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SOIL TILLAGE AFFECTED WEED COMMUNITY AND THE GROWTH AND YIELD OF SOYBEAN FOR EDAMAME PRODUCTION

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Abstract. *Edamame has been known as a vegetable soybean that is highly nutritious and has become popular in Indonesia. As for other crops, soybean cannot avoid the presence of weedy plants in the field. The study reported here aimed at determining the effect of tillage on weed and the growth and yield of soybean for edamame production. A randomized completely block design (RCBD) with three repetitions was used for the three tillage systems (zero, reduced, and conventional tillage). Data of soybean growth and yield component were collected and analysed with analysis of variance and mean separation of DNMRT at 5% level. Results show that most growth and yield parameter components (plant height, number of primary branches, number of leaves, number of pods per plant, pod weight per plant, number of seeds per plant, and yield) were highest in favor of reduced tillage system. The highest yield of edamame soybean (13.50 ton ha^{-1}) was observed in the treatment group of reduced tillage and the effect was similar to that of conventional tillage (13.29 ton ha^{-1}). Reduced and conventional tillage resulted in the emergence of new weed species such as Digitaria sanguinalis and Synedrella nodiflora with the total SDR value for all treatment groups of 54.38% and 37.74%, respectively. In contrast, the application of herbicide glyphosate prior to land cultivation has completely controlled Napier grass (Pennisetum purpureum Schumach.) and rough Mexican clover (Richardia scabra L.).*
Keywords: soil tillage; weed; edamame; soybean

1. Introduction

Soybean (*Glycine max* (L.) Merr.) is of the major important sources of protein worldwide. Demands for soybean produces continuously increase due to population growth. Indonesia has been importing soybean for decades and currently has imported soybean for as much as 200,000 tons per month. Soybean productivity in Indonesia was 1.69 ton/ha in year 2020. The total area of soybean land has been projected to reduce by 5-5.2% from 2020 to 2024. In addition, Indonesia had the total area of soybean cultivation of 344,612 ha in 2022 (Statistik, 2021). Despite the reduction in areas for planting soybean, the Indonesian Government has been putting efforts to reduce the import through intensification and extensification programs. However, the extensification program is not an appropriate choice as the amount of arable land declines constantly due to shifting in land use. On the other hand, global demand for soybean increases for its multiple useage include the need for fiber, fuel, and food diversification.

One variant of soybean product is known as 'Edamame' and has been popular in Indonesia for its nutritional benefits. One of the major producing areas of Edamame soybean in Indonesia is Jember in the Province of East Java. Soybean is harvested as early as 68-75 days after planting for

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Edamame production. This practice will help with the intensification program by increasing the harvesting index (HI).

Agricultural practices include water and nutrient management have been the key factors for maintaining high and constant soybean production (Jiang *et al*., 2019). However, the practices cannot avoid the impact of climate changes such as risen temperature, water scarcity, and changes in rainfall pattern. Moreover, soil compaction, soil water content, and soil aeration are directly affected by tillage system prior to crop planting (Fernandes *et al*., 2023; Liebhard *et al*., 2022; Soane & Owerkerk, 1994). Better soil physical properties due to tillage favors the growth of crop plants, seed germination, and weed early growth. Zero and reduced tillage are suitable for areas wherein water scarcity is an issue. The practices of zero tillage often include herbicide application prior to direct seeding of the crop.

The presence of weeds results in serious issues in global food production system to feed the ever-growing population. Yield reduction of food crops for weed presence has been extensively studied (Bana *et al*., 2020; Cheriere *et al*., 2020; Dossou-Yovo & Saito, 2021; Fahad *et al*., 2015; Hemanth Kumar & Jagannath, 2021; Onasanya *et al*., 2021; Oveisi *et al*., 2021; Safdar *et al*., 2015). The suppression of growth and yield of soybean due to weed presence may result from resource competition (Dilliott *et al*., 2022; Landau *et al*., 2022; Satorre *et al*., 2020), interference in nodulation and nodule function (Adamič & Leskovšek, 2021), and allelopathic effects (Mayerová *et al*., 2018; Sheldon *et al*., 2021). Successful weed management may be applied through various ways such as chemical and mechanical control including tillage. The experiment reported here aimed at determining the effect of tillage system on weed diversity and the growth and yield of soybean for Edamame production.

