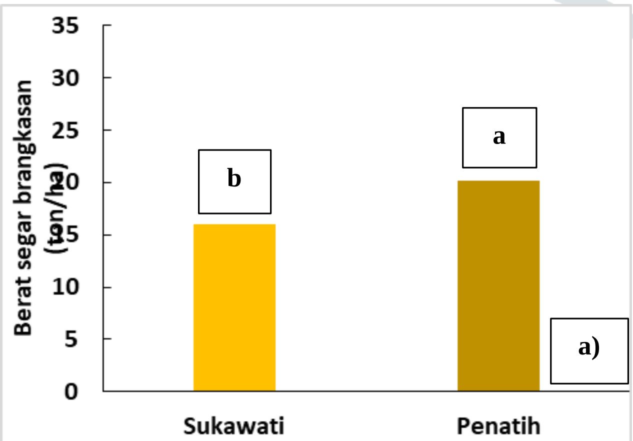


Figure 2 a) Soil microbe population, b) Soil microbe respiration, at three management systems at Sukawati and Penatih locations



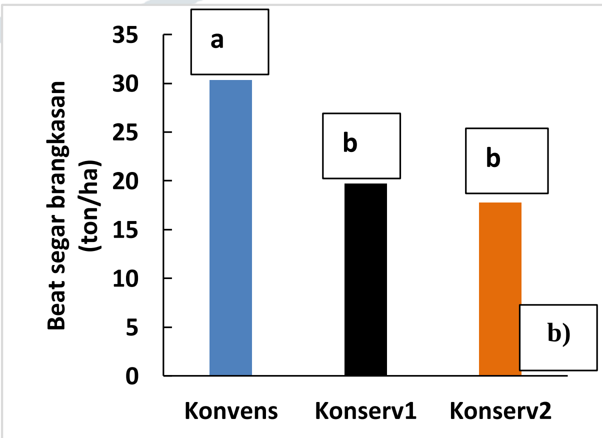


Figure 3 a) Fresh weight of maize residues at Sukawati and Penatih locations; b) Fresh weight of maize residues at three manajemen systems

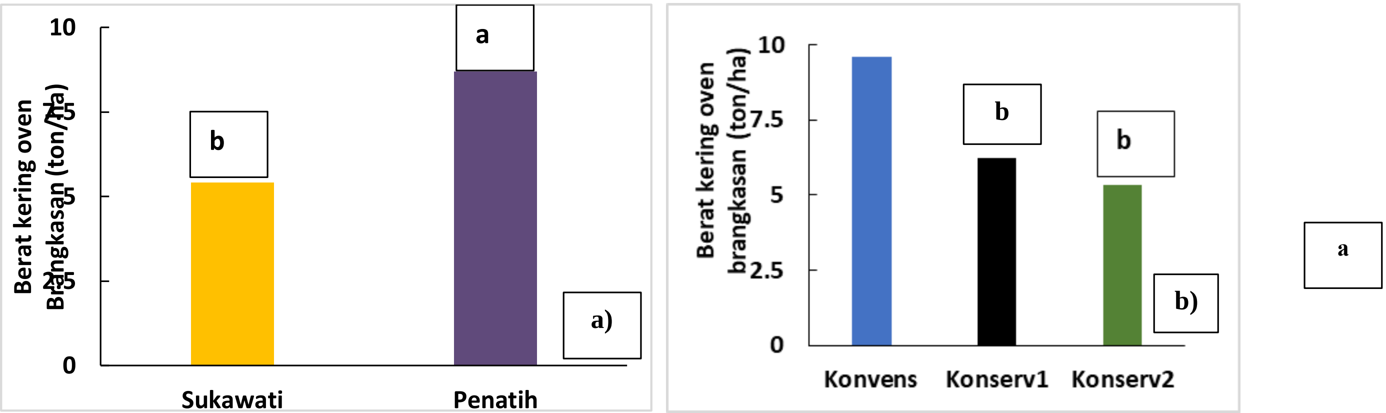


Figure 4 a) Oven dry weight of maize residues at Sukawati and Penatih locations; b) Oven dry weight of maize residues at three manajemen systems

