International Journal of Life Science and Agriculture Research

ISSN (Print): 2833-2091, ISSN (Online): 2833-2105

Volume 03 Issue 07 July 2024

DOI: https://doi.org/10.55677/ijlsar/V03I7Y2024-13

Impact Factor: 6.774 , Page No : 590-595

Application of Mycorrhiza-Biofertilizer to Increase Yield of Several Varieties of Soybean Intercropped Between Maize Double Rows of Different Row Spacings

Yanti Triguna[1], Wayan Wangiyana[2*], Lolita Endang Susilowati[2]

[1]Student, Master of Dryland Agriculture Study Program, University of Mataram (Unram)

[2]Postgraduate Program, University of Mataram, Mataram, Lombok, NTB, Indonesia

ABSTRACT: This research aimed to examine the effects of application of mycorrhiza biofertilizer on yield performance of several varieties of soybean relay-planted between double rows of maize plants grown under different planting distances between rows. The experiment was arranged according to Split Split Plot Design, with three treatment factors, i.e. mycorrhiza biofertilizer (M0= without; M1= with mycorrhiza biofertilizer) as the main plots, soybean varieties (V1= Detap, V2: Biosoy-2, V3= Dena-1) as the subplots, and planting distances between double rows of maize in which two rows of soybean were grown (D1= 80; D2= 90; D3= 100 cm) as the sub-subplots. The results indicated that among those treatment factors, different varieties resulted in significant differences on all measurement variables, while increasing planting distances between maize double rows also significantly increased yield components of soybean, including branch number, pod number, and grain yield per clump, as well as weight of 100 grains, whereas application of mycorrhiza biofertilizer to the soybean plants only significantly increased branch number, pod number, and grain yield per clump. However, mycorrhiza biofertilizer showed interaction effect on most variables, especially in interaction with varieties and double row distances. Based on the patterns of mycorrhiza-varieties interaction, application of mycorrhiza biofertilizer significantly increased pod number (28%) on V1 showing the highest pod number on M1V1 treatment (87.87 pod/clump), while grain yield was highest on M1V3 (26.54 g/clump) and lowest (17.19 g/clump) on M0V1 treatment. The intercropping/monocropping yield ratio was also increased by application of mycorrhiza biofertilizer (from 69.33 to 88.18%) on V2.

Published Online:
July 19, 2024

Corresponding Author:
Wayan Wangiyana

KEYWORDS: additive intercropping, maize, mycorrhiza biofertilizer, row spacings, soybean

1. INTRODUCTION

Due to the high protein content of the grains ranging from 35 to 45% (Liu et al., 2008), soybean (*Glycine max* (L) Merr) is the most important legume food crop in Indonesia, based on the total harvested areas of soybean (https://www.bps.go.id/indicator/53/21/1/luas-panen.html). However, the domestic soybean production is still unable to meet the domestic need for soybean so that soybean still has to be imported, which amount in 2021 more than 2.5 times as much the domestic soybean production (Sembiring, 2022). There are several factors causing the low soybean production, one of which is the low productivity of soybean that can be achieved by the farmers in the field, which was on average only 1.57 ton/ha (https://www.bps.go.id/indicator/53/22/1/produktivitas.html) compared with the potential productivity of soybean, which can be up to 4.1 ton/ha in Mutiara-1 variety (https://balitkabi.litbang.pertanian.go.id/). In addition, it is difficult to increase the land areas that can be used to grow soybean, because 65% of the soybean production areas in Indonesia are in the irrigated areas in competition with rice and maize production, in which soybean or maize is grown only during the dry season II after harvest of the second season rice crop (Adisarwanto 2010).

To overcome the competition for land area between soybean and maize, which in most cases, most farmers prefer to grow maize instead of soybean due to the higher profit of growing maize than soybean (Adisarwanto, 2010), one of the alternatives is to grow soybean in intercropping with maize. Wangiyana et al. (2020) reported that soybean additively relay-planted between rows of waxy maize plants of 75 x 20 cm plant spacing could produce up to 15.33 g/clump under insertion of one row of soybean between rows of maize plants that were grown following paddy rice crop on vertisol land. This means that up to 1.02 ton/ha of soybean grains could be additionally produced by additively intercropping soybean between rows of waxy maize without reducing the population of maize plants, and in fact, insertion of one row of soybean without fertilization between rows of waxy maize plants resulted in a higher grain yield of the maize plants under half dose of N fertilization (Wangiyana et al., 2020).

