http://dx.doi.org/10.22161/ijeab/4.3.39 ISSN: 2456-1878

Mycorrhizal Inoculation to Increase Yield of Soybean Direct-Seeded Following Rice of Different Growing Techniques in Vertisol Soil, Lombok, Indonesia

Wayan Wangiyana [1*], Ni Wayan Dwiani Dulur [2], Nihla Farida [1]

[1]Department of Agronomy, Faculty of Agriculture, University of Mataram, Mataram, Lombok, Indonesia
[2]Department of Soil Science, Faculty of Agriculture, University of Mataram, Mataram, Lombok, Indonesia
*Corresponding author

***Abstract*— *This study aimed to examine the impact of cultivation techniques and organic fertilization of rice, and arbuscular mycorrhizal fungi (AMF) inoculation of zero-tillage soybean on yield of soybean direct-seeded following rice in two year sequences of rice-soybean cropping (2010 and 2011) in vertisol soil taken from Central Lombok, Indonesia. The pot experiments were conducted in a glasshouse, with two treatment factors for rice crops, i.e. rice cultivation techniques (T1= Conventional, T2= SRI (System of Rice Intensification) without AMF, and T3= SRI with AMF inoculation in nursery), and organic fertilization (O1= without organic (NPK only), O2= organic manure + NPK at full recommended doses in the first or half the doses in the second year, and O3= organic manure + NPK at half the recommended doses in the first or without NPK in the second year), and AMF inoculation of soybean plants (M0= without, and M1= with AMF inoculation). The results indicated that AMF inoculation of zero-tillage soybean direct-seeded following rice crops in vertisol soil more significantly increased grain yields of soybean grown following conventional rice (with an average increase of up to 35.6%), compared with following SRI-rice (only 10.6 - 18.8% increase), indicating a need for AMF inoculation of soybean plants in rotation with conventional rice in vertisol soil. Different cultivation techniques and organic fertilization of rice plants also significantly affected yield of the soybean direct-seeded immediately after harvest of the preceding rice, which indicates positive impacts of organic fertilization of rice on grain yield of soybean following rice.*

Keywords*— *soybean, rice, arbuscular mycorrhiza, vertisols, Bokashi.

I. INTRODUCTION

Vertisol soil in southern areas of Central Lombok is hard and cracked when dry because of its high content of clay particles in addition to low content of organic matter (Kusnarta *et al*., 2017). In the areas, soybean is mostly planted without tillage in the dry seasons (dry season 1 or dry season 2) after harvest of paddy rice. Since it is grown in the dry season, the farmers generally do not fertilize their soybean crops, so that the yields are normally low. Although with complete NPK fertilization, from a field experiment in southern Lombok reported by Adisarwanto *et al*. (1992), soybean yield was also relatively low, i.e. 1.29 ton/ha in Sengkol and 1.48 ton/ha in Keruak, and there was no significant effect of fertilization.

When conditions of vertisol soils were hard and dry in the dry season, root growth will also be hampered and nutrient uptake from the soil will also be restricted. Under these conditions, it is very likely that soybean plants require a good symbiosis with arbuscular mycorrhizal fungi (AMF), because their tiny external hyphae can explore much larger volume of soil and help their host plants to take up more nutrients and water compared with the roots (Smith and Read, 2008). However, the establishment of arbuscular mycorrhizal (AM) symbiosis naturally by soybean grown after paddy rice is possibly hampered by the generally very low population of AMF after paddy rice crops, which are normally irrigated with flooded irrigation system, as has been reported by several researchers (Ilag *et al*., 1987; Wangiyana *et al*., 2006).

Another obstacle for soybean production is its very high N requirement for seed production, because of its high protein contents of the grains. Among the 24-seed plants examined by Sinclair and de Wit (1975), nitrogen requirement of soybean plants during the seed-filling phase is in the category of the highest, and N requirement of a soybean plant far exceeds the supplying capability of the root uptake, so that soybean crop is classified as a self-destructive plant, because it often has to remobilize N contents of the leaves to the growing seeds. Therefore, seed-coating with inoculants of *Rhizobium* sp at the time of planting is the standard procedure for cultivating soybean, especially in rotation with irrigated rice crops.

http://dx.doi.org/10.22161/ijeab/4.3.39 ISSN: 2456-1878

The use of soybean seed plus (which has been inoculated with *Rhizobium* BTCC-B 64) of the Indonesian Institute of Science (LIPI) was reported to be able to increase soybean grain yields to more than 3 tons/ha, and even in some places could reach 4.5 tons/ha (Malik, 2008).

