ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

Effects of Seaweed Extract on Rice Grain Yield and Yield Attributes

Yang Li[1, 2], Jingna Zhao[1]

[1]Shangqiu University, Shangqiu, 476000, China

[2]Key Laboratory of Crop Cultivation and Farming System, Guangxi University, Nanning, 530004, China

Abstract

Rice is an important crop in the world, and green and high-yield cultivation is the trend of its sustainable development, it can also alleviate the problem of excess production and use of chemical fertilizer in the current globalization. To study the effects of seaweed extract on rice growth and yield in different ways is a new way to cultivate green and high yield rice. This study starts from the two fertilization methods of foliar spraying and root application, and studies the influence of seaweed essence on rice yield and physiological indicators through three years of experimental data analysis to provide a new way for its green cultivation. The results showed that both foliar spraying and root application could promote the high yield of rice, and the yield increase rate is mainly concentrated in 3% -12%, which was related to the effect of seaweed extract on the improvement of rice leaf area index, dry matter accumulation, effective panicle and seed setting rate. The root application of 3.0kg ha^{-1}, 3.75kg ha^{-1} seaweed essence only in tillering period has the best effect on rice growth. The results showed that the law of foliar spraying was different from that of mixed fertilizer root application. With the greatest influence and best effect of tillering, jointing and pregnant ears at 1:1:1 spraying concentration of 1000 times and the medicinal liquid dosage of 450kg ha-1, was the most cost-effective way.

Keywords

Rice; Seaweed extract; Grain yield; Yield attributes.

1. Introduction

Accelerating the transformation of agricultural production's dependence on traditional chemical fertilizers and ensuring the vigorous development of new environmental protection fertilizers on the premise of stable and increased production are the requirements of sustainable agricultural development. As a natural plant growth regulator, seaweed extract contains abundant natural plant nutrients(Khanwr et al.,2009;Zodape et al.,2008), which provides a new way for the development of green agriculture.Previous studies have shown that known substances in seaweed extracts that can affect plant(Wally et al.,2012;Divya et al.,2015a,b)growth mainly include phytohormones and abundant auxins (IAA, IBA),g ibberellin, cytokinins and osmotic protectors, micronutrients, vitamins,amino, etc (Renuka Bai et al.,2007; Mathur et al.,2015; Pacholczak et al.,2016b).The use of seaweed extract can improved soil water holding capacity, increased enough micronutrients, and improved soil structure by plant growth(Dhargalkar and Pereia, 2005),reduce the amount of nitrogen, phosphorus and potassium fertilizer,inducing seed germination and improving crop yield(Sunarpi et al.,2010;Partani,2013).Since ancient times, seaweeds and their extracts have been used to improve plant growth and stress resistance.The trend of seaweed utilization was rooted in 1951 in European countries and the seaweeds were used directly or in composted form with

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

farmyard manure as soil conditioner to increase crop productivity in coastal areas and for recovery of alkaline soils where deficiency diseases are frequent(Rama Rao,1992; Booth,1969).In recent times seaweeds received worldwide attention in agriculture as organic/bio-fertilizers to supplement plant nutrients(Aitken and Senn,1964)and being applied in different formulation such as foliar spray, granules, powder and so on (Kumari et al.,2011, 2013; Gharakhani et al.,2016).It can promote plant growth under the condition of no pollution, the pollution caused by traditional chemical fertilizers can be effectively avoided, and the ecological, economic and social benefits can be taken into account to realize the unification of "three benefits". In addition, many studies pertaining to plant growth promoting effects of seaweeds have been reported (Zodape et al.,2011; Rao and Chatterjee,2014; Ali et al.,2016) and these have been proven as novel source of antioxidants, plant hormones, osmoprotectants, plant nutrients and other novel bioactive metabolites of pharmaceutical and industrial significance (Akila and Jeyadoss,2010;Ramarajan et al.,2013;Pacholczak et al.,2016a).

At present, research on seaweed extracts in agriculture is mainly concentrated on fruits and vegetables.After a series of comparative experiments on potato, corn, wheat, peanut, beet, cucumber, grape, spinach,etl., the results showed that seaweed extract could make increase yield (increase yield by 10%-30%) and improve quality, enhance resistance to pests and diseases, and prolong the preservation time of fruits and vegetables(Craigie J S.2011;Nabtl et al.,2016).It is reported that under drought and other environmental stresses, seaweed extracts can improve root activity, stress resistance, antioxidant enzymes and phenylalanine ammonia lyase activities, and drought resistance of tomatoes (Herrera et al.,2014; Liu R Z et al.,2009).Further, growth promotion was observed in okra after foliar application (Abbasi et al.,2010) in Vigna mungo by Sargassum myriocystum extracts (Kalaivanan and Venkatesalu,2012); application of Ulva fasciata extract on wheat var. charman has witnessed higher seed germination, increased growth parameters, pigment and carbohydrate content (Shahbazi et al.,2015);increase in root and shoot length and number of leaves with the application of seaweed sap in maize and rice (Singh et al.,2015a, b, 2016).Zodape et al.,(2010) reported that increase in mineral content of Na, P, K, Ca, Mg, Fe and N in green gram with foliar application of 10% sap of Kappaphycus alvarezii in comparison to control plots(Zodape et al.,2010).With the use of seaweed extracts claims have been made for stimulation of seed germination, better root development, enhanced frost resistance, increased nutrient uptake, resistance to phytopathogenic fungi(Younes et al.,2009),insects and other pests(Asha et al.,2012),bacteria(Alves et al.,2016),higher yields with better restoration of plant health under high salinity conditions(Nabti et al.,2010).According to the above research report, seaweed extracts have a positive impact on the growth of fruits, vegetables and crops, and it is of great significance to use it better in agriculture.

