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Weed density, growth and yield of sweet corn (*Zea mays* Saccharata (Sturt.) Bailey) after treatment with mycorrhiza fungi on marginal dry land

Halim[1], Tresjia Corina Rakian[1], Sarawa[1], Muhidin[1], Abdul Madiki[1], Muhammad Tufaila[2], Resman[2], Waode Siti Anima Hisein[3]and Aminuddin Mane Kandari[4]

[1]Department of Agrotechnology, Halu Oleo University, Kendari Southeast Sulawesi, **Indonesia**
[2]Department of Soil Science, Halu Oleo University, Kendari Southeast Sulawesi, **Indonesia**
[3]Departemnt of Plant Protection Faculty of Agriculture, Halu Oleo University, Kendari Southeast Sulawesi, **Indonesia**
[4]Department of Forestry Faculty of Forestry and Environmental Science Halu Oleo University, Kendari Southeast Sulawesi, **Indonesia**

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***Correspondence:** haliwu_lim73@yahoo.co.id **Accepted:** 10 Feb 2018 **Published online:** 25 Mar. 2018

The presence of weeds in the corn plant area is negatively affecting the growth and production of crops if the weeds are not controlled appropriately. This study aims to determine the effect of mycorrhizal fungi on the density of weeds, growth and yield of maize on marginal dry land. The experimental design used in this study was Randomized Block Design (RDB). The tested treatments were the mycorrhizal fungal consisting of 3 treatments: without mycorrhizal fungi propagules (A0), 15 g propagules of mycorrhizal fungi (A1), 30 g propagules of mycorrhizal fungi (A2), each treatment was repeated four times to 12 treatment unit. Observation variables in this research are: density of weed species, plant height, plant stem diameter, length of cob, diameter of cob, number of seeds/cob and percentage of mycorrhizal fungi infections at plant roots. The results showed that the dominant tinds of weeds from broad-leaved i.e.: *M.invisa*, *I.triloba*, *M.charantia*, *R.communis*, *S.torvum, P.niruri*, *A.conyzoides*, *A.gracilis*, *P.longisetum*r serta *C.plumieri*. The dominant kinds of weeds from grasses are: *S.viridus, E.indica*, *D.adscendes*, *P.repens* and *C.dactylon*. The kinds of weed dominant from sedges is *C.rotundus*. The length of cob, the diameter of cob and the highest number of seeds were found in treatment A1 with the values of 9.46 cm, 2.45 cm and 190.44 seeds/cobs respectively. The percentage of mycorrhizal fungi infections at the highest root of maize plants occurred at treatment of A2 as 53.33%.

Keywords: maize, marginal dry land, mycorrhiza fungi, weed

INTRODUCTION

Sweet corn in Indonesia is generally grown in the lowlands both in moor, rain-fed fields and irrigated rice fields. The pattern of cultivation of maize crops is still traditional and has not used much advanced farming innovation so that the increase of production is still far from the needs optimally. One important aspect in the cultivation of maize is the management of plant-causing organisms, especially the management of weeds that grow in plant areas. The research of Nedim et al., (2004) showed that the decrease of corn yields due to competition with weeds ranged between 35% - 40% and 25% - 50% (Hartzler and Pringnitz, 2005). The variations in crop losses are one of them determined by the critical period of the plant (Kevin et al., 2007). The critical period of the plant starts to occur at the age of 20-45 days after planting, since the plant grows to a period of one-quarter or one-third of the plant age (Ferrero et

al., 1996; Hartzler and Pringnitz, 2005). Therefore, weeds that grow in the plant area must be controlled so as not to cause economic losses both the quality and quantity of crops.

The basic concept that should be applied in weed control is the wise control of weeds with a view to minimizing the loss of crop yields. Thus, weeds that grow on certain plant areas need not be completely eradicated, but must be maintained as long as they do not cause a decrease in crop yields. Hartzler (2004) suggests that in the management of weeds one of them through the prevention of crop losses due to competition between weeds with plants that refer to the critical period of the plant.

Weed control done wisely can maintain the presence of microorganisms in the soil associated with rooting plants, especially microorganisms that are useful for plant growth (Gupta and Shubhashree, 2004). One of the microorganisms associated with plant roots is a mycorrhizal fungus. According to Gonzalo and Miguel (2006), the association between mycorrhizal fungi with plant roots is mutualism that is both mutually beneficial. Mycorrhizal fungi can utilize plant root exudates as a source of carbon and energy, while plants more easily absorb nutrients, especially nutrients P (Preston, 2007).

