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Research Article

The effect of System of Rice Intensification Cultivation (SRI) Implementation on Growth and Yield of Wetland Rice, and Changes in Soil Nitrogen, Phosphor and Potassium

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Abstract The research aimed to study the effect of SRI implementation on the growth and yield of wetland rice and changes in soil nitrogen, phosphor and potassium. The research used a Randomized Block Design (RBD) as its environmental. The cultivation methods included conventional, inorganic SRI, semi-organic SRI, and organic SRI.The research results showed that the implementation of the SRI methods accelerating plant flowering time (4.4 – 5.0 days), improving number of productive tiller (16.1 – 17.3 panicles clump^{-1}), number of rice grains (25.25 – 30.50 grains panicle^{-1}), reducing percentage of empty rice grains (7.92 – 8.13%), increasing grain yield (0.213 – 1.097 ton ha^{-1}), and raising harvest index (0.6 – 1.9%). The implementation of the SRI method lowered nitrogen concentration (13.9 – 35.9 ppm), and increased phosphorous (0.0579 – 1.289 ppm) and potassium (1.531 – 3.739 ppm) concentrations. Organic fertilizer added at the SRI method improved the concentrations of soil nitrogen (23.6 ppm), phosphor (1.232 ppm) and potassium (2.207 ppm).

Keywords SRI method, organic matter, wetland rice, nitrogen, phosphor, potassium

Introduction

Soil is an agricultural production factor playing a very important role. The balance between soil and organic matter content, microorganisms, biological activities along with the present of soil nutrients is vital in the sustainability of agriculture future.

One problem currently found in improving rice production is decreasing soil health and fertility. It is shown by difficulties in increasing the soil productivity even it tend to decrease. This condition is exacerbated by increasingly uses of inorganic fertilizers and chemical substances to control plant pests.

Intensive irrigated rice land management generally has not been followed by the implementation of soil fertility preservation causing soil to degrade physically and chemically [1]. Rice productivity has been leveling off although technical culture has maximally conducted. It is due to the loss of soil fertility through the uses of excessive inorganic fertilizer and uncontrollable leading to environmental balance disturbances, extinction of pests and diseases natural enemies which then cause rapid wide spreads of plant pests and diseases as well as residue accumulation in plant yield [2]. Decreasing in productivity of wetland rice intensification due to very high use of inorganic fertilizer is strongly related to imbalance of soil nutrient and fertilizer efficiency [3]. It also associated with soil fertility level, water availability and its use system management, cultivation technology, and climate factors [4].

Efforts to enhance rice productivity need better management particularly those related to the production decrease and technology saturation. System of rice intensification (SRI) is an approach to manage plant, land and water resources with the best. It emphasize on management of plant, fertilizer and water to support growth and development of rice root where anaerobic wetland rice ecology is converted to aerobic condition. Aerobic condition in SRI lead to soil biological strength recovery that produce natural fertilizer around rice roots which is resulting in more and fertile tillers [5].

Materials and Methods

Time and Place of Research

The research was conducted in Sidondo village, SigiBiromaru sub district, Sigi district of Central Sulawesi province (1^o $04^{'}$ $53^{''}$ South Latitude 119^o $52^{'}$ $12^{''}$ East Longitude and 127 m above sea level) from April to August 2014. Soil characteristics and climatic condition of the research location as well as organic fertilizer characteristics is depicted in Table 1.

Table 1: Soil characteristics, Meteorological conditions and Organic fertilizer characteristics

Soil characteristics		Meteorological conditions		Organic fertilizer characteristics	
pH	6.02	AP	1026,7 mm	pH	7.38
Organic matter	21.5 g kg^{-1}	AMT	27,8 ^oC	Organic matter	117.4 g kg^{-1}
Available N	2.4 g kg^{-1}	TSH	2732,1 h	Available N	12.5 g kg^{-1}
Available P	4.117 mg kg^{-1}			Available P	2.7 g kg^{-1}
Available K	128.8 mg kg^{-1}			Available K	7.3 g kg^{-1}

AP: annual precipitation; AMT: annual mean temperature; TSH: total sunshine hours.