Soybean plants grown following paddy rice in the dry season mostly show low grain yield even though with soil tillage and NPK fertilization. Adisarwanto et al. (1992) reported an average grain yield of soybean of only 1.29 ton/ha in Sengkol and 1.48 ton/ha in Keruak (eastern parts of Lombok island, Indonesia) from fully NPK fertilized plots. However, higher grain yield could also be obtained from soybean grown following paddy rice by application of Rhizobium bacteria although under half dose of NPK fertilizer application compared with under full NPK dose (Wangiyana et al., 2023). In addition, application of mycorrhiza biofertilizer in combination with Rhizobium inoculant without NPK fertilizer was reported to be able to increase grain yield of soybean grown following paddy rice, compared with fertilization using the recommended doses of NPK fertilizers (Wangiyana & Farida, 2019). Application of mycorrhiza to peanut relay-planted between rows of waxy maize plants was also reported to be able to increase grain yield per clump of peanut plants grown between rows of waxy maize plants, especially in the treatment of relay-planting only one row of peanut between rows of the maize plants (Wangiyana et al., 2021).

This study was aimed to examine the effects of application of mycorrhiza biofertilizer on yield performance of several varieties of soybean relay-planted between double rows of an open-pollinated maize variety grown under different planting distances between rows in dryland areas of East Lombok, Indonesia.

2. MATERIALS AND METHODS

The field experiment in this study was carried out on the experimental farm of "IP2TP Balitbangtan BPTP NTB" located in East Lombok, Indonesia, from from August to October 2022.

The experiment was arranged according to Split Split Plot Design, with three treatment factors, i.e. mycorrhiza biofertilizer application (M0= without mycorrhiza; M1= with mycorrhiza biofertilizer) as the main plots, soybean varieties (V1= Detap, V2: Biosoy-2, V3= Dena-1) as the subplots, and planting distances between double rows of maize in which two rows of soybean were additively intercropped (D1= 80; D2= 90; D3= 100 cm) as the sub-subplots. Therefore, there were 18 treatment combinations, and each combination was prepared in three blocks. To measure the effects of intercropping with maize plants on yield components of those varieties of soybean, which was calculated using intercropping/monocropping ratio (IMR) and expressed as its percentage, each variety was also grown in monocropping system in each block, either with or without application of mycorrhiza biofertilizer. The planting geometries of maize and soybean plants in each plot of different double row distances of maize plants are presented in Figure 1.

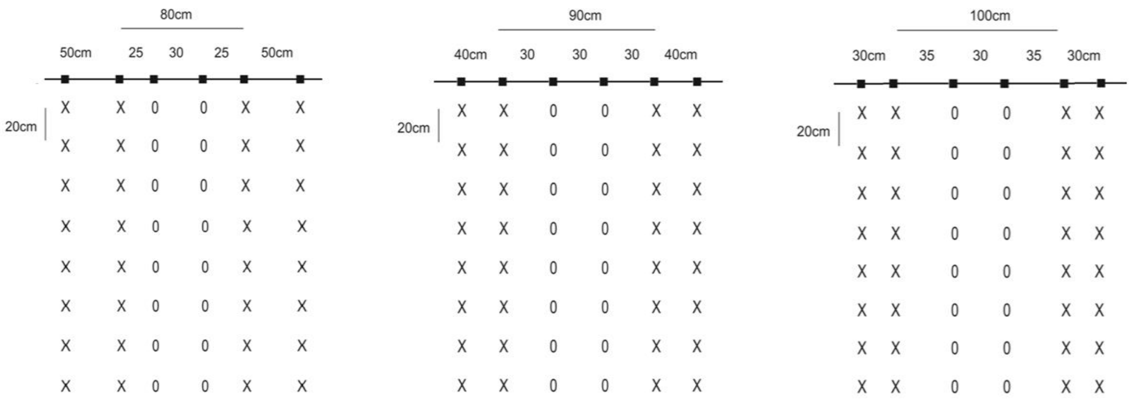

Figure 1. Lay out of the plants in each treatment of double-row distances between maize plants (x= maize plants, o= soybean plants) in the intercropping plots [D1= 80 cm (Left); D2= 90 cm (Middle); D3= 100 cm (Right)]