In the face of increasingly severe food security problems, high-yield green cultivation of rice is particularly important. It is of great significance to study the effects of seaweed extracts on rice growth and yield to improve the traditional water and fertilizer management of rice. In recent years, there are also reports about the application of seaweed extract in rice cultivation at home and abroad. For example, Spraying of seaweed extract 3% at fifty per cent flowering and milk stages recorded 26 percent higher grain yield when compared to control(M.P.Kavitha et al.,2008).Foliar spray of seaweed extract sap at 5% and above concentrations significantly increased plant height, dry matter accumulation, chlorophyll index, crop growth rate, yield attributes and yield of rice (5.4 to 18.4% higher) as compared to control(Jayanta Layek et al.,2017). Therefore, on the basis of predecessors, this study applied seaweed extract in two ways: foliar spraying and root mixing. Through comparative analysis of various indicators of rice growth, the specific effects of seaweed extract on rice plant growth were explored to provide scientific basis for green high-yield cultivation of rice.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

2. Introduction

2.1. Field Experiments

In this study, a three-year field experiment was conducted from 2016 to 2018 to explore the effects of Seaweed extract on rice growth and yield in two ways: mixed fertilizer root application and leaf spraying. the plots are arranged randomly and repeated three times. Urea 330 kg ha–1,superphosphate 675 kg ha–1,potassium chloride 450 kg ha^{-1}. Urea was applied three times according to 60% of base fertilizer, 30% of tiller fertilizer and 10% of panicle fertilizer. Superphosphate is all used as base fertilizer. Potassium chloride was applied three times according to 50% of base fertilizer, 30% of tiller fertilizer and 20% of panicle fertilizer. Base fertilizer was applied 3 days before rice transplanting, tiller fertilizer 10 days after transplanting and panicle fertilizer 28 days before heading. Diseases and insect pests should be well controlled according to production requirements during the experiment.

2.1.1. Leaf Spraying Test

Field test were conducted in rice net room of Guangxi University Agricultural College in 2016、2017(double-season rice). During the experiment, if a certain treatment needs to spray Seaweed concentrate solution, then there is no need to spray Seaweed concentrate solution treatment with spraying equal amount of clean water.

Table 1. Leaf spraying test design

Years	Varieties	Treatment	Methods
2016	Baixiangyou139	CK 0 T1 500 T2 1000 T3 1500 T4 2000	Spray the corresponding concentration of seaweed essence solution once during the tillering,elongation heading and maturation periods, with a pharmaceutical liquid dosage of 450kg ha^{-1}.
2017	Nongle1	CK (No seaweed essence solution is sprayed) T1 Tillering T2 Elongation T3 Heading T4 Tillering+Elongation+Heading	The concentration of seaweed essence solution was 1000 times,with a pharmaceutical liquid dosage of 450kg ha^{-1}.

2.1.2. Fertilizer Mixing Application Test

Fertilizer mixing application test in 2016, 2017 and 2018 are shown in Table 2, In 2016, only the application of seaweed essence and no application were set to confirm the effect of seaweed essence on rice production. Based on the basis of the 2016 test, the 2017 test plan was set to further determine when the application of seaweed essence had the best effect on rice yield. Based on the test plan of 2017, the 2018 test plan was set to clarify the appropriate application amount of seaweed essence in the tillering period. In order to prevent the infiltration of fertilizer and water between plots, each plot was separated by a PCR board.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

Table 2. Fertilizer mixing application test design

Years	Varieties	Treatment	Methods
2016	Baixiangyou139	CK	No seaweed applied
		T1 3.0kg ha^{-1}	The base fertilizer was administered 60 g, 60g tillering fertilizer, and 80g panicle fertilizer.
2017	Nongle1	CK	No seaweed applied
		T1 3.0kg ha^{-1}	Mixing into the base fertilizer application
		T2 3.0kg ha^{-1}	Mixing into tiller fertilizer application
		T3 3.0kg ha^{-1}	Mixing into panicle fertilizer application
		T4 3.0kg ha^{-1}	Mixing into the base fertilizer: panicle fertilizer :tiller fertilizer=1:1:1 application
2018	Guiyu9	CK	No seaweed applied
		T1 1.5kg ha^{-1}	Mixing into tiller fertilizer application
		T2 2.25kg ha^{-1}	
		T3 3.0kg ha^{-1}	
		T4 3.75kg ha^{-1}	

2.2. Parameters and Methods

At the maturity stage of rice, 20 holes of rice were randomly selected for investigation, and then 5 holes of representative plants were selected to measure the leaf area, dry matter and chlorophyll, analyze the panicle grain structure, weigh and record the rice yield. Leaf area was measured with a laser leaf area meter, chlorophyll content was measured with SPAD-502 measuring instrument.