Besides establishing symbiosis with *Rhizobium* sp, soybean crop is also capable of establishing symbiosis with arbuscular mycorrhizal fungi (AMF), and the soybean plants are categorized as having a high level of dependency on symbiosis with AMF (Anderson and Ingram, 1993). With *Rhizobium* sp and AMF, soybean plants establish a tripartite symbiosis (Meghvansi and Mahna, 2009; Subramanian *et al*., 2011), and the presence of AMF in the tripartite symbiosis is more profitable than simply symbiosis with *Rhizobium* bacteria (Ruiz-Lozano *et al*., 2001; Antunes *et al*., 2006a,b,c). However, some researchers also reported that different varieties of soybean may show different responses to infection by AMF (Nwoko and Sanginga, 1999; Powell *et al*., 2007). A different soybean variety may also show different responses to different AMF species (Antunes *et al*., 2006c).

This study aimed to examine the effect of AMF inoculation of zero-tillage soybean direct-seeded immediately after harvest of paddy rice crop grown with different cultivation techniques (between conventional and SRI techniques) and organic fertilization of the rice crops on grain yield of the soybean crop following rice in vertisol soil taken from vertisol riceland in Southern Lombok, Indonesia. The experiment was conducted in two consecutive years (2010 and 2011), which was twice planting of soybean, respectively after the rice harvest.

II. MATERIALS AND METHOD

Design of the experiments

The experiments were conducted in the glasshouse of the Faculty of Agriculture, University of Mataram, using soil samples taken from vertisol ricefield in Mujur village, Central Lombok (Indonesia). After being air-dried and sieved using test sieve of 2 mm opening, the soil samples were used to fill the pots (12 kg/pot) for growing the rice and soybean crops in these experiments. The soybean crop direct-seeded following harvest of rice crop in this case was used to examine the impact of cultivation techniques of the rice crop. Therefore, there were treatment factors applied to the rice crop preceding the soybean crop, and there was also a treatment factor applied to the soybean crop direct-seeded following the rice crop. The successive cropping of rice-soybean was carried out in 2010 and 2011, with the same treatments, except for reduced doses of inorganic fertilizer (N, P, K) in 2011, and the data reported here were results of observations made on the soybean plants.

The experiment was arranged according to the Completely Randomized Design, with 3 treatment factors (2 treatment factors applied to the rice plants and 1 treatment factor applied to soybean plants), with the following details:

1. The first factor, namely rice cultivation techniques (T), consisted of three treatment levels, i.e. T1 (Conventional techniques); T2 (SRI technique without AMF inoculation); and T3 (SRI technique with AMF inoculation in the nursery).
2. The second factor, namely organic fertilization (O) on rice, consisted of three treatment levels, i.e. O1 (without organic fertilizer or only fertilized with full recommended doses of NPK); O2 (organic fertilizer + full doses of NPK); and O3 (organic fertilizer + half doses of NPK). The doses of NPK in the second year (2011) were reduced to half doses on the O2 and without NPK on the O3 treatment.
3. The third factor, namely AMF inoculation (M) of soybean, consisted of two treatment levels, i.e. M0 (without AMF inoculation) and M1 (with AMF inoculants applied in the planting hole together with organic fertilizer).

Thus, the number of treatment combinations for soybean plants was 3x3x2 or 18 treatment combinations, each of which was made in three replications.

Implementation of the experiments

The experiments were started in 2010, beginning with preparation of growing media, continued with successive planting of rice-soybean in 2010 and in 2011. The organic fertilizer used in the experiments was “Bokashi” fertilizer, i.e. EM4 fermented cattle manure, with application dose of 10 ton/ha (or 62.5 g/pot). The recommended NPK fertilizer doses were 300 kg Urea, 150 kg SP36 and 100 kg KCl per ha. Rice seedlings of “Silugonggo” variety were prepared differently with different growth duration in the nursery, i.e. 9 days in the dry nursery for SRI technique and 25 days in flooded nursery for conventional technique. The growing media for rice nursery were prepared by mixing air-dried vertisol soil, river sand and rice husk ash of the same volume. AMF inoculation for rice seedlings was done by spreading “Technofert” biofertilizer on the nursery media which was then covered with rice husk ash, then pre-germinated rice seeds were spread on it. Technofert was supplied by the Institute of Biotechnology Research (BPPT), Serpong, Indonesia. No NPK fertilizers were applied to the nurseries but rice seedlings were sprayed with Urea fertilizer (5 g/L) every 5 days for wet and 3 days for dry nursery since 5 days after seeding (DAS).

Rice planting I (in 2010) was done by transplanting seedlings from the nurseries to the pots on the same day. The soil in the pots was puddled 2 days before transplanting by mixing the soil with water, then left thin standing water for two days. Just before transplanting, basic fertilization was done with 62.5 g Bokashi, 0.625 g Urea (1/3 dose), 0.938 g SP-36 and 0.625 g KCl per pot, which were mixed with the mud of 8 cm diameter and 5 cm depth on the center of the soil surface in the pot. Transplanting was done by planting 3 seedlings for conventional and 1 seedling for SRI technique in each planting hole in the center as the main plant and another planting hole of 10 cm apart as a reserve for a maximum of 10 days. The rest of the Urea was applied at 30 and 50 days after transplanting (DAT), each with 0.625 g/pot. The SRI rice plants were intermittent irrigated during vegetative growth stages by applying thin flooding every 7 days, and maintained in thin (2 cm) flooded condition during the reproductive growth stages, while the conventional rice plants were maintained in flooded condition (5-10 cm) from transplanting to the reproductive growth stages. The rice plants were harvested at 93 DAT.