After plowing and leveling the using a hand tractor, the treatment plots of 210 cm x 200 cm surface sizes were made, and the furrow of 50 cm width and 15 cm depth was also made to separate between plots. Soybean seeds were dibbled three weeks before seeding the maize seeds. Tinning of young soybean plants was done at 100 days after seeding, by leaving to grow only 2 plants per clump, followed by fertilization with NPK fertilizer at 200 kg/ha by dibbling the fertilizer (1.2 g per clump). Tinning the young maize plants was done 14 days after seeding (DAS) by leaving to grow only one maize plant per planting hole, followed by fertilization using NPK fertilizer at 300 kg/ha by dibbling the fertilizer between plants in each row (3.2 g/plant). The second fertilization for maize plants was done at 35 DAS with 200 kg/ha Urea (45% N). Further care for the soybean and maize plants was done following the government recommendation for cultivation of each crop.

The observations variables for soybean were plant height and brach number per clump at 42 DAS (seed-filling stage) and its yield components including number of filled and unfilled pods, weight of 100 grains, and grain yield per clump. Data were analyzed with ANOVA and Tukey's HSD using CoStat for Windows ver.6.303.

3. RESULTS AND DISCUSSION

The results of ANOVA and Tukey's HSD analyses show that among those treatment factors tested, the different varieties resulted in significant differences on all the variables measured, while increasing planting distances between double rows of maize plants, in which two rows of soybean plants were additively intercropped, also significantly increased yield components of soybean, including branch number, filled pod number, and grain yield per clump, as well as weight of 100 grains, especially under the changes of the planting distances between maize double rows from 80 to 100 cm. Although the application of mycorrhiza biofertilizer to soybean relay-planted between double rows of maize plants only significantly increased branch number, filled pod number, and grain yield per clump, mycorrhiza biofertilizer showed interaction effect on most yield components of soybean, especially in interaction with the soybean varieties and the planting distances between the double rows of maize plants (Table 1 and Table 2).

Table 1. Summary of ANOVA and HSD analyses for plant height, branch number, pod number, grain yield, weight of 100 grains, and unfilled pod number of soybean

Treatments	Plant height (cm)		Branch number		Filled pod number		Grain yield g		100 grain Weight		Sq-Unfilled pods [1]	
Row distance:												
D1: 80 cm	54.28	a	5.37	b	65.86	b	20.38	c	14.54	b	2.45	a[2]
D2: 90 cm	56.88	a	5.52	ab	67.27	b	21.81	b	14.94	b	2.39	a
D3: 100 cm	59.69	a	6.02	a	73.98	a	24.24	a	15.42	a	2.58	a
HSD 0.05	5.76		0.51		3.66		1.20		0.45		0.24	
Soybean varieties:												
V1: Detap	62.00	a	6.36	a	78.26	a	19.24	c	12.62	c	2.35	b
V2: Biosoy-2	47.40	b	5.03	b	58.78	c	22.22	b	17.85	a	2.06	c
V3: Dena-1	61.45	a	5.52	b	70.07	b	24.97	a	14.43	b	3.02	a
HSD 0.05	7.62		0.63		4.08		1.79		0.74		0.24	
Mycorrhiza:												
M0: without	57.16	a	5.08	b	63.56	b	20.25	b	14.81	a	2.57	a
M1: with myc.	56.74	a	6.19	a	74.50	a	24.04	a	15.12	a	2.38	a
HSD 0.05	16.50		0.50		3.81		1.96		1.35		0.36	
Interaction:												
Var x Myc	ns		*		**		ns		ns		ns	
D x Myc	ns		ns		ns		ns		ns		***	
D x Var	ns		ns		ns		ns		ns		*	
D x Var x Myc	ns		ns		ns		ns		ns		ns	