Microsoft Excel 2007 software was used to organize the data, and IBM SPSS17.3 software and DPS software were used for statistical analysis.

3. Results and Discussion

3.1. Analysis of Yield Data

It can be obtained from Figure 1 that both leaf spraying and mixing root application can improve rice yield to varying degrees. It can be obtained from Figure 2(a) that in 2016 test treatment T2,when spraying 1000 times the seaweed essence solution, the yield of early and late season rice reached the maximum, with an increase of 19.79% and 17.75%. In 2017 test treatment T4,1000 times of liquid was sprayed simultaneously at the tillering stage, elongation stage and heading stage of rice, with the dosage of 450kg ha^{-1}, the rice yield in the early and late seasons reached the highest value, with an increase of 16.54% and 11.83% respectively. It can be seen from Figure 2(b) that in the experimental treatment T2 in 2017, the rice yield in the early and late seasons reached the maximum with the increase of 9.75% and 12.38% respectively. In the experiment root application in 2018, the maximum increment of early and late rice yield appeared in treatment T4, which were 9.27% and 8.25% respectively. respectively. As can be seen from the above data, the application of seaweed extract increased the yield of early season rice more significantly.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

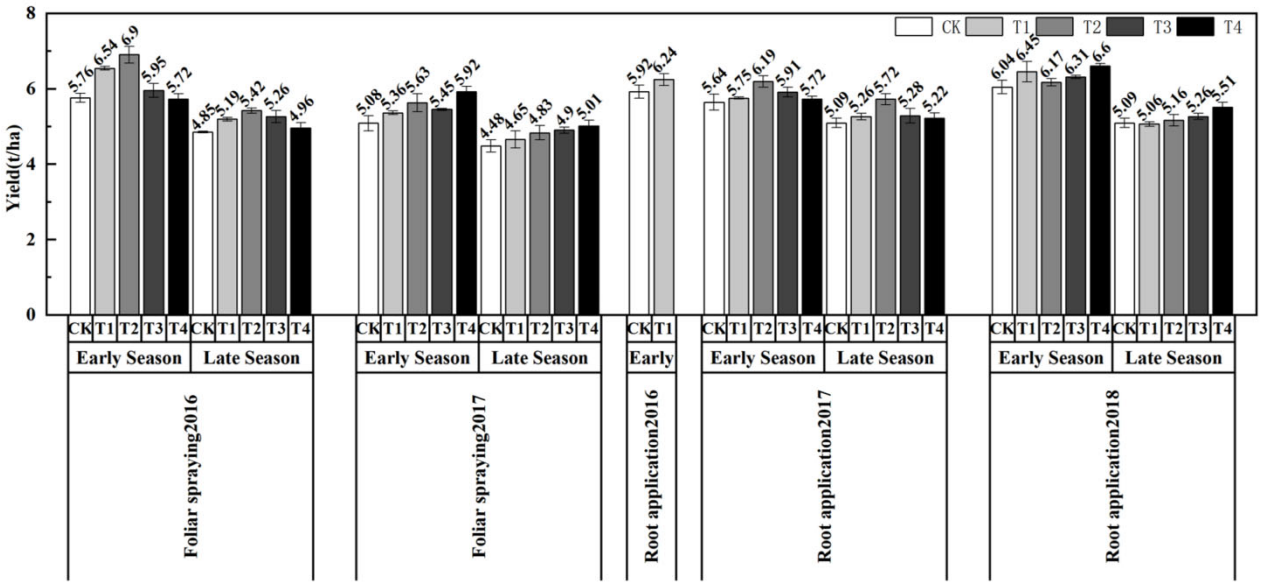


Figure 1. Comparative analysis of rice yield by spraying and root application on 2016-2018 test

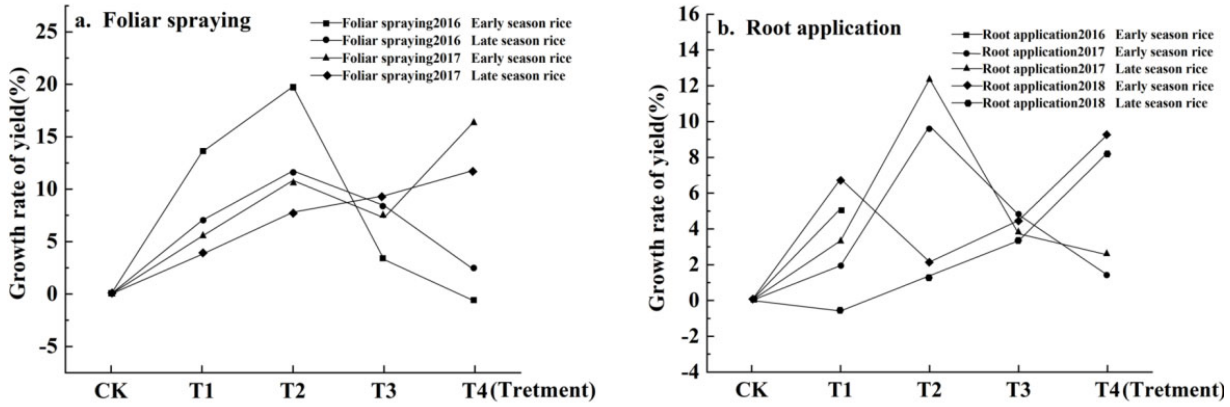


Figure 2. Comparative analysis of yield increase rate by spraying and root application on 2016-2018 tests

