Research Journal of Agriculture and Forestry Sciences ISSN 2320-6063
Vol. **3(11),** 1-5, December **(2015)** *Res. J. Agriculture and Forestry Sci.*

Optimum Seed Rate for Maximum yield in Rice (*Oryza sativa* L.)

Harris KD[1]* and Vijayaragavan R[2]
[1]Department of Crop Science, Faculty of Agriculture, Eastern University, Chenkalady, SRI LANKA
[2]Department of Agriculture, Sammanthurai, SRI LANKA

Available online at: www.isca.in, www.isca.me
Received 2nd October 2015, revised 25th October 2015, accepted 17th November 2015

Abstract

A field experiment was conducted at the Rice Research Station at Sammanthurai in Ampara, Sri Lanka to assess the optimum seed rate for maximum yield in rice. This experiment was laid out in a randomized complete block design (RCBD) replicated thrice. Five seed rates viz., 3, 5 (recommended), 7, 9 and 10 bu/ha were included in the study which is equivalent to 61.5, 102.5, 143.5, 184.5 and 205 kg/ha respectively. The dimension of each plot was 4m x 3m. The seeds were broadcasted and the seedlings were maintained inaccordance with the recommendation of the Department of Agriculture. The results revealed that the seed rate 143.5 kg/ha significantly increased the leaf area index, the number of panicles/m^2, the number of spikelets/m^2, percentage of filled grains, 1000 grain weight, yield/ha and harvest index. The highest grain yield/ha was achieved at 143.5 kg/ha. Yield could be increased by 57% by increasing seed rate from 61.5 to 143.5 kg/ha. A further increase in seed rate from 143.5 kg/ha to 205 kg/ha reduced the yield by 35%. However, the correlation between grain yield per hectare with the seeding rate revealed that the optimum seeding rate for maximum yield is 147.9 kg/ha (7.25bu/ac). Under the conditions in this experiment, optimum seed rate for rice yield is 147.9 kg/ha (7.25 bu/ac). So, the seed rate of 147.9 kg/ha (7.25bu/ac) is appropriate for obtaining maximum yield in rice at the Ampara District, Sri Lanka.

Keywords: Optimum, LAI, density, seeding rate.

Introduction

Crop establishment is one of the key factors that affect the success of grain crop[1]. Rate of establishment has a great impact on plant density and the competitiveness of the crop stand, tillering, time to maturity and yield. Therefore, high establishment rate improves yield, competes against weeds and provides uniform growth and maturity. Optimum crop establishment not only improves crop performance but also reduces seeding rates needed for field planting.

The decrease in plant density reduces the yield. Low plant density and improper sowing method are the most important factors of agronomic constraints for obtaining higher yields and have a positive influence on the yield of rice. Optimum plant density is the principal factor for obtaining higher yield in rice[2]. The increase in plant density increases total plant weight per unit area and decreases the total weight per plant[3]. The number of plants per unit area has an impact on plant architecture, modifies growth and development pattern and effects on the production photosynthates[4]. The increase in plant density increases the yield up to a limit and thereafter a leveling off or decline in yield[2]. The reason for the reduction in yield is due to the reduction in resources per plant. So the reduction in yield will not be compensated by increasing plant number. Increasing plant density is one of the ways to increase the yield.

Study on optimum plant population by using appropriate planting techniques has been reported by many workers for increasing the yield of rice[5]. On the other hand, high plant density limits the access of the growth resources such as light, water and nutrients due to greater competition among the plants[4]. Counce[6] reported that maximum yield could be produced from the plant density of 159 to 304 plants/m^2 under dry seeded and flooded rice production systems. Under direct seeded cultures, 50 to 168 kg seeds/ha is needed for gaining highest yield, and that depends on the inter-row spacing[7,8], date of planting[9] and density of panicles[10,11]. Kenneth and Helms[12] reported that number of panicles per unit area accounted to 90% of the variations in rough rice yield. In contrast, Jones and Synder[13] documented that 34% of yield variation was due to panicles per m^2 in direct seeded rice crop.

The recommended seed rate by Department of Agriculture, Sri Lanka is 5bu/ha (102.5 kg/ha). However, in the Ampara District, most of the farmers do not follow the actual recommendation and higher seed rates. Therefore, farmers had to face many problems such as high cost of production, pests and disease incidence, reduction in grain quality and lodging.

To date, no systematic studies have been carried out in order to reduce the cost of production and improve the quality of rice. With the view of considering the above, the present study was conducted to determine the optimum seed rate for maximum yield in rice (cv. BG 94-1) in the Ampara District, Sri Lanka.