Remarks: ns = non-significant; *; **; *** = significant at $p < 0.05$; $p < 0.01$; $p < 0.001$, respectively. [1]Data were transformed to square root; [2]Mean values followed by the same letters in each column indicate non-significant differences between levels of each factor

It can also be seen from Table 2 that the yield ratios (I/M ratios) increased with increasing the planting distances between the double rows of maize plants. This also means that yield penalties of soybean due to intercropping with maize plants were reduced by reducing the distances between double rows of maize plants in which soybean plants were additively intercropped. Among the varieties of soybean tested, Biosoy-2 variety (V2) experienced the most severe yield penalty due to intercropping with maize plants. Although application of mycorrhiza biofertilizer could not significantly reduce this yield penalty, there was a significant interaction effect between varieties and mycorrhiza biofertilizer on yield ratio of soybean, and based on the interaction patterns, there was a highly significant effect of mycorrhiza biofertilizer in reducing the yield penalty or increasing yield ratio, especially on the Biosoy-2 variety (Figure 2A).

Filled pod number and weight of 100 grains were also reduced (IMR<100%) due to intercropping soybean between double rows of maize plants, but increasing the planting distances between double rows of maize plants significantly increased the IMR of filled pod number and weight of 100 grains, but application of mycorrhiza biofertilizer only significantly increased the IMR of filled pod number, on average from 81.73% to 92.41%. In contrast, the number of unfilled pods per clump in general increased

(IMR>100%) due to intercropping soybean between double rows of maize plants, although there were significant effects the interaction between the planting distances of the maize double rows and mycorrhiza biofertilizer or varieties of soybean (Table 2), and the patterns of interaction effects can be seen from Figure 2B, which shows the significantly positive effects of the application of mycorrhiza biofertilizer in reducing the IMR of unfilled pod number due to intercropping not to be too much higher than 100%, although the significant reduction was only under maize planting distance of 80 and 90 cm but under 100 cm, the difference was not significant.

Table 2. Summary of ANOVA and HSD analyses for the intercropping/monocropping ratios (in %) of plant height, branch number, pod number, grain yield, weight of 100 grains, and unfilled pod number of soybean

Treatments	%-Plant height		%-Branch number		%-Filled pod number		%-Grain yield		%-100 grain Weight		%-Unfilled pods	
Row distance:												
D1: 80 cm	88.18	a	86.44	b	83.08	b	78.77	c	89.48	b	114.11	ab[2)]
D2: 90 cm	92.12	a	88.79	b	84.74	b	84.45	b	92.10	b	104.03	b
D3: 100 cm	95.74	a	96.46	a	93.39	a	93.42	a	94.83	a	129.78	a
HSD 0.05	8.64		7.43		4.75		4.58		2.65		24.20	
Soybean varieties:												
V1: Detap	87.00	b	89.33	a	88.88	a	90.36	a	92.80	a	122.09	a
V2: Biosoy-2	100.55	a	90.12	a	81.96	a	78.76	b	91.23	a	130.14	a
V3: Dena-1	88.50	b	92.24	a	90.37	a	87.53	ab	92.38	a	95.69	a
HSD 0.05	7.75		23.39		10.65		9.18		6.97		65.48	
Mycorrhiza:												
M0: without	95.18	a	86.86	a	81.73	b	82.74	a	91.52	a	123.45	a
M1: with myc.	88.85	a	94.26	a	92.41	a	88.36	a	92.75	a	108.50	a
HSD 0.05	16.68		19.59		8.38		7.79		9.47		88.34	
Interaction:												
Var x Myc	*		ns		ns		*		ns		ns	
D x Myc	ns		ns		ns		ns		ns		***	
D x Var	ns		ns		ns		ns		ns		*	
D x Var x Myc	ns		ns		ns		ns		ns		ns	

Remarks: ns = non-significant; *; **; *** = significant at $p < 0.05$; $p < 0.01$; $p < 0.001$, respectively. [2)]Mean values followed by the same letters in each column indicate non-significant differences between levels of each factor