2. Methods

The experiment was conducted at Jorong Padang Ranah, Subdistrict Sijunjung, District Sijunjung, the Province of West Sumatra, Indonesia (0°70´72.1″ S, 100°98´23.3″ E) from May to September 2022. The experimental site, with soil Order of Inceptisol, is located at an elevation of ±250 m above sea level with a daily temperature of 21°C - 31°C and rainfall of 161 mm during the experiment.

2.1. Experimental design and data collection.

The experiment was designed in a randomized completely block design (RCBD) with three replications. Treatment was soil tillage namely zero tillage with glyphosate application (ZT), reduced tillage (RT), and conventional tillage through ploughing (CT). Soybean seeds were planted in 40 cm x 10 cm planting distance in plot size of 200 cm x 120 cm for each experimental units. Fertilizer of urea, SP-36 and KCl was each applied at 200 kg ha^{-1}. Nitrogen fertilizer was applied at 150 kg ha^{-1} and 50 kg ha^{-1} at 10 and 21 days after planting (DAP); respectively. A faull dosage of SP-36 and KCl were applied at 3 DAP.

Data collection include weed identification and soybean growth and yield. Data of soybean growth and yield components were collected and analysed with analysis of variance and mean separation of DNMRT at 5% level. Weeds were collected prior to land preparation, then were counted, weighed, identified, and cut prior to air-dried at 80°C for 48 hours. Weeds were collected from 5 sampling plots taken from all four corners and at the center of the land with plot size of 50 x 50 cm each. Subsequent weed sampling was conducted at 6 weeks after planting (WAP) from the sampling plot of similar size and taken from each experimental unit. The weed data were used to calculate summed dominance ratio (SDR) value following Janiya and Moody (Rahayu *et al.*, 2019).

2.2. Land preparation and planting.

The land was cultivated according to the assigned treatment groups following land clearing with herbicide with glyphosate isopropylamine salt of 486 g a.i. L^{-1}. The herbicide dosage was 1.4 L ha^{-1} and a maximum volume of 500 L ha^{-1}. Nine experimental plots were then prepared with the size of 200 cm x 120 cm each. Cattle manure at the dose of 10 tons ha^{-1} was added to the soil surface of all treatment groups.

The soil was lightly loosened around the planting points followed by adding cattle manure around the planting points for the minimum tillage treatment group. The conventional tillage treatment group was prepared by ploughing the soil to make sure that the soil was completely loosened, then followed by incorporation of cattle manure. The soil was then left for one week prior to seeding.

Soybean seeds var. Ryoko were selected for good quality and did not have observed signs of pest or disease infection. The seeds were then soaked in water for 60 minutes followed by inoculation with Rhizobium for 30 minutes. The seeds were then planted in a row space of 40 cm x 10 cm. Plants were watered twice a day every day except for rainy days. Insecticide of Sipermetrin 50 g L^{-1} a.i. was applied at 3 WAP to protect the plants from twig caterpillar (*Hyposidra talaca* Wlk.). The plants were harvested at 70 DAP for edamame production. Weeding was conducted at 2 and 4 WAP for the reduced and conventional tillage treatment groups. The weeds found at both reduced and conventional tillage treatment groups were as follows: goatweed (*Ageratum conyzoides* L.), crabgrass (*Digitaria sanguinalis* (L.) Scop), goosegrass (*Eleusine indica* (L.) Gaertn, and yellow nutsedge (*Cyperus esculentus* L.).