3.2. Analysis of Panicle Grain Structure

From table 3 and 4, it can be seen that foliar spraying and root application of seaweed essence have varying degrees of improvement on effective panicle, grains per panicle, seed setting rate, and thousand grain weight, the above four indicators are positively correlated with yield, thus achieving the goal of increasing production. The application of seaweed extract increased the leaf area index(LAI), tiller number and chlorophyll content during the vegetative growth period of rice, provided a nutritional basis for the increase of panicles and grain plumpness at maturity, and promoted the high yield of rice. In Liu Peijing's study on cucumber, tomato and pepper, it was shown that during the growth period of seeds treated with seaweed liquid fertilizer, their root length, plant height, fresh weight, dry weight, chlorophyll content and LAI were significantly increased (Liu Peijing et al.,2014).

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

Table 3. Effects of foliar spraying on panicle grain structure of rice

Years	Season	Treatment	The effective panicle(ten thousand panicles ha^{-1})	Grains per panicle	Seed setting rate(%)	1000-grain weight(g)
2016	Early	CK	306.45b	156.70ab	72.87c	16.70ab
		T1	314.70ab	160.40a	78.74a	17.03a
		T2	318.90a	159.50a	78.38a	17.12a
		T3	308.40b	161.20a	75.16b	16.86a
		T4	302.25bc	157.40ab	74.71b	16.63ab
	Late	CK	264.75c	152.80ab	73.37b	16.91a
		T1	283.50ab	154.30a	75.24ab	17.18a
		T2	295.95a	150.90b	76.55a	17.02a
		T3	287.25ab	149.70b	76.57a	16.79ab
		T4	273.00bc	152.60ab	73.08b	16.88ab
2017	Early	CK	267.90c	148.67a	73.43a	17.25c
		T1	270.45bc	149.03a	73.51a	18.89b
		T2	280.35b	154.16a	77.37a	18.17b
		T3	284.55ab	151.52a	78.25a	17.51c
		T4	290.10a	153.63a	74.55a	19.72a
	Late	CK	260.10c	135.91c	73.16a	17.13a
		T1	266.10b	143.76b	75.95a	16.89a
		T2	271.65ab	149.74ab	73.23a	17.07a
		T3	269.70ab	150.72ab	74.37a	17.02a
		T4	279.30a	153.42a	73.08a	17.38a

Note: Different lowercase letters in the data indicate that the difference reaches the significant level of $P < 0.05$, the same below.

3.3. Mechanism of Seaweed Extract Promoting Rice Growth

The mechanism of Seaweed extract promoting rice yield could be analyzed from the growth and physiological characteristics of rice between different treatments. Taking the test data of foliar spraying and root application in 2017 as samples, the pairwise correlation analysis was conducted for four important indicators: dry matter accumulation, effective panicles, chlorophyll index and yield, the results are shown in figure 3a-c, g-i show that the leaf area index, dry matter accumulation and effective panicles showed positive correlation, and the dry matter and effective panicles were significant correlated during mixed fertilizer root application; followed, the number of effective panicles, dry matter accumulation and leaf area index(LAI) showed medium and low correlation.

Figure 3d-f foliar spraying test, dry matter accumulation, effective panicles and yield reached a high correlation, and LAI and yield showed a moderate correlation; figure 3j-l root application experiment, the number of effective panicles was significantly correlated with yield, and dry matter accumulation and LAI were moderately correlated with yield. From the correlation index, the dry matter accumulation and effective panicle number of the two application methods of seaweed essence had the greatest impact on rice yield.Moreover, the effective panicle number of root application of seaweed essence is significantly correlated with the yield, the reason may be that alginic acid and seaweed polysaccharide rich in seaweed essence combine with metal elements in soil and have chelation and hydrophilic properties,so as to improve rice field soil structure, increase fertility, promote rice root growth and improve tillering ability;cytokinin and auxin in seaweed essence stimulate seedling growth and

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

development, increase the number of tillers and effective ears of rice, thus affecting the rice yield.

Table 4. Effects of root application with mixed fertilizer on panicle grain structure of rice

Years	Season	Treatment	The effective panicle(ten thousand panicles ha-1)	Grains per panicle	Seed setting rate(%)	1000-grain weight(g)
2016	Early	CK	292.3b	164.12a	75.03a	17.02b
		T1	303.1a	164.17a	75.10a	17.11a
2017	Early	CK	287.55c	144.67b	75.96c	16.91c
		T1	300.75ab	146.03b	79.19ab	18.16a
		T2	306.75a	151.16ab	82.02a	18.26ab
		T3	302.85ab	159.52a	80.67a	18.19ab
		T4	294.45b	160.63a	82.01a	17.93b
	Late	CK	264.45b	149.35b	74.15bc	18.32c
		T1	277.20a	139.76c	75.85b	18.88b
		T2	288.90a	144.74bc	77.15a	19.39a
		T3	271.65ab	153.72b	76.01ab	19.16ab
		T4	273.75ab	155.42a	75.32b	18.69b
2018	Early	CK	281.70a	188.45b	69.04a	23.02c
		T1	311.18a	177.49b	72.34a	23.05c
		T2	307.58a	184.46b	69.12a	22.50d
		T3	285.53a	185.75b	74.00a	22.55d
		T4	292.73a	180.75b	73.26a	23.01c
	Late	CK	253.35b	173.71ab	75.51a	23.10c
		T1	266.85ab	183.18a	70.63ab	23.21bc
		T2	274.50a	172.91ab	70.02ab	23.14c
		T3	255.60b	168.38b	76.09a	23.37bc
		T4	271.35a	179.15ab	73.41a	23.47ab