Soybean planting I (in 2010) was done by dibbling soybean seeds ("Grobogan" variety) next to the rice stubble immediately after harvest of the rice crop without tillage, after seed-coating the seeds with "Rizoplus" (*Rhizobium* inoculants). For the M1 treatment, the planting hole was first filled 5 g "Technofert" in the bottom, which was then covered with "Bokashi" of 62.5 g/pot, and Rhizoplus-coated soybean seeds were then placed on it and covered with soil. Each pot after planting the soybean seeds was covered with pieces of rice straw harvested from that pot. NPK fertilization was done at 7 DAS by dibbling Phonska fertilizer (15-15-15) of 1.25 g/pot 5 cm beside the planting hole at 5 cm depth. Watering was done as necessary, and soybean plants were harvested at 76 DAS.

Rice planting II (in 2011) was done after puddling the soil and applying the basic fertilizers as in 2010 rice planting, except for the NPK doses, which were half dose for the O2 and zero for the O3 treatment. Puddling was done after fallowing for a month after harvest of 2010 soybean plants, which was then flooded with water for a week and puddled. The procedures for preparing the nursery and growing the rice plants were the same as those applied in 2010, except for the rice variety, which was "Inpari 13" in 2011.

Soybean planting II (in 2011) was also done by dibbling soybean seeds without tillage immediately after harvest of the 2011 rice. All the procedures applied were the same as those for growing the 2010 soybean plants.

Observation variables and data analysis

Observation variables for the soybean plants were plant dry weight, grain number, and dry grain yield per pot, and weight of 25 dry grains, both for 2010 and 2011 soybeans. Data were analyzed with analysis of variance (ANOVA) and the Tukey's HSD test at 5% level of significance using the statistical software CoStat for Windows ver. 6.303. The graph is displayed in the form of a bar chart using the values of Mean ± SE (standard error) based on Riley (2001).

III. RESULTS AND DISCUSSION

The results showed that AMF inoculation of soybeans direct-seeded following paddy rice significantly increased soybean seed yields, both in 2010 and 2011, as shown in Table 1. The increase in soybean yield due to AMF inoculation of soybeans is presented in more detailed in Figure 1 for soybean yields in 2010, and Figure 2 for soybean yields in 2011, on each combination of rice cultivation techniques and organic fertilization treatment on rice plants preceding soybean planting.

In addition to the AMF inoculation treatment that was applied directly to soybean plants, the two treatment factors applied to rice plants preceding the soybean plants, namely rice cultivation techniques (T) and organic fertilization (O) on rice plants, also affected grain yields of soybean direct-seeded following the rice crop. This indicates significant residual effects of rice growing techniques on yield of the subsequent soybean crop. There were also some significant interaction effects on soybean grain yields between AMF inoculation of soybeans and the treatments applied to the preceding rice plants, but the patterns of the interactions were different between year I (2010) and year II (2011). In year I, significant interactions occurred between AMF inoculation of soybeans and cultivation techniques of the preceding rice, whereas in year II, significant interactions occurred between AMF inoculation of soybeans and organic fertilization in the preceding rice plants (Table 1).

Based on the interaction effects on yield of soybeans following rice crop in 2010 (Figure 1), it appears that the significant effects of AMF inoculation of soybean on the soybean yield were more common on soybean plants direct-seeded following conventional paddy rice compared with following SRI rice, especially those with AMF inoculation in the nursery. This is also evident from the significant interactions between rice cultivation techniques and AMF inoculation of soybeans (Table 1), which is also graphically illustrated in Figure 3.

Table 1. Summary of ANOVA results of the effects of cultivation techniques and organic fertilization of rice plants and AMF inoculation of soybean direct-seeded following rice both on 2010 and 2011 soybean crops

Observation variables per year	Main effects			Interaction effects			
Experiment year I (2010):	**Tech**	**Org**	**Myco**	**TxO**	**TxM**	**OxM**	**TxOxM**
Soybean plant dry weight per pot	*	***	***	***	*	ns	ns
Soybean grain number per pot	***	***	*	ns	*	ns	ns
Soybean dry grain yield per pot	***	**	***	ns	*	ns	ns
Weight of 25 dry grains	ns	ns	***	ns	ns	ns	ns
Experiment year II (2011):	**Tech**	**Org**	**Myco**	**TxO**	**TxM**	**OxM**	**TxOxM**
Soybean plant dry weight per pot	***	***	***	***	ns	*	ns
Soybean grain number per pot	***	**	***	ns	ns	ns	ns
Soybean dry grain yield per pot	***	*	***	ns	ns	*	ns
Weight of 25 dry grains	ns	***	***	***	**	ns	**