3. Results and Discussion

3.1. Effect of tillage on weed population dynamic.

Tillage has shifted weed communities under this experimental condition and some weed species emerged following soil tillage (Table 1). The emergence of more weed species in both reduced and conventional tillage is in accordance with the work reviewed by (Alagbo *et al*., 2022) that tillages followed by raised-bed land (ridge) for cultivation provide better access to soil moisture, nutrients, and light in favor of the germination and early growth of weeds and crop (Blanco-Sepúlveda *et al*., 2021).

Table 1. Weedy species found in association with soybean at different methods of soil tillage.

No	Weed	Summed Dominance Ratio (SDR) (%)			
		Prior to tillage	ZT	RT	CT
1.	*Ageratum conyzoides* L.***	4.66	18.56	38.97	39.72
2.	*Borreria latifolia* Schum.***	0	0	12.79	0
3.	*Cyperus esculentus* L.*	0	9.7	0	7.58
4.	*Digitaria ciliaris* (Retz) Koeler.**	25.53	0	5.54	0
5.	*Digitaria sanguinalis* (L.) Scop.*	0	25.25	20.14	8.99
6.	*Echinochloa colona* L.**	0	6.79	0	0
7.	*Eleusine indica* (L.) Gaertn.**	54.42	39.65	7.26	12.67
8.	*Oldenlandia corymbosa* L.**	0	0	4.74	3.76
9.	*Pennisetum purpureum**	8.43	0	0	0
10.	*Richardia scabra* L.**	6.96	0	0	0
11.	*Synedrella nodiflora* (L.) Gaertn.***	0	0	10.5	27.24

Notes: Weed were collected at 6 WAP. ZT = zero tillage with glyphosate application, RT = reduced tillage, CT = conventional tillage through ploughing. * = sedges, ** = grasses, *** = broad leaves weed

Tillage will change the soil compactness and bring buried weed seeds from underground onto aboveground or move them closer to the soil surface (Liebhard *et al*., 2022). Once the seeds are exposed to oxygen, moisture, and other supporting factors they may start the germination process. The soil seed bank is vital for the establishment, existence, and dominance of weed species in various ecosystems. Furthermore, changes in weed communities that show weed population dynamics may result from soil tillage (Cabrera-Pérez *et al*., 2022). Other workers (Feledyn-Szewczyk *et al*., 2020) argued that more weed seeds accumulated in the topsoil layer of 0–5 cm under direct seeding in a zero tillage system. This weed seed bank accumulates over time and is ready to germinate if water and oxygen are available. Herbicide application prior to the experiment reported here had controlled weed stands. However, tillage resulted in the emergence of new weed species such as *Digitaria sanguinalis* and *Synedrella nodiflora* with a total SDR values for all treatment groups of 54.38% and 37.74%, respectively. In contrast, the application of herbicide glyphosate prior to land cultivation completely controlled *Pennisetum purpureum* and *Richardia scabra* indicating a low abundance of these weed seeds in the soil (Chauhan & Mahajan, 2022; Comeau & Fraser, 2018; Deligios *et al*., 2019).

Soil tillage has been reported to affect the presence and abundance of weeds. Reducing the intensity of tillage may result in an increase in the amount and types of weed (Cheţan *et al*., 2022; Ciaccia *et al*., 2020; Cordeau *et al*., 2020). Tillage is expected to prepare weed-free land in all cropping systems. In contrast, tillage may cause erosion, reduce soil structure and soil organic matter content (Cabrera-Pérez *et al*., 2022). The presence of weeds impairs agricultural productivity and work efficiency. No matter what type of soil tillage is practiced, the weed community always exists and is dynamic. However, weeds may bring hope to farmers through their potential to be used as a source of organic fertilizer (Pujiwati *et al*., 2021) which is one of the ways to environmentally friendly agricultural practices.

3.2. Effect of tillage on the growth and yield of soybean for edamame production.

Different tillage had significant effect on the growth and yield of soybean except for plant height and number of primary branch (Table 2).

Table 2. Response of growth and yield of soybean var. Ryoko to different tillage.