Material and Methods

The experiment was carried out at the Rice Research Station at Sammanthurai in Ampara, Sri Lanka during the period November 2013 to March 2014. It falls into the DL_2 agro-ecological region of the LCDZ (low country dry zone) in Sri Lanka. All the treatments were arranged in a randomized complete block design (RCBD) with three (3) replicates. Five seed rates viz., 3, 5 (recommended), 7, 9 and 10 bu/ha were included in the study, which is equivalent to 61.5, 102.5, 143.5, 184.5 and 205 kg/ha respectively. The plot size was 4 m x 3m. The seeds were broadcasted and the seedlings were maintained as recommended by the Department of Agriculture, Sri Lanka. Ten plants were randomly selected for sampling at each occasion. At harvest, plants were uprooted from an area of $1m^2$. Recorded data were statistically analyzed using SAS 9.1 and means were separated using Least Significant Difference test at 5% significant level.

Results and discussion

Plant height: Plant height was statistically differed among seeding treatments at different stages of plant growth (table-1). In all stages, plant height was highest at the seed rate of 205 and 184.5 kg/ha. At 30 days after sowing (DAS), seed rate did not influence the plant height. At 60 ($P<0.01$) and 90 DAS ($P<0.05$), highest eight was observed at the seeding densities of 205 and 184.5kg/ha. At 90 DAS, lowest plant height was observed ($P<0.05$) at the seed rate of 143.5 and 61.5 kg/ha recorded lowest value of 58.33 and 57.33 cm respectively. This indicates that when the plant spacing becomes closer (high seeding rate), the plant tends to grow taller in search of light. That means as the number of plant/m^2 increases, plant competes severely for light. Thus, the plants grow taller. This result is in consistent with those reported by Zhang *et al.*[14] and Sharma[15]. In contrast, Akbarand Ehsanullah[16] reported that seeding density had no significant effect on height.

Leaf area index: The changes in LAI/plant with time and seed rates are presented in table-2. In general, seed rates at 60 and 90 DAS had an effect on LAI/plant (Table 2). In 30 DAS, seed rates did not influence the LAI/plant. At 60 DAS, highest LAI/plant was obtained at the seed rates of 205 and 184.5kg/ha followed by 61.5 kg/ha. At 90 DAS, seed rate treatment significantly affected the LAI/plant and the highest LAI value of 5.88 was observed at the seeding rate of 102.5 kg/ha which is not significantly different from the seed rates 143.5 (5.24), 184.5 (5.72) and 205 (5.79) kg/ha. Lowest LAI//plant was recorded in seed rate of 61.5 kg/ha.

It appears that maximum LAI/plant in this experiment was 5.9. However, LAI/plant was similar at 102.5, 143.5, 184.5 and 205 kg/ha. Hu *et al.*[17] indicated that the plant population had a significant effect on photosynthetic characters of the rice crop.

Table-1
Effect of different seed rates on plant height (cm) atfour weeksinterval

Seed rate (kg/ha)	Days After Planting (DAS)		
	30	60	90
61.5	28.33	38.66^{bc}	57.33^{b}
102.5	29.00	32.00^{c}	66.33^{ab}
143.5	28.66	44.66^{ab}	58.33^{b}
184.5	30.66	48.33^{a}	71.0^{a}
205	25.00	51.00^{a}	70.33^{a}
F Test	ns	*	*

*P<0.05; ns – not significant; **Means followed by the same letter in each column, are not significantly different to Least significant different at 5% level.*

Table-2
Effect of different seed rates on leaf area index/plant

Seed rate (kg/ha)	Days After Planting (DAS)		
	30	60	90
61.5	1.11	2.08^{c}	4.37^{b}
102.5	1.66	2.36^{bc}	5.88^{a}
143.5	1.57	2.78^{bac}	5.24^{a}
184.5	1.62	3.07^{ab}	5.72^{a}
205	1.5	3.04^{ab}	5.79^{a}
F Test	ns	*	*

*P<0.05; ns – not significant; **Means followed by the same letter in each column, are not significantly different to Least significant different at 5% level.*

Increase in density (seed rate) increased LAI per plant. This means enhanced LAI per unit area is due to increase in number of plants per unit area. So this leads to more area available for the production of photosynthates. This result is in agreement with findings reported by Akita[18].

Yield and yield components: Yield: At 105 days, grain yield of rice was significantly different at different seed rates (table-3). Maximum grain yield/ha was recorded ($P<0.05$) at the seeding density of 143.5 kg/ha (6.65 Mt/ha) and the minimum grain yield/ha was observed in the 61.5 kg seeds/ha (4.23 Mt/ha) (table-3).