Remarks: Tech (T)= rice cultivation technique; Org (O)= organic fertilization of rice; Myco (M)= mycoriza (AMF) inoculation of soybean; ns= non-significant (at p-value □ 0.05); *, **, *** = significant at p-value < 0.05, p-value < 0.01, and p-value < 0.001, respectively

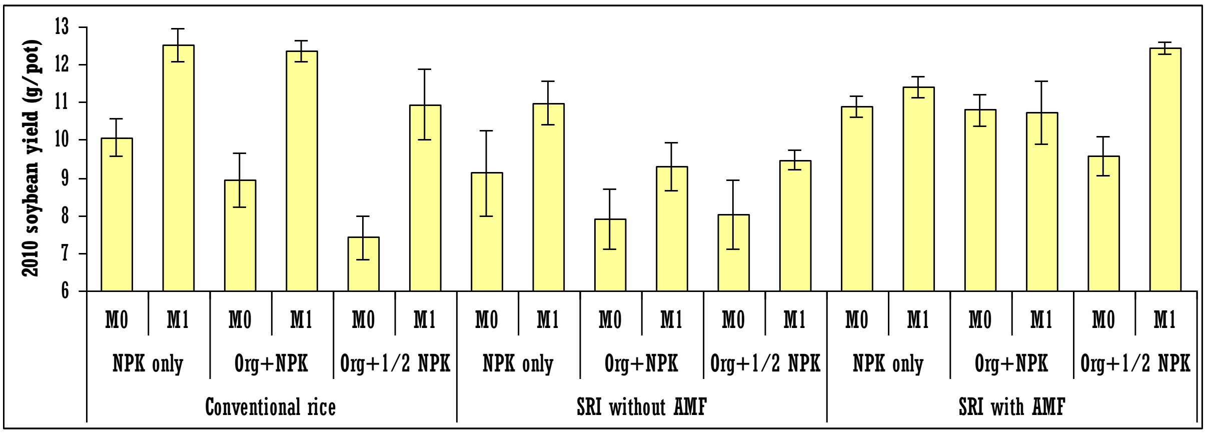

Fig.1. Average (Mean ± SE) grain yield (g/pot) of soybean in year I (2010) as affected by AMF inoculation of soybean and residual effects of cultivation techniques and organic fertilization on rice plants preceding the soybean crop

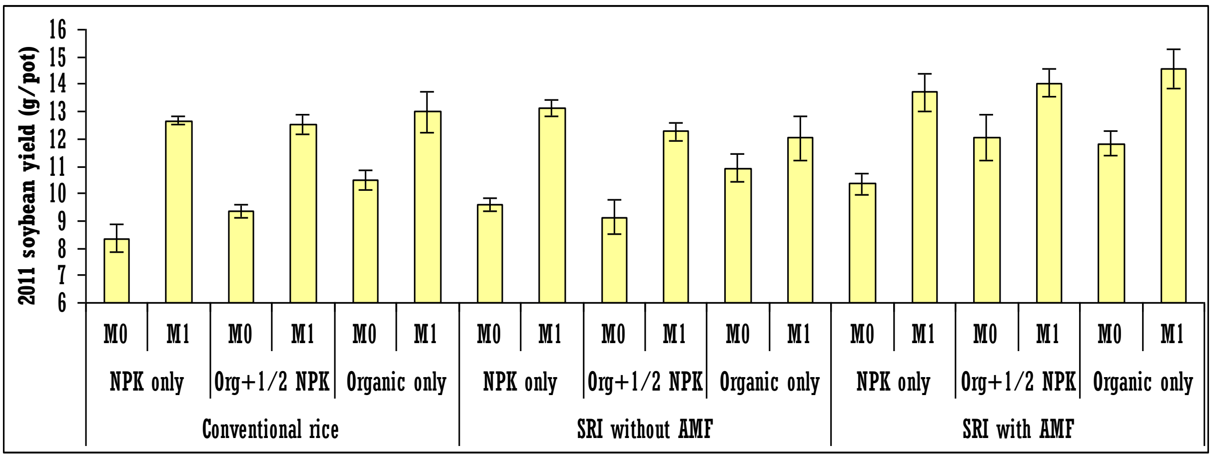

Fig.2. Average (Mean ± SE) grain yield (g/pot) of soybean in year II (2011) as affected by AMF inoculation of soybean and residual effects of cultivation techniques and organic fertilization on rice plants preceding the soybean crop