Total weed eradication will have an impact on the growth and development of the mycorrhizal fungi associated with weed rooting. The root exudates of certain weeds may stimulate the growth of mycorrhizal fungi. According to Manthey et al. (1994), in general root exudates content included glucose, fructose, organic acids, amino acids, lipids, vitamins, nucleotides, flavonoids, and enzymes. Thus, the diversity of plants in a particular area can determine the quantity and quality of exudates available in rooting. Miyasaka et al., (2003), suggests that the low population of mycorrhizal fungi associated with rooting of plants is due to the composition of root exudates produced by each plant species. The kinds of weeds found to be symbiotic with mycorrhiza fungi include: *Cleome rutidosperma, Euphorbia hirta, Dactyloctenium aegyptium, Digitaria ciliaris, Heliotropium indicum, Scoparia dulcis, Cyperus rotundus* (Gupta and Shubhashree, 2004), *Imperata cylindrica, Eupatorium odorata* (Halim, 2009), *Ageratum haustianum, Amaranthus gracilis, Alternathera sesilis, Alternathera philoxeroides, Croton hirtus, Cleome rutidosperma* (Halim et al., 2014) and *Ageratum conyzoides* (Halim et al., 2016). While the kinds of mycorrhizal fungi that associate with the weeds rooting i.e.: *Glomus* sp, *Gigaspora* sp and *Acalauspora* sp (Halim, 2009).

MATERIALS AND METHODS

Study Area and Experimental Setup

This research was conducted in Teteasa Village, District of Motaha, South East Sulawesi Indonesia. The land cleared from weeds by using a machete, then done soil processing twice. The first treatment is done by reversing the soil using a hoe and the second treatment is done by breaking the chunk into a smooth soil condition soil loose. Clearing and raised bed making were manually carried out. Making plot of research done after soil processing, then made a plot with 4 m x 3 m in size, a drainage channel 0.5 m in size. The maize seeding is done by using manual pit (2 seeds per planting holes), spacing of 30 cm x 75 cm. The experimental design used in this study was Randomized Block Design (RDB). The tested treatments were the mycorrhizal fungal propagules (spores, hyphae, soil that clings to the roots, colonized roots) consisting of 3 treatments: without mycorrhizal fungi propagules (A0), 15 g propagules of mycorrhizal fungi (A1), 30 g propagules of mycorrhizal fungi (A2), each treatment was repeated four times to 12 treatment unit.

Observation of Variable

The variables were observation in this research include:

(1) Importance value of weed, calculated on 21 and 42 ay after planting (DAP) at 5 points of observation with formula was recommended by Chaves and Bhadanari (1982):

$$\text{Relative density} = \frac{\text{number of individuals of species}}{\text{Total number of individual}} x\ 100\%\ \text{Relative dominance} = \frac{\text{dominance of species}}{\text{dominance of all species}} x\ 100\%\text{Relative frequency} = \frac{\text{frequency of species}}{\text{sum frequency of all species}} x\ 100\%$$

Importance value = Relative density + relative dominance + relative frequency

(2) Plant height and plant stem diameter were calculated at 7, 14, 21, 28, 35 and 42 DAP.

(3) The cob length, the cob diameter and grain number per cob each was calculated at the end of the study.

(4) The percentage of mycorrhizal fungal infections at plant roots was calculated at the end of the study. Before calculating the percentage of

mycorrhizal fungus infections at the root, firstly rooting is done (Brundrett, 1999). The number of roots observed is 10 pieces with a size of 1 cm. Next calculated the percentage of mycorrhizal fungal infections by using the formula recommended by Brian and Schultz (1980):

IP = $\frac{r1}{r2} \times 100\%$,

Where: IP = Percentage of root infections, r1= Number of instances of infected root, r2= Number of instances of uninfected root

Data Analysis

Data of each variable were observed were analyzed by variance of analysis. If the value of F count is greater than the value of F table, then continued with then Least Significant Difference (LSD) at 0.05% confidence level.