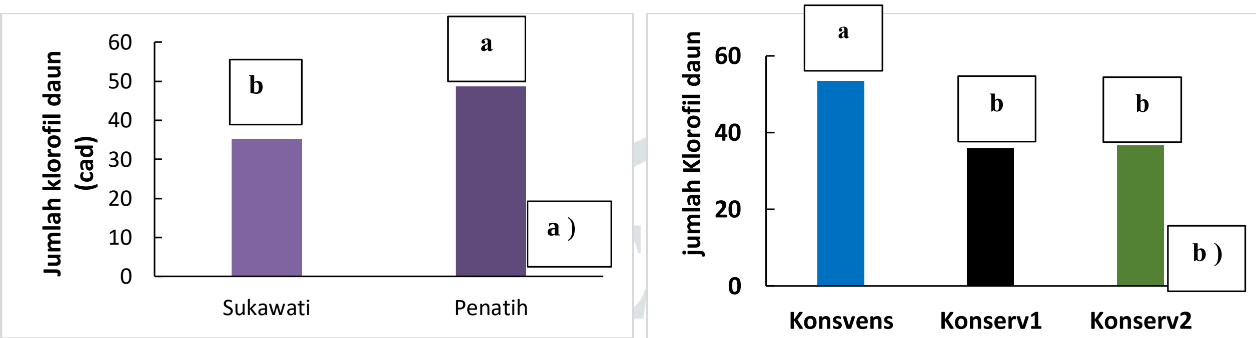


Figure 5 a) Chlorophyll content of maize leaf at Sukawati and Penatih locations; b) Chlorophyll content of maize leaf at three manajemen systems

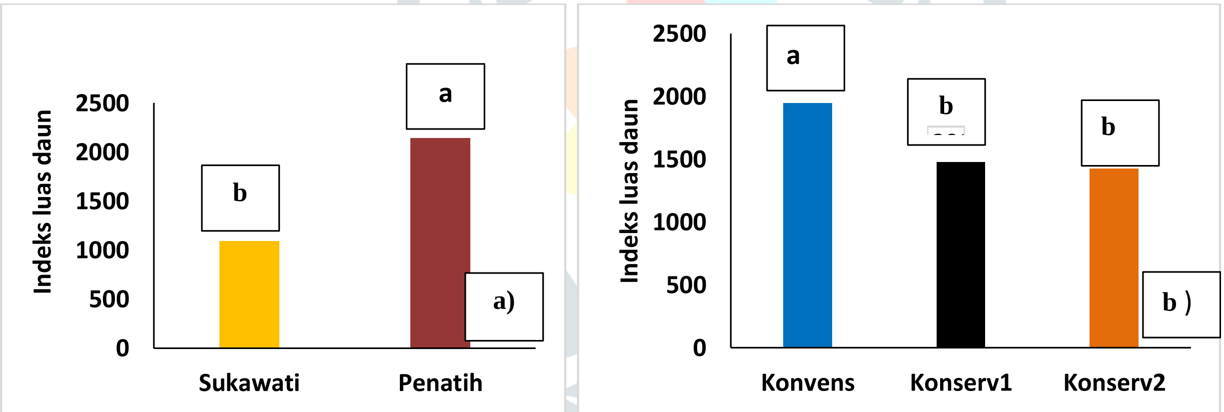


Figure 6 a) Leaf are index of maize at Sukawati and Penatih locations; b) Leaf are index of maize at three manajemen systems