http://dx.doi.org/10.22161/ijeab/4.3.39 ISSN: 2456-1878

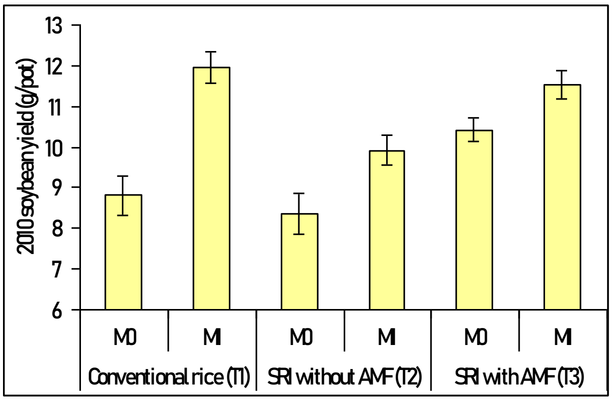

Fig.3. Average (Mean ± SE) grain yield (g/pot) of soybean in year I (2010) as affected by interaction between AMF inoculation of soybean and cultivation techniques of the rice crop preceding the 2010 soybean (conventional; SRI without; or SRI with AMF inoculation in the rice nursery)

From Figure 3 it can be seen that AMF inoculation of soybeans increased soybean yield, which was higher in soybeans direct-seeded following conventional paddy rice compared with following SRI technique of growing rice which seedlings were inoculated with AMF in the nursery. As described in the methods that rice plants in conventional techniques were grown with a flooded irrigation system whereas in the SRI techniques, they were irrigated intermittently between thin flooding and dry conditions with a 7 day watering interval. Thus the conditions of the growing media were more aerobic in SRI techniques compared with in conventional techniques. These aerobic conditions in the SRI techniques seem to be more conducive for better development of AMF propagules in the root systems and rhizosphere of the rice plants under SRI than under flooded conditions. This better development of AMF in the SRI can be inferred from the higher grain yield of uninoculated soybean (M0) direct-seeded following SRI-rice having AMF inoculation in the nursery (T3M0) compared with following conventional (T1M0) or SRI-rice having no AMF inoculation in the nursery (T2M0).

Because of the high potentials in highly reducing AMF population by inundated conditions in conventional rice (Ilag *et al*., 1987; Wangiyana *et al*., 2006), which was flooded since the nursery, then the uninoculated soybean plants (M0) direct-seeded following conventional rice did not have sufficient infective propagules of AMF to establish optimum AMF symbiosis in the uninoculated soybean plants grown following conventional rice, just like the "post flood syndrome" that was stated by Ellis (1998). Due to its high dependency on AMF symbiosis (Anderson and Ingram, 1993), then the uninoculated soybean plants, which were direct-seeded following dried conventional rice soil of vertisol type, would not be able to take up sufficient nutrients and water to support high growth and grain yield. On the other hand, AMF inoculated soybean plants (M1) direct-seeded following the conventional rice (T1), because of the direct AMF inoculation, would be able to immediately establish a good AM symbiosis, hence AMF functions in helping their hosts (in this case, the soybean plants) to take up more nutrients and water (Smith and Read, 2008; Smith and Smith, 2011), even in compacted soils (Miransari *et al*., 2009), would be well established since the beginning of the soybean growth stages. Therefore, AMF inoculation on soybean direct-seeded following conventional rice would be more advantageous than following SRI-rice having AMF inoculation in the nursery (T3), as shown in Figure 3.

In year II (2011), unlike in Figure I, it can be seen from Figure 2 that the difference in soybean grain yield between AMF inoculation (M1) and without inoculation (M0) is higher in soybean direct-seeded following rice plants receiving no organic than following those receiving organic fertilization. This indicates a change in the effect of organic fertilization of rice plants on yields of the subsequent soybean between year I and year II, which had a more significant impact on the soybean crops after two years of organic fertilization to rice plants. Figure 4 also shows those differences, which also shows a significant interaction between AMF inoculation of soybeans and organic fertilization of the rice plants preceding the soybean plants. This possibly occurred as a result of the positive influence of organic fertilization on the development of AMF in the soil, as reported by several other researchers (Joner, 2000; Gryndler *et al*., 2001, 2006). As also shown in Figure 4, after 2 years, grain yields were also higher in soybean plants direct-seeded following rice receiving organic fertilization for two years, compared with those following rice receiving no organic fertilization, although the soybean plants were not inoculated with AMF at planting. Thus, organic fertilization for two years in rice plants had a positive impact on AMF symbiosis with soybean plants grown following rice crops (Figure 4).