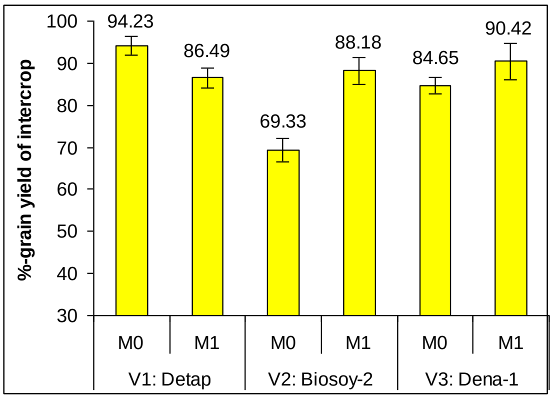

Fig. 2A. Percentage of I/M ratio of grain yield of intercropping (Mean ± SE) due to interaction between mycorrhiza and soybean varieties

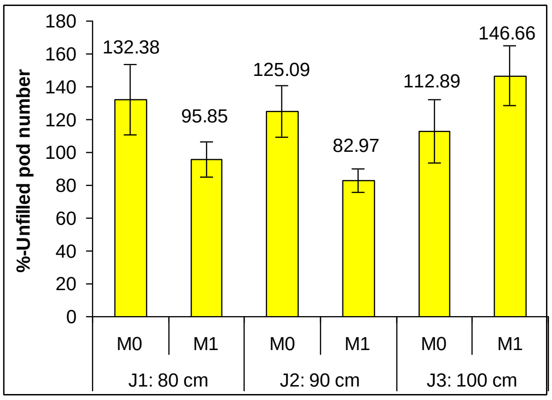

Fig. 2B. Percentage of I/M ratio of unfilled pod number (Mean ± SE) due to interaction between mycorrhiza and maize planting distances

In terms of grain yield of soybean, the two variables resulting a regression with the highest R^2 based on the best subset regression are filled pod number per clump (X1) and weight of 100 grains (X2) with a regression equation Y (grain yield) = - 12.8 + 0.23 X1 + 1.27 X2 (R^2= 46.7%, p-value <0.001), with the coefficient statistics as listed in Table 3. This can be understood because higher number of filled pods per clump will result in higher grain number per clump, and it can be seen from Table 1 that by increasing the planting distances between double rows significantly increased filled pod number per clump followed by increasing weight of 100 grains, which resulted ini increasing grain yield per clump. However, the patterns of interaction between mycorrhiza and varieties are not the same between filled pod number and grain yield per clump (Figure 3A and Figure 3B).

Table 3. The statistics of the regression Y = - 12.8 + 0.23 X1 + 1.27 X2

Predictors	Coef	SE Coef	T	P
Constant	-12.75300	5.24600	-2.43	0.019
X1= Filled pod number per clump	0.22974	0.04095	5.61	0.000
X2= Weight of 100 grains	1.27190	0.20450	6.22	0.000

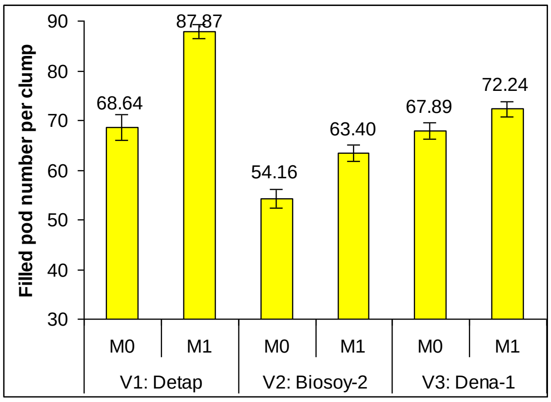

Fig. 3A. Filled pod number per clump (Mean ± SE) due to interaction between mycorrhiza and soybean varieties

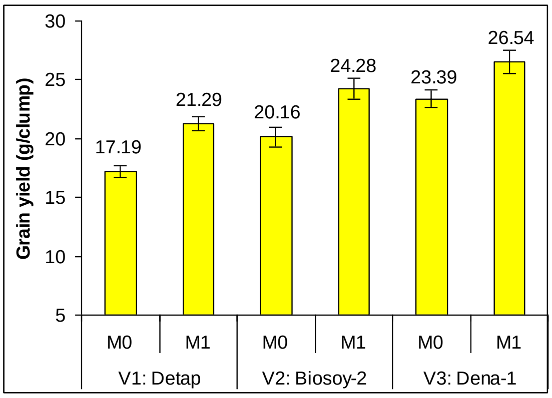

Fig. 3B. Grain yield per clump (Mean ± SE) due to interaction between mycorrhiza and soybean varieties