Table 5 shows that the accumulation of dry matter in the treatment with seaweed essence is mostly increasing, and the increase of dry matter quality is related to the increase of rice main stem and root after the application of seaweed essence.Anisimov et al. treated rye seeds with seaweed extract and measured the root length, it was found that the root length of rye seeds treated with seaweed extract increased by more than 15% compared with the control group (Anisimov et al.,2013), indicating that the application of seaweed extract will have an impact on plant roots and stems. In conclusion, the application of seaweed extract can promote the growth of dry matter accumulation by improving the size and morphology of rice roots and stems, thus affecting the yield of rice.

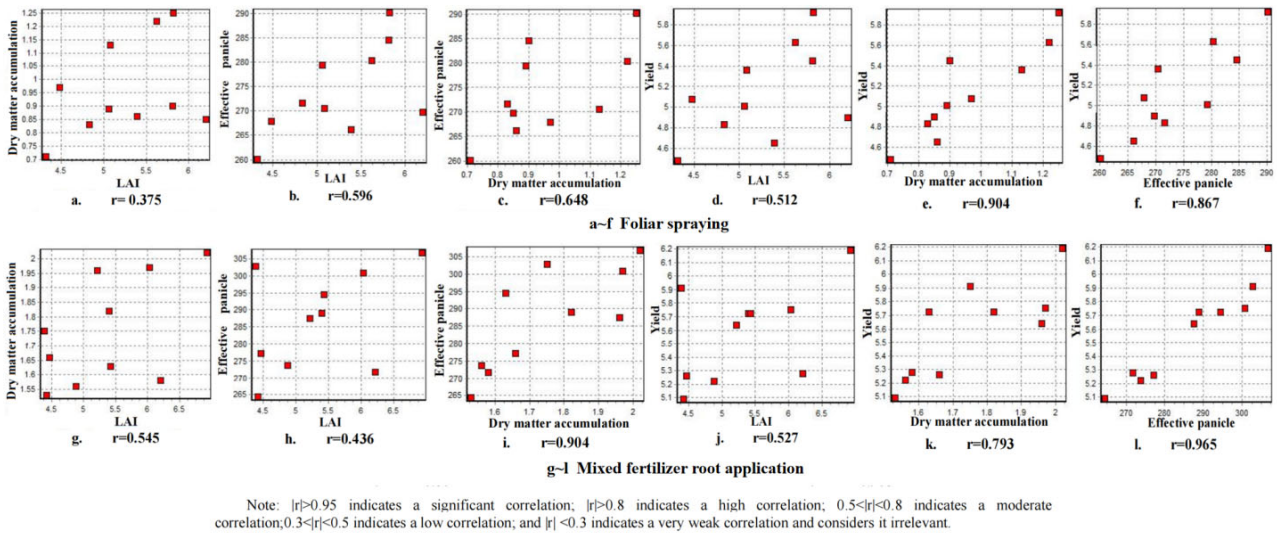
The experimental data Figure 3d and j show that the LAI of rice is moderately correlated with the yield, indicating that the improvement of rice LAI by seaweed extract is one of the mechanisms to promote rice yield. LAI is the ratio of total leaf area of plants to land area per unit area, the increase of LAI indicates the increase of plant leaf area. Leaf is the place where plants carry out photosynthesis,the increase of its area will improve the photosynthesis of plant groups. Generally, the increase of crop LAI can increase the nutrient absorption in the

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

vegetative growth stage, so as to provide a strong driving force for the later reproductive growth stage of the plant, which is closely related to the final yield.

Table 5. Effects of two application methods of seaweed essence on physiological indexes of rice at maturity in 2017 test.

Method of application	Season	Treatment	chlorophyll content (SPAD)	Leaf area index(LAI)	The effective panicle(ten thousand panicles ha^{-1})	Dry material accumulation (Kg/m^2)	Harvest index(%)
Leaf spray	Early Season	CK	35.13a	3.67a	267.93c	0.97b	51.27b
		T1	36.33a	3.84a	270.45bc	1.13a	54.19ab
		T2	36.27a	3.89a	280.35b	1.22a	52.36b
		T3	32.06a	3.41a	284.55ab	0.94a	53.33 ab
		T4	35.53a	3.74a	290.12a	1.25a	55.41a
	Late Season	CK	37.23b	2.93a	260.05c	0.71b	51.36a
		T1	41.02ab	3.48a	266.21b	0.86ab	52.64a
		T2	41.83ab	3.36a	271.65ab	0.83ab	51.53a
		T3	42.23a	2.94a	269.75ab	0.85ab	52.35a
		T4	42.77a	4.13a	279.26a	0.89a	52.42a
Root application	Early Season	CK	31.63b	4.32a	287.55c	1.96a	51.13a
		T1	38.03a	4.44a	302.25ab	1.97a	52.30a
		T2	36.36ab	4.50a	306.8a	2.02a	54.29a
		T3	32.21b	4.57a	302.85ab	1.75ab	50.33a
		T4	39.82a	4.81a	294.45b	1.63b	49.47a
	Late Season	CK	25.33a	2.50a	264.45b	1.53b	48.30a
		T1	26.27a	2.49a	277.2a	1.66b	50.24a
		T2	23.83a	3.11a	288.87a	1.82b	52.14a
		T3	26.03a	3.13a	271.65ab	1.58b	49.26a
		T4	26.24a	2.99a	273.75ab	1.56b	48.79a