It can also be seen from Table 2 that, based on the main effect, in year I (2010), grain yield of soybean direct-seeded following rice receiving organic fertilizer but only half doses of NPK fertilizers (T3) were lower than following rice receiving full doses of NPK although without organic fertilization (T1). In contrast, in year II, i.e. after two years of organic fertilization of rice, grain yields were on average higher in soybean following rice receiving full organic fertilization (T3) compared with following rice that received only full doses of NPK fertilizers.

http://dx.doi.org/10.22161/ijeab/4.3.39 ISSN: 2456-1878

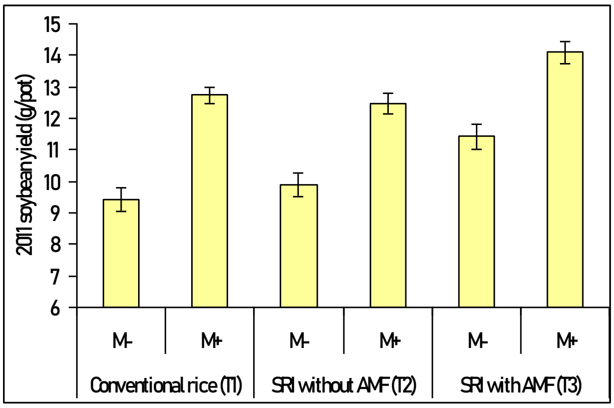

Fig.4. Average (Mean ± SE) grain yield (g/pot) of soybean in year II (2011) as affected by interaction between AMF inoculation of soybean and organic fertilization on the rice crop preceding the 2011 soybean

In addition, there appears to be an increase in soybean grain yield from year I to year II. The increase was more common in soybean plants inoculated with AMF compared with no AMF inoculation, as shown in Table 3. However, the increase in soybean seed yield was also related to the positive impact of organic fertilization of rice plants on yields of soybean plants grown following rice, which possibly happen through positive impacts of organic fertilization on AMF development. On the other hand, it seem that grain yields declined from year I to year II in soybean plants following rice receiving no organic fertilizer, especially following rice plants cultivated under flooded systems or conventional rice (T1). This also indicates a negative impact of rice flooding on the development of AMF infective propagules in the soil (Ilag *et al*., 1987; Ellis, 1998; Wangiyana *et al*., 2006).

Table 2. Mean plant dry weight, grain number, dry grain yield, and weight of 25 dry grains of soybean for each levels of the treatment factor in 2010 and 2011 planting

Treatment factors and year:	**Mean values of yield component data**			
Results of 2010 treatments	**Plant dry weight (g/pot)**	**Grain number/pot**	**Grain yield (g/pot)**	**Weight of 25 dry grains (g)**
T1= Conventional rice	18.88 ab	55.78 a	10.38 a	4.64 a [1)]
T2= SRI without AMF	17.62 b	50.67 b	9.14 b	4.50 a
T3= SRI with AMF inoculation	19.60 a	60.11 a	10.98 a	4.59 a
Tukey's HSD 5%	1.57	4.57	0.88	0.30
O1= No organic (NPK only)	17.23 b	61.00 a	10.84 a	4.47 a
O2= Organic + 100% NPK	19.01 a	52.44 b	10.01 ab	4.75 a
O3= Organic + 50% NPK	19.86 a	53.11 b	9.65 b	4.52 a
Tukey's HSD 5%	1.57	4.57	0.88	0.30
M0= No AMF inoculation	15.97 b	53.96 b	9.20 b	4.27 b
M1= With AMF inoculation	21.42 a	57.07 a	11.13 a	4.89 a
Tukey's HSD 5%	1.06	3.09	0.60	0.20
General mean of all factors	**18.70**	**55.52**	**10.17**	**4.58**
Results of 2011 treatments	**Plant dry weight (g/pot)**	**Grain number/pot**	**Grain yield (g/pot)**	**Weight of 25 dry grains (g)**
T1= Conventional rice	16.14 a	59.33 b	11.07 b	4.60 a
T2= SRI without AMF	13.90 b	61.67 b	11.18 b	4.54 a
T3= SRI with AMF inoculation	17.62 a	68.94 a	12.76 a	4.61 a
Tukey's HSD 5%	1.95	3.90	0.75	0.08
O1= No organic (NPK only)	13.96 b	62.72 ab	11.30 b	4.49 b
O2= Organic + 100% NPK	16.41 a	60.89 b	11.57 ab	4.70 a
O3= Organic + 50% NPK	17.29 a	66.33 a	12.14 a	4.55 b
Tukey's HSD 5%	1.95	3.90	0.75	0.08
M0= No AMF inoculation	13.71 b	59.11 b	10.24 b	4.32 b
M1= With AMF inoculation	18.06 a	67.52 a	13.10 a	4.84 a
Tukey's HSD 5%	1.32	2.64	0.51	0.06
General mean of all factors	**15.89**	**63.31**	**11.67**	**4.58**

Remaks: [1)] Mean values in each column followed by the same letter are not significantly different between levels of a treatment factor in each year

Table 3. Changes in mean grain yield (g/pot) of soybean direct-seeded following rice year I (2010) and rice year II (2011)