RESULTS AND DISCUSSION

Importance Value of Weed

Table 1 showed that's at the plot observation were found 23 kinds of weed from broadleaves, 8 from grasses and 2 from sedges. The dominant kinds of weed from broadleaves namely: *M.invisa*, *I.triloba*, *M.charantia*, *R.communis*, *S.torvum, P.niruri*, *A.conyzoides*, *A.gracilis*, *P.longisetum*r and *C.plumieri*. The dominant kinds of weed from grasses namely: *S.viridus, E.indica*, *D.adscendes*, *P.repens* and *C.dactylon*. The dominant kinds of weed from sedges is *C.rotundus*. The kinds of weeds not found at 21 DAP namely: *C.rutidospermae*, *E.hypericifolia*, *P.longisetum, E.crusgalli*, *C.iria, C. rotundus*. This indicates that the kinds of weeds that do not grow are still experiencing dormancy. The incidence of seed dormancy is caused by an increase in soil temperature after the cleaning of vegetation by mechanical means followed by soil tillage. Halim (2010), stated that clearing of vegetation on land causes the soil to be exposed so that the temperature at the soil surface becomes high which affects the occurrence of seed dormancy from certain weed species. Similarly, soil cultivation, where weed seeds rise above the soil surface so that the seeds of the weeds are exposed directly by the sun. The soil treatment affects the dormancy properties of certain weeds.

The dominant kinds of weed at the 42 DAP namely: *A.haustianum*, *B.pilosa*, *B.alata*, *C.nudiflora*, *C.rutidospermae*, *G.parviflora*, *H.capitata*, *E.odorata*, *E.peltescens*, *E.hypericifolia, M.invisa*, *P.niruri*, *P.oleracea*, *S.torvum* and *S.nodiflora*. The dominant kinds of weed from grasses namely: *D.adscendes*, *E.crusgalli*, *P.repens*, *P.distichum* and *S.viridus*. While the dominant kinds of weed from sedges is *C.iria*. The kinds of weeds not found at 42 DAP namely: *E.crusgalli*, *C.iria, C.rotundus*, *E.peltescens*, *E.hirta*, *E.hypericifolia*, *E.crusgalli*, *I.cylindrica, P.repens*, *E.hirta, E.hypericifolia*, *P.distichum*, *C.iria, C. rotundus*.

In general, the kinds of weeds that grow at 42 DAP are less than 21 DAP. This happens because the weed seeds that previously experienced dormancy cannot grow because the surface of the soil has been covered by a plant canopy. Although the ground surface temperature are relatively low, but weed seeds can not grow. Mortimer (1991), increased soil temperature and light quality can break the dormancy of certain weeds. In addition, weed control methods applied to shift the weed composition become uniform. While the kinds of weeds that grow predominantly it rooting allegedly have been infected by mycorrhizal fungi (Weaver et al., 1992) which affects the height of root exudates in certain weed species (Juge at al., 2002). The root exudates will be exploited by the mycorrhizal fungi as a source of carbon and energy (Janos, 1992; Moutoglis and Widden, 1996).

Plant Height

Table 3, showed that the height of corn plant at the age of 7 DAP highest was obtained at treatment of A1 which was significantly different from other treatment. At the age of 14 DAP the highest plant height was obtained at treatment of A1 which was significantly different from the control. At the age of 21, 28, 35 and 42 DAP the highest plant height was obtained at treatment of A2 which was significantly different from the control. The based on the results of this study showed that the application of mycorrhizal fungi able to increase the height of corn plants in all treatments, although the increase is different. The difference is closely related to the infection of mycorrhizal fungi on plant roots, thus affecting the absorption of nutrients. Wilarso (1990) suggests that the mycorrhizal fungi may be symbiotic with plant roots and through its external hyphae can increase the absorption of immobile nutrients from the soil.