Table-3
Effect of different seed rates on grain yield

Seed rate (kg/ha)	Yield (at harvest)	
	Per plant(g)	Per ha (Mt)
61.5	5.66[a]	4.23[c]
102.5	5.33[ab]	4.92[bc]
143.5	4.66[bc]	6.65[a]
184.5	4.00[cd]	5.56[ab]
205	3.66[d]	5.15[bc]
F Test	**	*

*P<0.05; ns – not significant; **Means followed by the same letter in each column are not significantlydifferent to Least significant different at 5% level.*

At harvest, the weight of grains increased up to the seed rate 143.5 kg/ha (4.66 Mt/ha) (figure-1). An increase in seed rate from 61.5 to 102.5 and 102.5 to 143.5 kg/ha, yield went up by 16 and 41.5% respectively. Thereafter, a further increase in seeding density from 143.5 to 184.5 kg/ha decreased grain yield by 26%. Therefore, the optimum seed rate under the conditions of the present investigation was 147.9 kg/ha which is equivalent to 7.25 bu/ha). Similar results showing that yield of rice linearly increased with seed rate (density) has been reported by Baloch *et al.*[5]. The plants at low seed rate have sufficient space and this enables to utilize more nutrients, water and solar radiation for better photosynthesis. Hence, the individual plants performed better. This is in agreement with the studies reported by Baloch *et al.*[5].

On per plant basis, highest grain yield/plant was obtained ($P<0.01$) in the lowest seeding density of 61.5 kg/ha (5.66 Mt/ha) (table-3) followed by 143.5 kg/ha (4.66 Mt/ha). Lowest grain yield/plant obtained in the highest seed rate of 205 kg/ha (3.66 Mt/ha). As the seed rate increased, yield per plant decreased. Although per plant yield was higher at the lowest seed rate (density), this did not compensate for the contribution in terms of yield by more plants at the higher density.

It may be possible that at the highest seed rate, the contribution from each plant towards flower and grain formation is greater than that from the lowest seed rates and greater radiation during the reproductive and ripening stages[19]. The highest yield may also be due to the panicle and spikelet number /m^2, % of filled grains, 1000- grain weight and harvest index.

Significant ($p<0.05$) relationship between seeding density and yield of rice plant is revealed by the equation $Y = -0.115\ x^2 +1.669x + 0.061$ (figure-1 and equation-1). The optimum seed rate of rice was recorded in this study was 7.25 bu /ha.

$$Y = -0.115\ x^2 +1.669x + 0.061. \qquad (1)$$

Where: Y= Grain yield (Mt/ha), X= seed rate.

The recommended seed rate is 6.25 bu/ha. However, farmers in Ampara district are using 10 to 12 bu/ha. The present investigation indicates the optimum seed rate is 7.25 bu/ha (147.9 kg/ha).

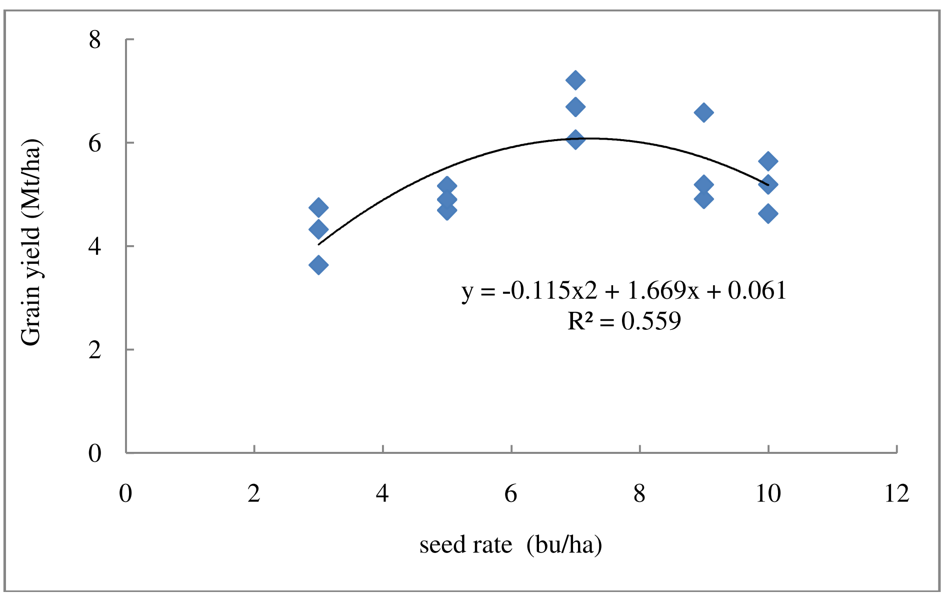

Figure-1
Effect of density of plant on grain yield

Number of panicles/m^2: At 105 days, increasing seed rate from 61.5 to 102.5 kg/ha (P< 0.001) and from 102.5 to143.5 kg/ha gave a substantial rise in panicle number/m^2 (table-4). A further increase from 143.5 to 184.5 and 184.5 to 205 kg/ha did not significantly affect the number of panicles/m^2. This non-significance in number of panicles/m^2 might be due to restriction in space as the seed rate increased. Increasing seed rate would also increase the number of plants per unit area and results in additional unhealthy seedlings with small panicle due to competition and enhance the susceptibility to pests and diseases. These findings are supported by Baloch *et al.*[5] who reported that greater number of plant per unit area multiplies the panicle number per area unit. Miller *et al.*[10] found that panicle density is a key factor that determines and contributes 89 % of differences in yield. These results are in line with those of Kenneth *et al.*[12] who reported rough rice has gained high yield in the optimum plant stand.