Research Design and Technique Implementation

The research was an experiment with one factor of four treatments arranged in a Randomized Block Design. The cultivation methods consisted of conventional method (M_1; 138 kg N ha^{-1}+ 69 kg P_2O_5 ha^{-1} + 60 kg K_2O ha^{-1}); inorganic SRI method (M_2; 138 kg N ha^{-1} + 69 kg P_2O_5 ha^{-1} + 60 kg K_2O ha^{-1}), semi organic SRI method (M_3;69 N kg ha^{-1} + 34,5 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1}+ 5 ton organic fertilizer ha^{-1}) and organic SRI (M_4; l0 ton organic fertilizer ha^{-1}). The organic fertilizer was applied three days before planting whereas phosphorous, potassium and nitrogen (40%) fertilizers were spreading added three days after planting. The applications of the remaining nitrogen fertilizer were done at 30 and 60 days after planting 30% for each application.

Soil plowing was conducted twice which then followed by harrowing. Experimental plots were made with size of 4.2 m x 4.2 m each. Twenty days old seedlings were transplanted under the conventional method and ten days old under the SRI methods. Planting space was 20 cm x 20 cm for the conventional method with three seedlings $hole^{-1}$ (25 clumps m^{-2}) and 30 cm x 30 cm for the SRI method with one seedling $hole^{-1}$ (11.1 clumps m^{-2}).

Results and Discussion

Number of Tillers, Flowering Time and Number of Panicles

Based on the median value test, the number of tillers, flowering time, and number of panicles were significantly different under the four cultivation method tested. Table 2 shows that the implementation of the SRI cultivation has larger number of tillers and panicle $clump^{-1}$ than the conventional system. Increasing number of tillers and panicles under the SRI can be associated with only one seedling was planted for each hole and wider planting space as well as the use of younger seedling age for transplanting. Other condition such as unflooded soil and better aeration also create better environment for plant root to penetrate soil deeper absorbing more nutrients and water. Transplantation at young age of seedlings could reduce seedling stagnation and improve the plant ability to produce tillers and roots during its vegetative growth period, thus the tillers growth faster and their number increase in one clump [6]. Aerobic condition under the SRI leads to recovery of soil biological strengths and fertilizing of plant roots which then more and fertile tillers are produced [5]. Besides, under anaerobic condition, plant roots obtain more oxygen so they can explore the soil deeper to absorb more nutrients leading to lower unproductive tillers. Rice plant under the SRI cultivation will produce better and healthier root growth, many more tiller and panicle numbers [7].

The results of median value test shows that flowering time under the SRI method is significantly faster. This is due to younger seedlings (10 days) were directly transplanted in the rice field preventing them to experience growth stagnancy. Fast flowering of plant rice planted when seedlings are still young can be related to the seedlings ability to evade growth delay during seedling transplantation [8]. Young seedling transplantation also shorten the period of plant growth, thus the utilization of land is more effective (increase planting index) [21].

Table 2: Effect of cultivation method on tiller number, panicle number and flowering time

Cultivation methods	Number of tillers clump^{-1}	Flowering time (days)	Number of panicles clump^{-1}
Conventional	26.45^{a}	79.4^{b}	14.04^{a}
Inorganic SRI	50.83^{b}	74.4^{a}	30.17^{b}
Semi inorganic SRI	50.85^{b}	74.5^{a}	31.33^{b}
Organic SRI	46.32^{b}	75.0^{a}	30.31^{b}
HSD	9.47	1.2	15.31

Numbers followed by same letters at same column are not significantly different at HSD test (p = 5%).

Number of Grain, Thousand Grain Weight, and Percentage of Empty Grain

Based on the results of median value test, the four cultivation methods significantly influence grain number panicle^{-1}, 1000 grain weight, and empty grain percentage. Table 3 depicts that the implementation of the SRI significantly increase the number of grains panicle^{-1} as well as significantly decrease the percentage of empty grains. Increasing number of grain panicle^{-1} and reducing empty grain percentage under the SRI method is caused by the unflooded soil condition which promotes extensive root system development due to sufficient oxygen availability for respiration. The extensive root development is the key for nutrient absorption leading to better vegetative and generative plant growth. Besides, less plant density under the SRI method cause more light infiltrate to lower part of plant leaves lessening parasitic leaves and enhancing photosynthesis yield toward seed filling. Under flooded condition (anaerobic), rice plants need much energy to form and activate aerenchym cell for supplying oxygen. This leads to reduction in the formation of productive tillers and seed filling.