In Figure 3A, the increase in filled pod number due to application of mycorrhiza biofertilizer is the highest among those varieties, but the differences in grain yield look similar among the varieties of soybean. These could be due to the different seed sizes, which can be inferred from the weight of 100 grains, which is the lowest among the varieties of soybean (Table 1). However, what the significant results from this experiment are the significant effects of the application of mycorrhiza biofertilizer, and the significant effects of increasing the planting distances between the double rows of maize plants in which two rows of soybean were additively intercropped. The implication of these results that soybean can be produced between rows of maize by changing the row pattern to double rows and increasing the distances between the double rows of maize plants, as well as by application of mycorrhiza biofertilizer.

Although yield penalty due to additively intercropping soybean between rows of maize plant cannot be avoided, because plant height of soybean is much less than that of maize so that soybean plants must be shaded by the maize plants in an intercropping system, it can be seen from Figure 2A that application of mycorrhiza biofertilizer significantly increase the I/M ratios of soybean grain yield, especially that of the Biosoy-2 variety. Many researchers have reported that soybean plants are very responsive to symbiosis with arbuscular mycorrhizal fungi (AMF). Application of mycorrhiza biofertilizer was found to be significantly increase growth and grain yield of soybean grown during dry season on vertisol soil (Wangiyana & Farida, 2019). Zhang et al. (2024) also reported that intercropping soybean and maize significantly increased the content of root exudates, the concentration of available N, available P, and improved AMF colonization, which finally boosted plant growth.

In this experiment, soybean was seeded 21 days before seeding maize, and application of mycorrhiza biofertilizer was done at seeding by placing the biofertilizer in the base of the planting holes (Wangiyana & Farida, 2019; Wangiyana et al., 2022). Therefore, when soybean plants were at flowering stage (30-35 DAS), maize plants were at 9 DAS, and they have not started to shade the soybean plants, and they started to partially shade the soybean plants at 30-35 DAS, during which soybean plants were at the peak of seed filling stage. Therefore, increasing the planting distances between double rows of the maize plants had a significant effect in increasing grain yield of soybean, through an increase in the weight of 100 grains as well as filled pod number per clump (Table 1). Application of mycorrhiza biofertilizer under monocropping systems was also found to increase biomass weight of soybean plants of the same varieties (Wangiyana et al., 2022). In this experiment, soybean was also inoculated with Rhizobium in addition to application of mycorrhiza biofertilizer, which means that soybean received co-inoculation of both types of biofertilizer, and co-inoculation has been found to significantly increase growth and yield of soybean (Wangiyana & Farida, 2019; Marro et al., 2020; Wangiyana et al., 2022). Wang et al. (2016) also reported that co-inoculation significantly increased biomass and N contents of soybean and maize plants in an intercropping system, and higher biomass and N content is required by soybean plants to increase the rates of seed-filling and grain yield (Sinclair & de Wit, 1975).

4. CONCLUSION

It can be concluded that soybean can be produced through relay planting it between double rows of maize plants, and grain yield can be increased by application of mycorrhiza biofertilizer and increasing the planting distances between the double rows of maize plants in which two rows of soybean were additively intercropped. However, there are differences among the varieties in the yield penalties of soybean due to intercropping it between double rows of maize plants, but the yield penalties can be reduced by the application of mycorrhiza biofertilizer on both soybean and maize plants.