Number of spikelet/m^2: At 105 days, seed rates had a significant (P < 0.001) effect on number of spikelet/m^2 (table-4). Maximum number of spikelet/m^2 (92967) was recorded at 143.5 kg/ha (table-4). However, there is a trend to indicate an increase in seeding density from 61.5 to 102.5 kg/ha, increased the number of spikelet/m^2 by 95%. A further increase from 102.5 to 143.5 increased the number of spikelet/m^2 by 54% and a further increase from 143.5 to 184.5 and 205 kg/ha, reduced the number of spikelet/m^2 by 63% and 67% respectively. This suggests that marked reduction in number of spikelet/m^2 occurs only beyond an optimum plant density, ie. 147.5 kg/ha in this experiment[20]. When seed rate is increased beyond an optimum point, it increases the leaf area and vegetative parts per unit area, thus increasing the respiration which in turn could lead to a reduction of number of grains[21].

Percentage of filled grain/plant: At 105 days, the highest percentage of filled grain/plant was obtained at 61.5 and 143.5 kg/ha, (table-4) followed by 184.5 and 205 kg/ha. It revealed that as seeding rate increased, the filled grains per panicle remarkably reduced. When seed rate is increased beyond an optimum point, it increases the photosynthetic apparatus and vegetative parts per unit area, thus increasing the respiration which in turn could lead to a reduction of filled[21]. High percentage of filled grains was obtained in lower planting density. This is in agreement with the studies reported by Nadeem Akbar and Ehsanullah[22] and Baloch *et al.*[5]. This indicates that compared to panicle density, the effect of filled grains per panicle is the most important factor in contributing to yield which is positive in this study.

1000-Grain weight: At 105 days, maximum 1000-grain weight was recorded at 143.5, 61.5, 102.5 and 184.5 kg/ha (table-4) and the lowest 1000- grain weight observed at 205 kg/ha. The higher value was probably owing to more filling of starch in better grain development.

This investigation also showed that increasing seed rate beyond 143.5 kg/ha will not be beneficial as it will increase the mutual shading and respiration. It would, thereby, bring about the reduction of number of panicles/plant and grains/panicle and percentage of filled grains which will result in lower yields. It should also be noted that rise in plant density increases the number of panicles/unit area did not compensate for the reduction in above yield parameters, thus resulting in a decrease in yield.

Harvest index: At 105 days, harvest index was highest at the seeding rates of 61.5, 102.5 and 143.5 kg/ha. Lowest harvest index was recorded in seed rates of 205 kg/ha (table-4). One of the ways to increase the yield is to increase harvest index[18]. Sink formation and ripening are the two physiological processes that explain the improvement in HI[18].

Table-4
Effect of seed rates on yield and yield components

Seed rate (kg/ha)	Number of panicles/m^2	Number of spikelet/m^2	Percentage of filled grains	1000 - grain weight (g)	HI
61.5	554.07^c	30977^c	92.67^a	29.40^a	0.28^a
102.5	863.70^b	60363^b	89.00^{ab}	29.10^a	0.25^{b}0.190^b
143.5	1184.31^a	92967^a	92.00^a	29.90^a	0.22^a
184.5	1073.45^a	58928^b	85.67^b	29.00^a	0.19^{b}0.20^b
205	1159.99^a	61846^b	84.67^b	24.00^b	0.14^{b}0.20^b
F Test	***	**	*	***	**

P<0.05; ns – not significant; *Means followed by the same letter in each column are not significantly different to Least significant different at5% level*

Conclusion

The seed rate (143.5 kg/ha) significantly increased the LAI, the number of panicles and spikelets/m^2, 1000 grain weight and yield/ha. The lowest and the highest yields/ha were obtained at the seed rate of61.5 and143.5 kg/ha respectively. Therefore, yield could be improved by 57% by increasing seed rate from 61.5 to 143.5 kg/ha. A further increase of seed rate from 143.5 to 205 kg/ha reduced the yield by 35%. However, the correlation between grain yield per hectare with the seeding rate shown optimum seed rate is 147.9 kg/ha.

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