Treatments for rice crops preceding soybean crops		AMF ino-culation on soybean	Mean (± SE) soybean grain yield (g/pot) in Year I (2010) and Year II (2011)		Grain yield differences (g/pot)
Rice cultivation technique	Organic fertilization *)		(2010 ± SE)	(2011 ± SE)	(2011-2010)
Conventional rice (T1)	No organic (NPK only)	M0	10.08 ± 0.48	8.36 ± 0.50	-1.72
		M1	12.53 ± 0.44	12.67 ± 0.17	0.13
	Organic + 100% NPK	M0	8.95 ± 0.71	9.37 ± 0.24	0.43
		M1	12.37 ± 0.27	12.52 ± 0.38	0.15
	Organic + 50% NPK	M0	7.42 ± 0.56	10.50 ± 0.37	3.09
		M1	10.95 ± 0.93	13.00 ± 0.75	2.05
SRI without AMF inoculation (T2)	No organic (NPK only)	M0	9.13 ± 1.13	9.59 ± 0.22	0.46
		M1	10.99 ± 0.59	13.10 ± 0.30	2.11
	Organic + 100% NPK	M0	7.90 ± 0.80	9.14 ± 0.66	1.25
		M1	9.30 ± 0.64	12.27 ± 0.32	2.97
	Organic + 50% NPK	M0	8.04 ± 0.92	10.93 ± 0.49	2.89
		M1	9.48 ± 0.26	12.02 ± 0.81	2.55
SRI with AMF inoculation in the nursery (T3)	No organic (NPK only)	M0	10.89 ± 0.27	10.36 ± 0.38	-0.54
		M1	11.41 ± 0.28	13.70 ± 0.67	2.29
	Organic + 100% NPK	M0	10.79 ± 0.41	12.06 ± 0.85	1.27
		M1	10.73 ± 0.82	14.05 ± 0.53	3.31
	Organic + 50% NPK	M0	9.58 ± 0.52	11.83 ± 0.46	2.25
		M1	12.44 ± 0.15	14.56 ± 0.73	2.11

*) Organic fertilization for O2 and O3 treatments were: in year I (2010), O2= organic + 100% NPK doses, and O3= organic + 50% NPK doses, while in year II (2011), O2= organic + 50% NPK doses, and O3= organic fertilization only (0% NPK)

Thus, it is suggested that in a rice-based cropping system with a cropping sequence of rice-soybean or rice-rice-soybean, especially in vertisol ricelands, rice plants should not always be flooded. In addition, application of organic fertilizers also has a positive impact on the sustainability of the production system due to better development of soil biota, especially AMF, especially if rice is cultivated under the System of Rice Intensification (SRI) using seedlings produced in a dry nursery initiated with AMF inoculation in the nursery.

IV. CONCLUSION

It can be concluded that AMF inoculation of zero tillage soybean direct-seeded following rice crops in vertisol soils more significantly increased grain yields of soybean plants grown following conventional rice, with grain yield increase of up to an average of 35.6%, compared with following SRI-rice (10.6 - 18.8%), which indicates a negative impact of conventional rice cultivation techniques on post-rice soybean. Different cultivation techniques and organic fertilization of rice plants in vertisol soils also had significant effects on grain yield of soybean direct-seeded immediately after harvest of the rice crops. However, AMF inoculation of soybean plants showed significant interaction with cultivation techniques of the preceding rice in year I, whereas in year II, with organic fertilization of the preceding rice, indicating changes in the impact of organic fertilization of rice on yield of soybeans grown following rice after two years of organic fertilization of rice in vertisol soils.

ACKNOWLEDGEMENTS

Through this article the authors would like to thank the Directorate of Research and Community Service of the Directorate General of Higher Education of the Ministry of Research, Technology and Higher Education of the Republic of Indonesia for the "Stranas" Research Grants in 2010 and 2011 to carry out the two-year research, from which parts of the data were used in this article.

REFERENCES

[1] Adisarwanto, T., Suhendi, R., Sinaga, M.A. and Ma'shum, M. 1992. Kajian residu pupuk nitrogen untuk padi gora terhadap hasil kedelai yang ditanam setelah padi gora". In: Suyamto H., Achmad 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.

[2] Anderson, J.M., and Ingram, J.S.I. 1993. Tropical Soil Biology and Fertility: A Handbook of Methods. 2nd edition. Wallingford, UK: CAB International.

[3] Antunes, P.M., de Varennes, A., Rajcan, I., Goss, M.J. 2006a. Accumulation of specific flavonoids in soybean (*Glycine max* (L.) Merr.) as a function of the early tripartite symbiosis with arbuscular mycorrhizal fungi and *Bradyrhizobium japonicum* (Kirchner) Jordan. *Soil Biology and Biochemistry*, 38: 1234-1242.

[4] Antunes, P.M., de Varennes, A., Zhang, T., Goss, M.J. 2006b. The tripartite symbiosis formed by indigenous arbuscular mycorrhizal fungi, *Bradyrhizobium japonicum* and soya bean under field conditions. *J. Agronomy and Crop Science*, 192: 373-378.