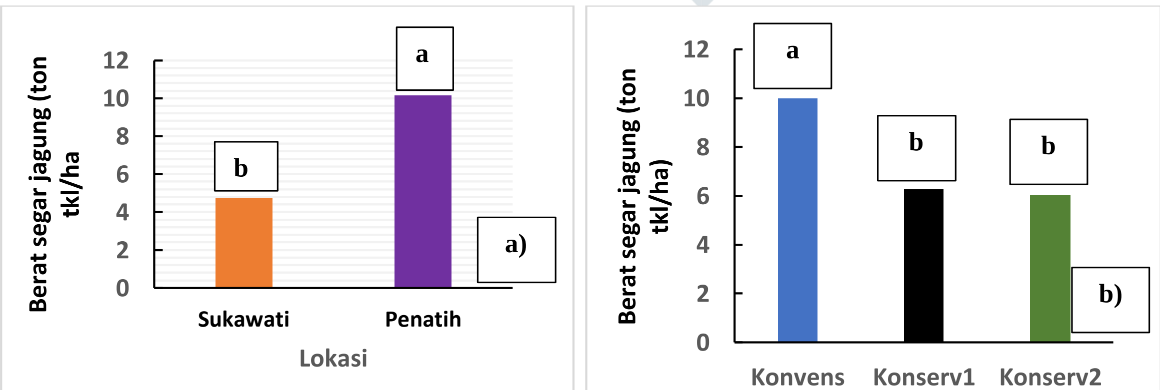


Figure 7 a) Fresh weight of maize at Sukawati and Penatih locations; b) Fresh weight of maize at three manajemen systems

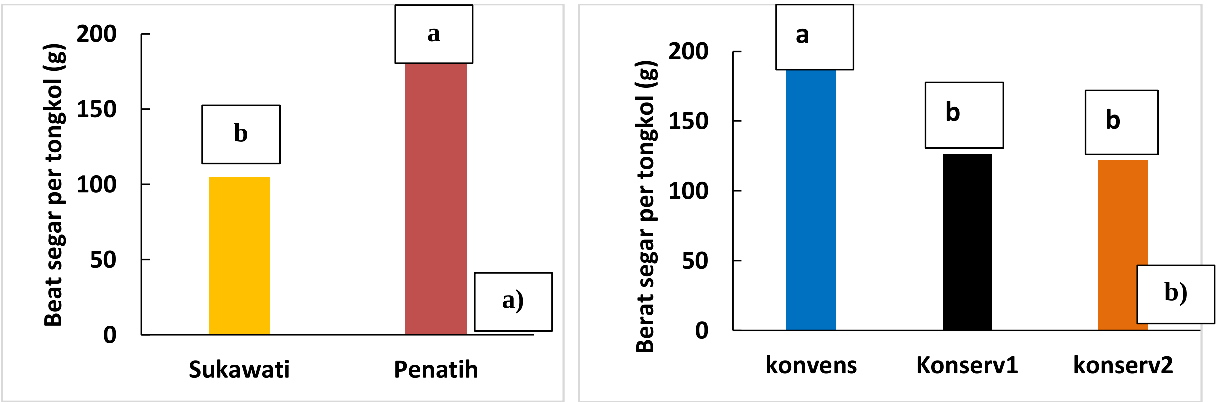


Figure 8 a) Fresh weight of maize cob at Sukawati and Penatih locations; b) Fresh weight of maize cob at three manajemen systems

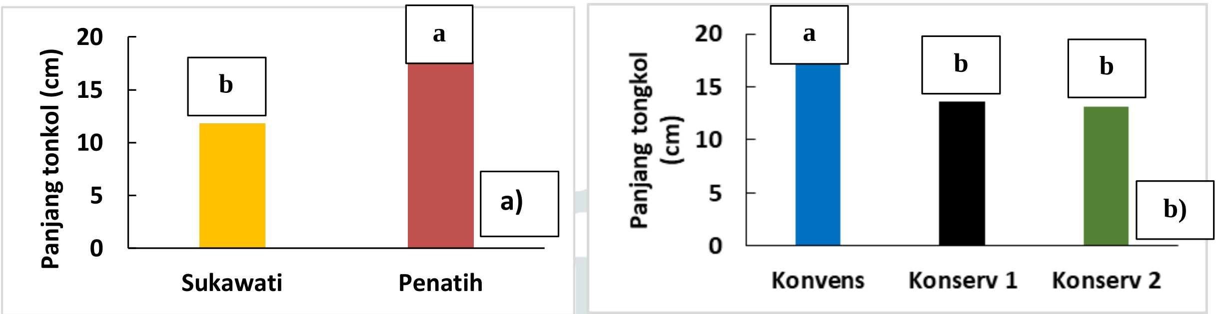


Figure 9 a) Length of maize cob at Sukawati and Penatih locations; b) Length of maize cob at three manajemen systems

4. COCLUSION

Conservation agriculture improved soil fertility in drylands by increasing soil organic-C, available-P and available-K, as well as soil microbial respiration at the two locations. Conservation system provides 38.58% lower maize yields than Conventional farming on dryland.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest relevant to the content of this article.

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