Note: |r|>0.95 indicates a significant correlation; |r|>0.8 indicates a high correlation; 0.5<|r|<0.8 indicates a moderate correlation;0.3<|r|<0.5 indicates a low correlation; and |r| <0.3 indicates a very weak correlation and considers it irrelevant.

Figure 3. Correlation analysis of two ways of spraying ang root application on Rice Panicle grain structure (Dry matter accumulation, Effective panicle, LAI, Yield) in 2017 test

3.4. Other Mechanisms of Seaweed Extract Promoting Rice Growth

Seaweeds are known to add major plant nutrients N, P and K in addition to different micronutrients and trace elements in adequate required for the plant growth(Sethi,2012; Mirparsa et al.,2016).Nitrogen, phosphorus and potassium are nutrient elements that need

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

more in the process of rice growth and development, and their content is very important to the improvement of rice yield. Nitrogen is the main element in the synthesis of protein and chlorophyll and the basis of plant photosynthesis.Phosphorus participates in the metabolic process of rice in many ways, so as to accelerate the growth of rice and promote high yield. Rathore et al. applied seaweed extract to pea, and the results showed that the plant's absorption capacity of nutrient elements N, P, K and S was enhanced,indicating that seaweed extract had a positive effect on the plant's absorption of nitrogen, phosphorus and potassium(Rathore.D.R.and G.N.Chaudhary,2009);Zodape et al.reported that increase in mineral content of Na, P, K, Ca, Mg, Fe and N in green gram with foliar application of 10% sap of Kappaphycus alvarezii in comparison to control plots(Zodape et al.,2010).It can be speculated that increased rice production is related.

The application of seaweed essence can improve the resistance of crops and enable plants to reduce the damage caused by stress resistance,some studies speculate that the improvement of seaweed essence's stress resistance to crops may be related to cytokinins and oligosaccharides(Gongtao et al.,2016).Although there is no systematic study on the effect of seaweed essence on rice resistance, it has a significant effect on other crops.For example,Sultana et al.found that after the application of seaweed essence,the probability of tomato and sunflower root infection with fungi decreased(Sultana et al.,2005).Recent findings have revealed that the bioactive compounds viz., polysaccharides, fatty acids, tannins, pigments, lectins, alkaloids, terpenoids and halogenated compounds extracted from green, brown and red algae were promising in controlling root infecting fungi in okra seedlings(Perez et al.,2016). Foliar application of seaweed extracts found to inhibit fruit rot with increase in yield of strawberry (Washington et al.,1999).Speculation is from the above experiment that the application of seaweed essence can improve the biology ability to resist adversity, therefore, the increase of rice yield may be related to the improvement of seedling resistance to biotic and abiotic adversity.

3.5. Results

The results showed that the application of seaweed extract by mixed fertilizer root application and foliar spraying could improve rice yield. The root application of 3.0kg ha^{-1}, 3.75kg ha^{-1} seaweed essence only in tillering period has the best effect on rice growth. The law of foliar spraying test is different from that of mixed fertilizer root application. The period with the greatest impact on leaf area, chlorophyll and dry matter and the best effect is when the average spraying concentration in the three periods is 1000 times and the dosage of liquid medicine is 450kg ha^{-1}, which is the most cost-effective and synergistic way.

This dosage method has the advantages of convenient operability and safety, and is conducive to the establishment of a new rice water and fertilizer management mode with high efficiency and environmental protection. Its effect makes up for the deficiency of large application amount and low efficiency of traditional chemical fertilizer in China. In the agricultural market, it also conforms to the guidance of relevant national policies, and the market potential is huge.

References

[1] Khanwr U.P,Subramanian S,Jithesh M.N,et al.(2009) Seaweed Extracts as Biostimulants of Plant Growth and Development[J].Journal of Plant Growth Regulation 28(4):386-399.

[2] Zodape S T, Kawarkhe V J, Patolia J S, Warade A D (2008) Effect of liquid seaweed fertilizer and quality of okra (Abelmoschus esculentus L). J Sci Ind Res 67:1115–1117.

[3] Wally O S, Critchley A T, Hiltz D, Craigie J S, Han X, Zaharia L I, Abrams SR, Prithiviraj B (2012) Regulation of phytohormone biosynthesis and accumulation in Arabidopsis following treatment

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

with commercial extract from the marine macroalga Ascophyllum nodosum. J Plant Growth Regul 32:324–339.

[4] Divya K, Roja M N, Padal S B (2015a) Effect of seaweed liquid fertilizer of Sargassum wightii on germination, growth and productivity of brinjal. Int J Adv Res Sci Eng Technol 2:868–871.