Treatment	Plant height (cm)	Number of primary branch	Number of leaves	Number of pods per plant	Pod weight per plant	Number of seeds per plant	Yield (ton/ha)
Zero tillage	31.47	5.67	7.39 a	8.55 a	20.81 a	18.55 a	5.15 a
Reduced tillage	40.22	6.67	11.55 b	18.94 b	54.18 b	41.61 b	13.50 b
Conventional tillage	39.30	6.94	11.44 b	18.11 b	53.28 b	39.44 b	13.29 b
SEM	4.14	0.84	1.04	2.83	8.92	6.13	0.98

Number followed by same small letters are not significantly different according to DNMRT at 5% level. SEM = standard error mean

Soil tillage improves aeration and drainage which in turn increases the growth of roots for both volume and architecture (Adamič & Leskovšek, 2021; Yang *et al*., 2022). Reduced tillage consistently demonstrated better soybean growth and yield than that of zero tillage. The effect of reduced tillage is similar to that of conventional tillage. Soil tillage results in changes in soil compaction (Soane & Owerkerk, 1994), soil water content (Liebhard *et al*., 2022), soil bulk density (Anda, 2021), and soil aeration (Fernandes *et al*., 2023; Tian *et al*., 2022). Better soil structure results in better growth of soybean due to the availability of water and nutrient. The incorporation of cattle manure in this experiment provides better soil water holding capacity (Chen *et al*., 2022; Cui *et al*., 2022; Ndzelu *et al*., 2022) and better environmental conditions for soil microorganisms (Li *et al*., 2022a; Li *et al*., 2022b; Pu *et al*., 2022). A similar effect has been observed in the increased yield of spring onions (Atman *et al*., 2022).

On one hand, zero tillage reduced the weed community under experimental condition. On the other hand, reduced and conventional tillage resulted in a higher number of weed species emerging (Table 1). Significant reduction in growth and yield of soybean under the zero-tillage system resulted from the presence of weeds associated with soybean during the growing period. Weeds were left at the field and had not been controlled for the treatment group of zero tillage. Better growth and yield of soybean despite the presence of higher amounts and species of weed has been observed. Tillage improves the quality of soil structure and aeration which in turn provides better conditions for seed germination and early growth for both weed and soybean. Both weed and soybean compete for resources such as nutrients and water (Jiang *et al*., 2019; Lawrence *et al*., 2020) but the competition may be lessened by better soil compaction due to tillage (Liebhard *et al*., 2022). The better yield of soybean found in this experiment is in accordance with the work of others wherein tillage consistently improves the growth and yield of food crop such as maize (Adeux *et al*., 2017; Blanco-Sepúlveda *et al*., 2021), potato (Carter *et al*., 2009; Özgöz *et al*., 2017; Tiessen *et al*., 2007; Uribe *et al*., 2018), grain crops (Bartel *et al*., 2022; Dhaliwal *et al*., 2021; Guo *et al*., 2022; Gupta *et al*., 2022; Li *et al*., 2022c; Messelhäuser *et al*., 2022), and legumes (Bojarszczuk & Podleśny, 2020; Cheţan *et al*., 2022; Gawęda & Haliniarz, 2022; Halwani *et al*., 2019; Karavidas *et al*., 2022). Furthermore, zero or reduced tillage is suitable for areas where water scarcity has become issue (Huang *et al*., 2021; Rahman *et al*., 2021; Zhang *et al*., 2022).

4. Conclusion

The tillage system shifted the weed community in soybean var. Ryoko for Edamame production. Reduced and conventional tillage resulted in the emergence of new weed species such as *Digitaria sanguinalis* and *Synedrella nodiflora* with a total SDR values for all treatment groups of 54.38% and 37.74%, respectively. In contrast, the application of herbicide glyphosate prior to land cultivation completely controlled *Pennisetum purpureum* and *Richardia scabra*. Reduced tillage is the best land preparation system to grow soybean for Edamame production and resulted in 13.5 tons ha^{-1} of yield. However, herbicide application is not suggested for edamame production of soybean for the long run as this practice is not environmentally friendly.

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