[5] Antunes, P.M., Deaville, D., Goss, M.J. 2006c. Effect of two AMF life strategies on the tripartite symbiosis with *Bradyrhizobium japonicum* and soybean. *Mycorrhiza*, 16: 167-173.

[6] Ellis, J.R. 1998. Post flood syndrome and Vesicular-Arbuscular Mycorrhizal fungi. *J. Prod. Agric.*, 11: 200-204.

[7] Gryndler, M., Hršelová, H., Vosatka, M., Votruba, J., and Klir, J. 2001. Organic Fertilization Changes the Response of Mycelium of Arbuscular Mycorrhizal Fungi and Their Sporulation to Mineral NPK Supply. *Folia Microbiol.*, 46: 540-542.

[8] Gryndler, M., Larsen, J., Hršelová, H., Řezáčová, V., Gryndlerová, H., and Kubát, J. 2006. Organic and mineral fertilization, respectively, increase and decrease the development of external mycelium of arbuscular mycorrhizal fungi in a long-term field experiment. *Mycorrhiza*, 16: 159–166.

[9] Ilag, L.L., Rosales, A.M., Elazegui, F.A., Mew, T.W. 1987. Changes in the population of infective endomycorrhizal fungi in a rice-based cropping system. *Plant and Soil*, 103: 67-73.

[10] Joner, E.J. 2000. The effect of long-term fertilization with organic or inorganic fertilizers on mycorrhiza-mediated phosphorus uptake in subterranean clover. *Biol Fertil Soils*, 32: 435–440.

[11] Malik. 2008. Kedelai Plus, Biaya Murah Hasil Melimpah (Soybean plus, Low cost, abundent yield). http://lifestyle.okezone.com/read/2008/01/18/56/76261/kedelai-plus-biaya-murah-hasil-melimpah. Accessed: 4 Maret 2012.

[12] Meghvansi, M.K. and Mahna, S.K. 2009. Evaluating the Symbiotic Potential of *Glomus intraradices* and *Bradyrhizobium japonicum* in Vertisol with Two Soybean Cultivars. *American-Eurasian Journal of Agronomy*, 2: 21-25.

[13] Miransari, M., Bahrami, H.A., Rejali, F., Malakouti, M.J. 2009. Effects of soil compaction and arbuscular mycorrhiza on corn (*Zea mays* L.) nutrient uptake. *Soil & Tillage Research*, 103: 282-290.

[14] Nwoko, H., and Sanginga, N. 1999. Dependence of promiscuous soybean and herbaceous legumes on arbuscular mycorrhizal fungi and their response to bradyrhizobial inoculation in low P soils. *Applied Soil Ecology*, 13: 251-258.

[15] Powell, J.R., Gulden, R.H., Hart, M.M., Campbell, R.G., Levy-Booth, D.J., Dunfield, K.E., Pauls, K.P., Swanton, C.J., Trevors, J.T., Klironomos, J.N. 2007. Mycorrhizal and rhizobial colonization of genetically modified and conventional soybeans. *Applied and Environmental Microbiology*, 73: 4365-4367.

[16] Riley, J. 2001. Presentation of statistical analyses. *Experimental Agriculture* (Cambridge), 37:115–123.

[17] Ruiz-Lozano, J.M., Collados, C., Barea, J.M., and Azcón, R. 2001. Arbuscular mycorrhizal symbiosis can alleviate drought-induced nodule senescence in soybean plants. *New Phytologist*, 151: 493-502.

[18] Sinclair, T.R., and de Wit, C.T. 1975. Photosynthate and nitrogen requirements for seed production by various crops. *Science*, 189: 565-567.

[19] Smith, S.E., and Read, D.J. 2008. Mycorrhizal Symbiosis. Third Edition. Elsevier, Amsterdam.

[20] Smith, S.E., and Smith, F.A. 2011. Roles of Abuscular Mycorrhizas in Plant Nutrition: New Paradigms from Cellular to Ecosystem Scales. *Annu. Rev. Plant Biol.*, 62: 227-250.

[21] Subramanian, K.S., Jegan, R.A., Gomathy, M., and Vijayakumar, S. 2011. Biochemical and Nutritional Responses of Tripartite Soybean-*Rhizobium-Glomus* Association Under Low and High P Fertilization. *Madras Agric. J.*, 98: 224-228.

[22] Uphoff, N. 2003. Higher Yields with Fewer External Inputs? The System of Rice Intensification and Potential Contributions to Agricultural Sustainability. *International Journal of Agricultural Sustainability*, 1(1): 38-50.

[23] Wangiyana, W, Cornish, P.S., and Morris, E.C. 2006. Arbuscular Mycorrhizal Fungi Dynamics in Contrasting Cropping Systems on Vertisol and Regosol Soils of Lombok, Indonesia. *Experimental Agriculture* (Cambridge), 42: 427–439.