The results of median values test shows that the implementation of the organic SRI significantly increase the weight of 1000 grains compared to that of the conventional method. It indicates that under the semi-organic SRI method soil nutrient content is in balance condition as both inorganic and organic fertilizers supply the nutrients. The addition of organic fertilizer aims to provide nutrients for plant growth and to maintain soil fertility. The use of organic fertilizer without adding inorganic fertilizer as well has less influence in plant growth and yield because the organic fertilizer contain only very low nutrients not sufficient to fulfill plant need for its growth and production [9]. The application of organic matter along with urea fertilizer significantly increase plant yield [10]. Organic fertilizer plays a very important role in rice production through its ability to supply nitrogen and to regulate nitrogen immobilization and mineralization in soils [11].

Tabel 3: Effect of cultivation methods on number of grain, thousand grain weight and empty grain percentage

Cultivation method	Number of grains panicle^{-1}	Weight of 1000 grains	Empty grains (%)
Conventional	142,18^{a}	28,07^{a}	11,61^{q}
Inorganic SRI	168,99^{b}	28,52^{ab}	3,63^{p}
Semi-organic SRI	172,68^{b}	28,74^{b}	3,48^{p}
Organic SRI	167,43^{b}	28,47^{ab}	3,69^{p}
HSD	18,54	0,53	2,21

Numbers followed by same letters at same column are not significantly different at HSD test (p = 5%).

Grain Yield, Biomass Total, and Harvest Index

Based on the median value test, the four cultivation methods significantly affects grain yield, total biomass and harvest index. Table 4 depicts that the implementation of SRI methods significantly increase the grain yield, total biomass and harvest index, while the organic SRI is not significantly different with the conventional method. Increasing grain yield under the SRI method is due to optimal growth accumulation resulting in more number of productive tillers and panicles, more filled grains and lower percentage of empty grains. The concept of SRI develops all rice plant potentials by providing suitable condition for its growth [12]. Furthermore, the

SRI cultivation creates healthier rice plant root growth leading to larger number of tillers with healthier panicles and more filled grain eventually higher yield [7].

Table 4: Effect of cultivation methods on grain yield, biomass dry weight and harvest index

Cultivation method	Grain yield (ton ha^{-1})	Total biomass (ton ha^{-1})	Harvest index
Conventional	7,375^{a}	20,709^{a}	0,356^{a}
Inorganic SRI	8,320^{b}	21,859^{bc}	0,373^{c}
Semi-organic SRI	8,472^{b}	22,140^{c}	0,375^{c}
Organic SRI	7,606^{a}	21,013^{ab}	0,362^{b}
HSD	0,291	1,019	0,003

Numbers followed by same letter at same column are not significantly different at HSD test (p = 5%).

Increasing total biomass under the SRI method compared to the conventional method is associated with the wider planting space of the first in which there is no clump leaves overlapping between rows, thus sufficient sun light penetration can reach lower leaves. Sun radiation determine the distribution of photosynthesis yield for plant growth, the lower the radiation intensity the lesser the photosynthesis reaches the plant parts.

Harvest index is higher under the SRI method than under the conventional method because the increase of grain yield under the first is due to total plant biomass rising followed by reduced percentage of empty grains. Plant yield can be improved by increasing its total dry weight [13]. The increase of grain yield is mainly caused by higher harvest index when plant is no longer producing dry weight for vegetative growth instead for grain yield.