Table 1. Ratio of weed dominance (%) at 21 DAP

No.	Kinds of weed	Number of Plot Observation				
	Broadleaves	**1**	**2**	**3**	**4**	**5**
1.	*Ageratum conyzoides* (L.)	5.20	1.76	2.94	4.87	3.66
2.	*Ageratum haustianum* Mill	4.02	1.81	1.90	1.85	1.25
3.	*Amaranthus gracilis* Desf	3.75	3.77	3.80	5.34	1.25
4.	*Bidens pilosa* (L.) Var Minor	2.06	1.92	1.97	3.56	1.19
5.	*Borreria alata* (Aubl.) DC	1.88	1.74	1.82	1.71	1.25
6.	*Centrosema plumieri* (Pers) Beath	3.75	3.47	5.48	1.85	2.88
7.	*Commelina nudiflora* (L.)	1.61	1.90	2.13	1.71	3.35
8.	*Cleome rutidospermae* DC	0.00*	1.81	2.87	1.78	1.12
9.	*Galingsonga parviflora* Cav	2.06	1.89	1.90	1.71	2.88
10.	*Hyptis capitata* Jack	1.88	3.70	1.66	1.78	2.75
11.	*Ipomea triloba* L.	10.29	8.81	8.34	8.42	5.07
12.	*Eupatorium odorata* (L.)	1.79	3.12	1.97	1.83	3.60
13.	*Eupatorium peltescens* (L.)	1.44	2.26	1.82	1.83	1.25
14.	*Euphorbia hirta* (L.)	1.53	3.76	1.90	1.78	1.25
15.	*Euphorbia hypericifolia* (L.)	1.70	1.81	1.97	1.65	0.00*
16.	*Mimosa invisa* Mart.ex. Colla	11.47	6.90	7.61	5.11	10.77
17.	*Momordica charantia* (L.)	5.47	9.67	5.28	5.46	5.53
18.	*Phyllanthus niruri* (Auct)	3.93	3.77	4.03	4.79	3.86
19.	*Polygonum longisetum* De Br	6.07	1.89	5.16	3.50	0.00*
20.	*Portulaca oleracea* (L.)	1.97	5.67	3.56	1.71	3.53
21.	*Ricinus communis* (L.)	5.64	3.88	6.98	6.71	7.01
22.	*Solanum torvum* SW	2.53	6.58	3.80	3.56	5.35
23.	*Synedrella nodiflora* (L.) Gaertn	2.06	1.81	1.90	3.29	1.12
	Grasses					
1.	*Cynodon dactylon* (L.) Pers	3.67	3.55	3.41	3.43	5.14
2.	*Digitaria adscendes* (H.B.K.) Henr	4.15	3.70	3.96	1.78	1.45
3.	*Echinochloa crusgalli* (L.) Beauv	1.89	1.59	1.90	2.96	0.00*
4.	*Eleusine indica* (L.) Gaertn	1.79	4.71	1.90	3.50	1.25
5.	*Imperata cylindrica* (L.) Beauv	1.70	1.66	1.97	1.71	1.38
6.	*Panicum repens* (L.)	1.88	3.77	3.88	5.07	3.47
7.	*Paspalum distichum* (L.) Ridley	1.70	1.59	1.66	1.71	5.01
8.	*Setaria viridus* (L.) Beauv	3.58	1.66	5.01	3.43	3.60
	Sedges					
1.	*Cyperus iria* (L.)	2.96	0.00*	1.90	1.83	1.51
2.	*Cyperus rotundus* (L.)	4.65	0.00*	1.97	1.78	3.01
	Total ratio of weed dominance	**110.07**	**105.93**	**108.35**	**103.00**	**96.99**