[5] Divya K,Roja M N,Padal S B (2015b) Influence of seaweed liquid fertilizer of Ulva lactuca on the seed germination, growth, productivity of Abelmoschus esculentus(L). Int J Pharmacol Res 5:344–346.

[6] Renuka Bai N, Banu L N R, Prakash J W, Goldi S J (2007) Effects of Asparagopsis taxiformis extract on the growth and yield of Phaseolus aureus. J Basic Appl Biol 1:6–11.

[7] Mathur C, Rai S, Sase N, Krish S, Jayasri MA (2015) Enteromorpha intestinalis derived seaweed liquid fertilizers as prospective biostimulant for Glycine max. Braz Arch Biol Technol 58:813–820.

[8] Pacholczak A, Szydlo W, Jacygrad E, Federowicz M (2016b) Effect of auxins and the biostimulator algaminoplant on rhizogenesis in stem cuttings of two dogwood cultivars (cornus alba 'AUREA' and 'Elegantissima'). Acta Sci Pol Hortorum Cultus 11:93–103.

[9] Dhargalkar V K, Pereira N (2005) Seaweed: promising plant of the millennium. Sci Cult 71:60–66.

[10] Sunarpi A J, Rina K, Nur I J, Aluh N (2010) Effect of seaweed extracts on growth and yield of rice plants. Bioscience 2:73–77.

[11] Partani T (2013) Determination of the effect rates of seaweed extract on growth and performance of corn (Sc704) in Gorgan. Int J Agric Crop Sci 6:219–224.

[12] Rama Rao (1992) Seaweeds as biofertilizers in India horticulture. Seaw Res Util 14:99–101.

[13] Booth E (1969) The manufacture and properties of seaweed extracts.In:Proceeding of sixth international seaweed symposium, La marina Merchante, Madrid Spain, pp 655–662.

[14] Aitken J B, Senn T L (1964) Seaweed products as a fertilizer and soil conditioner for horticultural crops. Bot Mar 8:144–148.

[15] Kumari R, Kaur I, Bhatnagar A K (2011) Effect of aqueous extract of Sargassum johnstoniiSetchell & Gardner on growth, yield and quality of Lycopersicon esculentum Mill. J Appl Phycol 23:623–633.

[16] Kumari R, Kaur I, Bhatnagar A K (2013) Enhancing soil health and productivity of Lycopersicon esculentum Mill. using Sargassum johnstonii Setchell & Gardner as a soil conditioner and fertilizer. J Appl Phycol 25:1225–1235.

[17] Gharakhani H, Mirhadi S M, Yazdandoost M (2016) The effect of different foliar application amount and different times of seaweed using (Acadian) on potato yield and yield components. J Curr Res Sci 1:23–27.

[18] Rao G M N, Chatterjee R (2014) Effect of seaweed liquid fertilizer from Gracilaria textorii and Hypnea musciformis on seed germination and productivity of some vegetable crops. Univ J Plant Sci 2(7):115–120.

[19] Zodape S T, Abha G, Bhandari S C, Rawat U S, Chaudhary D R, Eswaran K, Chikara J (2011) Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (Lycopersicon esculentum Mill.). J Sci Ind Res 219:215–219.

[20] Ali N, Aidan F,Adesh R, Jayaraj J (2016) The effect of Ascophyllum nodosum extract on the growth,yield and fruit quality of tomato grown under tropical conditions. J Appl Phycol 28:1353–1362.

[21] Akila N, Jeyadoss X(2010) The potential of seaweed liquid fertilizer on the growth and antioxidant enhancement of Helianthus annuus L.Orient J Chem 26:1353–1360.

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

[22] Ramarajan S, Henry J L, Saravana G A (2013) Effect of seaweed extracts mediated changes in leaf area and pigment concentration in soybean under salt stress condition. RRJoLS 3:17–21.

[23] Pacholczak A, Szydlo W, Jacygrad E, Federowicz M (2016b) Effect of auxins and the biostimulator algaminoplant on rhizogenesis in stem cuttings of two dogwood cultivars (cornus alba 'AUREA' and 'Elegantissima'). Acta Sci Pol Hortorum Cultus 11:93–103.

[24] Craigie J S(2011) Seaweed extract stimuli in plant science and agriculture.J Journal of Applied Phycology 23(3):371393.

[25] Nabtl E, Jha B, Hartmann A.(2016) Impact of seaweeds on agricultural crop production as biofertilizer[J].International Journal of Environmental Science Technology 14(5):1-16.

[26] HERNÁNDEZ-HERRERARM,SANTACRUZ-RUVALCABAF,RUIZ-LÓPEZMA,et.al.(2014) Effect of liquid seaweed extraction growth of tomato seedlings(Solanum lycopersicum L).J.Journal of Applied Phycology 26(1):619-628.

[27] Liu R Z, Jiang X L, Guan H S,et al.(2009) Promotive effects of alginate-derived oligosaccharides on the inducing drought resistanceoftomato.J Journal of Ocean University of China 8(3):303-311.

[28] Abbasi FF, Baloch MA, Aia-ulhassan WKH, Shah AN, Rajpar I (2010) Growth and yield of okra under foliar application of some new multinutrient fertilizer products. Pak J Agric Eng Vet Sci 26:11–18.