Effect of Cultivation Methods on Changes in Soil N, P, and K after Harvest

The result of variance analysis shows that the application of the SRI significantly affects the concentration of soil nitrogen, phosphor and potassium (Table 5). The result of orthogonal contrast test (Table 5) shows that the SRI cultivation method implemented significantly reduces soil nitrogen concentration. This is related to the unflooded and an optimal water content condition of the rice field where leaching is inhibited. By contrast under the conventional method, the soil is flooded causing nitrogen loss through leaching. The flooded soil also creates anaerobic condition where oxygen availability in soil is very limited. According to Indranata (1994) lack of oxygen in soils can be due to leaching, denitrification and volatilization. Water plays a very important role in the dynamic of soil nitrogen, when water content at an optimum condition all biological processes of uptake and mineralization occur at maximal rate. Excessive water causes nitrogen to loss through leaching and increasing denitrification [14]. Table 5 also shows that the fertilizer added increases soil nitrogen. Organic matter can improve soil nutrient availability [11]. Similarly, according to Basir-Cyio, organic matter also improves soil cation adsorption and exchangeable cation capacity, and increases nitrogen availability by forming an organic bond thus inhibits it from leaching [15].

The result of contrast orthogonal test on phosphorous content changes shows that the implementation of the SRI cultivation significantly increases soil phosphorus content in soil whereas the inorganic method is not significant compared to the conventional method. This is due to the bio-physicochemical changes under flooded condition in the conventional method. Soil characteristics and nutrient availability under unflooded condition are different to that under flooded condition. The changes are dominantly in redox potential, pH and organic matter decomposition [16].

Table 5: The averages of nitrogen, phosphorous, and potassium concentrations under various cultivation methods

Cultivation method	Concentration change			Source of Variance	DF	F_{-count}(p<0.01)		
	N (%)	P (ppm)	K (ppm)			N	P	K
Conventional (M_1)	-0.00158	0.0690	0.841	Treatment	3	216.96**	645.90**	38.49**
Inorganic SRI (M_2)	-0.00019	0.1265	2.372	M_1 vs M_2, M_3, M_4	1	413.26**	699.19**	73.81**
Semi-organic SRI (M_3)	0.00181	0.1461	3.911	M_1 vs M_2	1	43.04**	2.33^{ns}	16.20**
Organic SRI (M_4)	0.00237	1.3580	4.579	M_2 vs M_4	1	195.43**	1083.14**	24.25**

^{ns} not significant; **highly significant

The organic matter added significantly increased the concentration of phosphorous soil due to the soil characteristic changes. Organic matter improves soil physical and biological characteristics, and also soil chemical characteristics such as soluble aluminum decrease and enhancing soil nutrient availability [11]. It also reduces soil plasticity and increase the number and types of microbes beneficial for soil fertility [17]. The advantageous of adding organic matter also include increasing in adsorption capacity, exchangeable cation capacity, and available phosphorous soil [18].

The result of orthogonal contrast test (Table 5) shows that the implementation of the SRI cultivation method significantly increases soil potassium concentration. This is related to the unflooded condition under the SRI cultivation method and the flooded condition under the conventional cultivation method. Under the latter condition, potassium might easily loss through leaching resulting in lower potassium availability. The availability of potassium is influenced by soil water content in which its availability increases when a moist soil is dried out [19].

The addition of organic fertilizer was tested significantly increasing potassium concentration in soil. Organic fertilizer changes the soil chemical characteristics. According to Hakim *et al*. (1986), organic matter improves soil adsorption capacity and cation exchangeable capacity, and number of exchangeable cation in the form of organic bond thus preventing them from leaching [20].

Conclusions

1. The SRI method accelerates flowering (4.4-5.0 days), increases number of productive tillers (16.1-17.3 tillers clump^{-1}) and number of grain (25.25-30.50 grain panicle^{-1}), decreases percentage of empty grain (7.92%-8.13%), increases grain yield (0.231-1.097 ton ha^{-1}), and augments harvest index (0.6%-1.9%).
2. The SRI method reduces soil nitrogen concentration (13.9 – 35.9 ppm), increases phosphorous concentration (0.0579-1.289 ppm) dan potassium (1.531-3.739 ppm).
3. Organic fertilizer added under the SRI method increases soil nitrogen concentration (23.6 ppm), phosphorous concentration (1.322 ppm) and potassium concentration (2.207 ppm).

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