*Notes : * not found at the plot observation*

Table 2. Ratio of weed dominance (%) at 42 DAP

No.	Kinds of weed	Number of Observation Sample				
	Broadleaves	**1**	**2**	**3**	**4**	**5**
1.	*Ageratum conyzoides (L.)*	1.77	6.89	4.78	3.35	5.36
2.	*Ageratum haustianum Mill*	1.59	1.72	2.02	1.71	5.49
3.	*Amaranthus gracilis Desf*	5.19	4.14	3.65	3.67	4.86
4.	*Bidens pilosa (L.) Var Minor*	2.76	1.64	1.82	1.71	4.80
5.	*Borreria alata (Aubl.) DC*	1.59	1.64	3.21	3.61	3.37
6.	*Centrosema plumieri (Pers) Beath*	3.30	3.67	3.78	1.71	3.77
7.	*Commelina nudiflora (L.)*	1.71	2.03	3.02	3.04	1.85
8.	*Cleome rutidospermae DC*	2.99	1.72	2.07	2.98	3.77
9.	*Galingsonga parviflora Cav*	1.65	1.56	2.07	2.07	3.57
10.	*Hyptis capitata Jack*	1.77	1.72	1.76	7.01	1.72
11.	*Ipomea triloba (L.)*	6.61	7.68	10.11	5.63	7.41
12.	*Eupatorium odorata (L.)*	3.72	2.11	1.95	4.32	3.77
13.	*Eupatorium peltescens (L.)*	1.71	2.03	0.00*	1.77	1.85
14.	*Euphorbia hirta (L.)*	1.71	2.11	1.88	0.00*	1.78
15.	*Euphorbia hypericifolia (L.)*	1.89	1.40	0.00*	0.00*	1.72
16.	*Mimosa invisa Mart.ex. Colla*	6.37	8.83	7.80	6.19	7.94
17.	*Momordica charantia (L.)*	3.54	6.25	5.66	3.54	3.50
18.	*Phyllanthus niruri (Auct)*	3.66	3.67	4.97	3.48	5.09
19.	*Polygonum longisetum De Br*	3.60	3.43	5.03	3.22	3.37
20.	*Portulaca oleracea (L.)*	1.95	5.62	3.91	1.58	1.72
21.	*Ricinus communis (L.)*	4.12	4.67	3.52	3.61	3.70
22.	*Solanum torvum SW*	6.75	5.54	4.46	3.74	3.64
23.	*Synedrella nodiflora (L.) Gaertn*	3.42	3.90	3.78	3.80	1.58
	Grasses					
1.	*Cynodon dactylon (L.) Pers*	1.59	1.87	1.57	1.77	2.27
2.	*Digitaria adscendes (H.B.K.) Henr*	1.71	2.17	1.76	5.95	3.08
3.	*Echinochloa crusgalli (L.) Beauv*	1.71	0.00*	1.69	2.03	1.52
4.	*Eleusine indica (L.) Gaertn*	3.36	5.14	3.78	5.30	3.90
5.	*Imperata cylindrica (L.) Beauv*	3.42	1.64	0.00*	1.97	1.85
6.	*Panicum repens (L.)*	3.66	1.95	0.00*	4.22	1.65
7.	*Paspalum distichum (L.) Ridley*	1.71	2.98	3.65	3.54	0.00*
8.	*Setaria viridus (L.) Beauv*	5.98	5.22	1.76	1.84	3.64
	Sedges					
1.	*Cyperus iria (L.)*	1.77	0.00*	3.91	1.84	0.00*
2.	*Cyperus rotundus (L.)*	1.77	0.00*	3.78	3.41	0.00*
	Total ratio of weed dominance	**100.05**	**104.94**	**103.15**	**103.62**	**103.54**

*Notes : * not found at the plot observation*

Table 3. The average of plant height (cm) at 7, 14, 21, 28, 35 and 42 DAP

Treatment	Time of observation					
	7	14	21	28	35	42
Without mycorrhiza fungi (A0)	5.13^{b}	13.43^{b}	23.23^{a}	36.13^{b}	44.37^{b}	70.13^{b}
15 g propagule of mycorrhiza fungi (A1)	5.33^{a}	13.60^{ab}	23.37^{a}	36.37^{ab}	44.63^{ab}	70.67^{b}
30 g propagule of mycorrhiza fungi (A2)	5.23^{ab}	13.50^{ab}	23.43^{a}	36.70^{a}	44.87^{a}	77.17^{a}

Notes: the numbers followed by unequal letters in the same column differ significantly with Smallest Significant Difference Test at 95% confidence level.

Stem Diameter

Table 4, showed that the highest plant stem diameter at age 7 DAP obtained at treatment of A2 was not significant with other treatments. At the age of 14 DAP the highest plant stem diameter obtained at the different treatment of A2 was not significant with other treatments. At the age of 21 DAP the highest plant stem diameter obtained at different with treatment of A1 was not significant with controls and other treatments. At 28 DAP the highest plant stem diameter at different with treatment of A1 was not significant with other treatments. At the age of 35 DAP the highest stem diameter of plants obtained at different with treatment of A1 was not significant with other treatments. Furthermore, at age 42 DAP the highest stem diameter of plant on treatment of A2 was significantly different from other treatments.