REFERENCES

1. Adisarwanto, T. (2010). Strategi peningkatan produksi kedelai sebagai upaya untuk memenuhi kebutuhan di dalam negeri dan mengurangi impor. *Pengembangan Inovasi Pertanian* 3(4): 319-331.
2. Adisarwanto, T., R. Suhendi, M. Anwari, Sinaga and M. Ma'shum (1992). Kajian residu pupuk nitrogen untuk padi gora terhadap hasil kedelai yang ditanam setelah padi gora". In: H. Suyamto, A. Winarto, Sugiono and Sunardi (Eds), Risalah Seminar Hasil Penelitian Sistem Usahatani di Nusa Tenggara Barat (Proceedings of a seminar on farming systems, held in Mataram, 22-26 October, 1991). Malang, Indonesia: Balai Penelitian Tanaman Pangan Malang.
3. Liu, C., Wang, X., Ma, H., Zhang, Z., Gao, W., & Xiao, L. (2008). Functional properties of protein isolates from soybeans stored under various conditions. *Food Chemistry*, 111(1), 29-37.
4. Marro, N., Cofre, N., Grilli, G., Alvarez, C., Labuckas, D., Maestri, D., & Urcelay, C. (2020). Soybean yield, protein content and oil quality in response to interaction of arbuscular mycorrhizal fungi and native microbial populations from mono-and rotation-cropped soils. *Applied Soil Ecology*, 152, 103575.
5. Sembiring, L.J. 07 March 2022. RI impor kedelai 2,5 juta ton setahun, nilainya capai Rp 21 T. CNBC Indonesia. https://www.cnbcindonesia.com/news/20220307122046-4-320572/ri-impor-kedelai-25-juta-ton-setahun-nilainya-capai-rp-21-t#:~:text=Dari%20data%20Badan%20Pusat%20Statistik,sebanyak%202%2C47%20juta%20ton
6. Sinclair, T.R., and de Wit, C.T. (1975). Photosynthate and nitrogen requirements for seed production by various crops. *Science*, 189: 565-567.
7. Wang, G., Sheng, L., Zhao, D., Sheng, J., Wang, X., & Liao, H. (2016). Allocation of nitrogen and carbon is regulated by nodulation and mycorrhizal networks in soybean/maize intercropping system. *Frontiers in Plant Science*, 7, 1901.
8. Wangiyana, W., and N. Farida, 2019. Application bio-fertilizers to increase yields of zero-tillage soybean of two varieties under different planting distances in dry season on vertisol land of Central Lombok, Indonesia. *AIP Conference Proceedings 2199*, 040009 (2019); DOI: https://doi.org/10.1063/1.5141296.
9. Wangiyana, W., Arianti, D.F. and Ngawit, I.K. 2023. Improvement of Growth and Yield of Several Varieties of Soybean Following Paddy Rice Using *Rhizobium* Biofertilizer with Reduced NPK Doses. *IOP Conf. Ser.: Earth Environ. Sci*., 1253, 012054 (Oct 2023). DOI: https://doi.org/10.1088/1755-1315/1253/1/012054.
10. Wangiyana, W., Farida, N., Cabasan, M.T.N. (2021). Growth and yield of peanut relay-planted between rows of waxy maize as affected by row proportion and mycorrhiza biofertilizer. *J. Sust. Dryland Agric. Sys*., 1(2): 68-77 (Des 2021). https://jurnalpasca.unram.ac.id/index.php/josdas/article/view/207/107
11. Wangiyana, W., Irwinsyah, L.R., Parawinata, and Kisman. 2020. Additive Intercropping with Legume Crops Increases Waxy Maize Yield on Vertisol Riceland in Lombok, Indonesia. *Russian Journal of Agricultural and Socio-Economic Sciences*, 102(6): 57-64 (June 2020). DOI: https://doi.org/10.18551/rjoas.2020-06.07.
12. Wangiyana, W., Suheri, H., & Jaya, I. K. D. (2022). Response of Several Soybean Varieties to Co-inoculation with Rhizobium and Mycorrhiza Biofertilizers in Dryland of East Lombok, Indonesia. *International Journal of Horticulture, Agriculture and Food science*, 6(6), 01-09.
13. Zhang, S., Li, S., Meng, L., Liu, X., Zhang, Y., Zhao, S., & Zhao, H. (2024). Root exudation under maize/soybean intercropping system mediates the arbuscular mycorrhizal fungi diversity and improves the plant growth. *Frontiers in Plant Science*, 15, 1375194.