[29] Kalaivanan C, Venkatesalu V (2012) Utilization of seaweed Sargassum myriocystum extracts as a stimulant of seedlings of Vigna mungo (L.) Hepper. Span J Agric Res 10:466–470.

[30] Shahbazi F, Nejad SM, Salimi A, Gilani A (2015) Effect of seaweed extracts on the growth and biochemical constituents of wheat. Int J Agric Crop Sci 8:283–287.

[31] Singh RP, Kumari P, Reddy CR (2015a) Antimicrobial compounds from seaweed-associated bacteria and fungi. Appl Microbiol Biotechnol 99:1571–1586.

[32] Singh SK, Thakur R, Singh MK, Singh CS, Pal SK (2015b) Effect of fertilizer level and seaweed sap on productivity and profitability of rice (Oryza sativa). Indian J Agron 60:420–425.

[33] Singh S, Singh MK, Pal SK, Trivedi K, Yesuraj D, Singh CS, Anand VKG, Chandramohan M, Patidar R, Kubavat D, Zodape ST, Ghosh A (2016) Sustainable enhancement in yield and quality of rain-fed maize through Gracilaria edulis and Kappaphycus alvarezii seaweed sap. J Appl Phycol 28:2099–2112.

[34] Zodape, S.T., Mukhopadhyay, S., Eswaran, K., Reddy, M.P. and Chikara, J.(2010) Enhanced yield and nutritional quality in green gram (Phaseolus radiata L) treated with seaweed (Kappaphycus alvarezii) extract. Journal of Scientific and Industrial Research 69: 468–71.

[35] Younes F, Etahiri S, Assobhei O (2009) Activite antimicrobienne des algues marines de la lagne d'Oualidia (Maroc): criblage et optimization de la periode de la recolte. J Appl Bio sci 24:1543–1552.

[36] Alves RC, Merces PFF, Souza IRA, Alves CMA, Silva APSA, Lima VLM, Correia MTS, Silva MV, Silva AG (2016) Antimicrobial activity of seaweeds of Pernambuco, northeastern coast of Brazil. Afr J Microbiol Res 10:312–318.

[37] Asha A, Rathi JM, Raja PD, Sahayaraj K (2012) Biocidal activity of two marine algal extracts against third instar nymph of Dysdrcus cingulatus (Fab.) (Hemiptera, Pyrrhocoridae). J Biopest 5:129–134.

[38] Nabti E, Sahnoune M, Adjrad S, Van Dommelen A, Ghoul M, Schmid M, Hartmann A (2007) A halophilic and osmotolerant Azospirillum brasilense strain from Algerian soil restores wheat growth under saline conditions. Eng Life Sci 7:354–360.

[39] Nabti E, Sahnoune M, Ghoul M, Fischer D, Hofmann A, Rothballer M, Schmid M, Hartmann M (2010) Restoration of growth of durum wheat (Triticum durum var. waha) under saline conditions due to

ISSN: 2637-6067 DOI: 10.6918/IJOSSER.202205_5(5).0006

inoculation with the rhizosphere bacterium Azospirillum brasilense NH and extracts of the marine alga Ulva lactuca. J Plant Growth Regul 29:6–22.

[40] M.P. Kavitha, V. Ganesaraja and V.K.(2008) Paulpandi. Effect of foliar soraying of sea weed extract on growth and yield of rice (ORYZA SATIVA L.).J Agric.Sci.Digest,28(2):127-129.

[41] Liu Peijing, Wang Fei.(2014) Effect of seaweed bioorganic liquid fertilizer on vegetable seed germination and seedling growth.J Agricultural Science & Technology 15(03):407-411.

[42] [Sethi P (2012) Biochemical composition of the marine brown algae Pedina terastromatica Hauck. Int J Curr Pharm Res 4:117–118.

[43] Mirparsa T, Ganjali H R, Dahmardeh M (2016) The effect of biofertilizers on yield and yield components of sunflower oil seed and nut. Int J Agric Biosci 5:46–49.

[44] Rathore.D.R.&G.N.Chaudhary.(2009) Effect of seaweed extract on the growth, yield and nutrient uptae of soybean (Glycine max) under rainfed conditions[J] .South African Journal of Botany 75(2):5.

[45] Zodape, S.T., Mukhopadhyay, S., Eswaran, K., Reddy, M.P. and Chikara, J.(2010) Enhanced yield and nutritional quality in green gram (Phaseolus radiata L) treated with seaweed (Kappaphycus alvarezii) extract.J Journal of Scientific and Industrial Research 69: 468–71.

[46] Gong Tao, Liu Dehai, et al.(2016) Progress in trehalose synthesis pathway and molecular biology.J China Agricultural Science Bulletin 32(14):62-67.

[47] Perez J, Falque E, Domınguez H (2016) Antimicrobial action of compounds from marine seaweed. Mar Drugs 14:1–38.

[48] Sultana V, Ehteshamul-Haque S, Ara J, Athar M (2005) Comparative efficacy of brown, green and red seaweeds in the control of root infecting fungi and okra. Int J Environ Sci Technol 2:129–132.

[49] Washington W S, Engleitner S, Boontjes G, Shanmuganathan N (1999) Effect of fungicides, seaweed extracts, tea tree oil, and fungal agents on fruit rot and yield in strawberry. Aust J Exp Agric 39:487–494.