Cob Length, Cob Diameter and Grain Number per Cob

Table 5, shows that the highest length of cobs occurring in treatment of A1 which is not significantly different from with treatment of A2, but significantly different with control. The highest average diameter of cob was the treatment of A1 which was not significantly different with treatment of A2, but was significantly different from with control. The highest average number of grain per cobs in treatment of A1 (190.44 grain) was not significant with treatment of A2, but significantly different from with control. This suggests that the inoculation of mycorrhizal fungi at low doses or high doses is able to expand the uptake of nutrients that directly affect the growth and production of plants (Manjunath and Habte, 1990).

The Percentage of Mycorrhizal Fungi Infections at Plant Roots

The results of research showed that the percentage of mycorrhizal fungi infections at the highest root of maize plants occurred in the treatment of A2 as 53.33% which was not significantly different from with treatment of A1, but significantly different from the control. It appears that the higher the dose of the mycorrhizal fungi, the higher the percentage of the infection in the rooting of the plants, although statistically these treatments differ only with the controls. This suggests that corn crops are well suited for the development of mycorrhizal fungi which further form a mutualism relationship. The ability of mycorrhizal fungi to infect plant roots is strongly influenced by the characteristics of the host plant, the abundance of root exudates and the type of mycorrhizal fungi. Carenho et al. (2007) plant, soil and climatic factors are related to the development these fungi and show varied effects on establishment of the mycorrhiza symbiosis and its efficiency.

Table 4 The average of stem diameter (cm) at 7, 14, 21, 28, 35 and 42 DAP

Treatment	Time of observation					
	7	14	21	28	35	42
Without mycorrhiza fungi (A0)	0.03^{a}	0.10^{a}	0.20^{a}	0.20^{a}	0.20^{b}	0.23^{c}
15 g propagule of mycorrhiza fungi (A1)	0.07^{a}	0.10^{a}	0.20^{a}	0.23^{a}	0.27^{ab}	0.30^{bc}
30 g propagule of mycorrhiza fungi (A2)	0.10^{a}	0.13^{a}	0.17^{a}	0.20^{a}	0.23^{ab}	0.33^{b}

Notes: the numbers followed by unequal letters in the same column differ significantly with Smallest Significant Difference Test at 95% confidence level.

Table 5. Effect of mycorrhizal fungi on average cob length, cob diameter and grain number per cob

Treatment	Cob Length(cm)	Cob Diameter (cm)	Grain Number per Cob
Without mycorrhiza fungi (A_0)	6.56 b	2.40 a	89.33 b
15 g propagule of mycorrhiza fungi (A_1)	9.46 a	2.45 a	190.44 a
30 g propagule of mycorrhiza fungi (A_2)	8.32 a	2.21 b	186.33 a

Notes: the numbers followed by unequal letters in the same column differ significantly with Smallest Significant Difference Test at 95% confidence level.

Table 6.The percentage of mycorrhiza fungi infection at plant roots

Treatment	The percentage of mycorrhiza fungi infection (%)
Without mycorrhiza fungi (A0)	0.00b
15 g propagule of mycorrhiza fungi (A1)	50.00a
30 g propagule of mycorrhiza fungi (A2)	53.33a

Notes: the numbers followed by unequal letters in the same column differ significantly with Smallest Significant Difference Test at 95% confidence level.

CONCLUSION

Based on the results of research and discussion, it can be concluded: (1). In the observation plot found 23 species of weeds from broadleaves, 8 species of grasses and 2 species from sedges. The dominant kinds of weeds from broadleaves are: *M.invisa*, *I.triloba*, *M.charantia*, *R.communis*, *S.torvum, P.niruri*, *A.conyzoides*, *A.gracilis*, *P.longisetumr* serta *C.plumieri*. The dominant kinds of weed from grasses are: *S.viridus, E.indica*, *D.adscendes*, *P.repens* and *C.dactylon*. While the dominant kind of weed from sedges is *C.rotundus*. (2). The length of cob, the diameter of cob and the highest average number of grain per cob was found in treatment of A1 with the values each 9.46 cm, 2.45 cm and 190.44 grain per cob. (3).The percentage of mycorrhizal fungi infections at the highest root of maize plants occurred at the treatment of A2 as 53.33%.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Halim designed and performed the experiments and also wrote the manuscript. Tresjia Corina Rakian, Sarawa, Muhidin, Muhammad Tufaila and Aminuddin Mane Kandari were reviewed the manuscript. Abdul Madiki analyzed and interpreted the data. Resman and Waode Siti Anima Hisein were collected the data. All authors read and approved the final version.

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