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RESEARCH ARTICLE

GROWTH PERFORMANCES AND GRAIN YIELD RESPONSE OF RICE VARIETIES (*Oryza sativa* L.) ESTABLISHED AT DIFFERENT SEED BROADCASTING RATES IN IRRIGATED FIELDS OF LOW COUNTRY DRY ZONE OF SRI LANKA

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Abstract

Seed broadcasting rate has an enormous influence on rice plant density and the competition of the crop stands, tiller number, time taken to maturity and grain yield. Relatively low plant densities due to inappropriate sowing methods are the most significant aspects of agronomic restrictions for obtaining higher grain yields and weed competitiveness. A research study was conducted in *Maha* 2019/20 and *Maha* 2020/21 seasons to study the effect of different seed broadcasting rates on the yield and weed competitiveness of rice. The experiment was established with 3 different seed broadcasting rates 100, 150 and 200 kg ha^{-1} for the rice variety At 362 (Long grain) and 75, 112.5 and 150 kg ha^{-1} for the rice variety At 307 (Intermediate grain). The experiment was conducted under the irrigated condition of the low country dry zone of Sri Lanka in imperfectly drained reddish brown and low humic gley soils at the Rice Research Station (RRS), Ambalantota. Parallel to the research field experiment, recommendation and farmer practiced seed broadcasting rates (100 and 150 kg ha^{-1}) were evaluated at farmers' fields using rice variety At 362. Grain yield, plant height, tiller count, filled and unfilled grain per panicle, spikelet count per panicle, 1000 grains weight and weed performance were determined. Results of this experiment have shown that elevated seed rates beyond 100 kg ha^{-1} do not improve the tiller count, effective panicles or the grain yield of two rice varieties At 362 and At 307. Diseases like sheath blight may affect the rice crop more severely causing significant yield losses in favourable weather with increased populations (150 kg ha^{-1}). Therefore, a 100 kg ha^{-1} seed broadcasting rate can be recommended as the best seed rate for farmer field cultivation where better weed management practices are adopted. Finally, the results of this experiment reconfirmed that exceeding the recommended seed broadcasting rates of 100 kg ha^{-1} or 75 kg ha^{-1} for At 362 or At 307 respectively will not be effective to get a higher yield response from paddy under irrigated conditions in the dry zone. Recommended seed application rate of 100 kg ha^{-1} for long grain rice and 75 kg h^{-1} for intermediate grain rice in the paddy farming system had been recorded as cost effective seed broadcasting rates.

Keywords: Growth, Rice, Seed rate, Weed, Yield

INTRODUCTION

Rice is the staple food is cultivated in all the districts in Sri Lanka while dry zone rice production contributes to the national rice supply mainly. Compared to any other paddy establishment techniques direct sowing of sprouted paddy to the fields is the most popularly adapted practice in paddy farming in Sri Lanka. Under direct seed broadcasting, the seeding rate has been recognized as the main liable factor for altering the optimum plant density, which realizes a well-suited rice growth and high grain yield of rice (Khalifa *et al.* 2005; Haque 2016; El-Dalil *et al.* 2017). Apart from the recommended seed broadcast-

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ing rate of 100 kg ha^{-1} given by the Department of Agriculture (DOA), farmers are adopted to use different seeding rates for cultivation mostly more than the recommended rate (Illangakoon 2020). Rice seed rate greatly influence for plant density and the competition of different crop stands such as tiller count per unit area, time taken to maturity and yield advantage (Gupta 2006). Low plant tiller density due to inappropriate seed broadcasting methods are significant aspects of agronomic restrictions in consisting higher yields and has a progressive influence on the yield of rice (Sivaesarajah *et al*. 1995). According to Abuzar *et al*. (2011) higher plant density increases total plant biomass per unit area but declines the total biomass per plant. Therefore, the number of individual plants per unit area (no. / m^2) has an influence on the plant architecture, adaptive growth and developmental configuration and properties of productive photosynthesis. A dense population of rice crop influences negatively on grain yield of rice due to the inadequacy of the soil inputs and micro-environment.

Optimal plant space ensures the ideal plant count per unit area, leads to grain yield optimizing by characters and finally for the grain yield. Optimal plant spacing or density may facilitate plants to grow properly consuming more soil nutritional inputs and solar radiation (Mia *et al*. 1990; Bhowmik *et al*. 2012). The Small Brown Plant Hoppers (SBPH) *Laodelphax spp*, Brown Plant Hoppers (BPH) *Nilaparvata spp* and White Backed Plant Hoppers (WBPH) *Sogatella spp* were a serious risk to rice production areas mainly in the Asian and South East Asian regions of the world which may be crucial with high plant density. Many parts of Pakistan have reported the grain yield of the rice crop is relatively low when compared to other advanced rice cultivation countries of the world causing many issues with high plant solidarity (Rehman *et al*. 2017). Yield damages of rice have been reported more than 50 % under the most favorable micro-environments for fungal growth. Favorable conditions such as high humidity and low temperature created due to high plant density may tend to spread infections rapidly (Matsukawa *et al*. 2015; Sivasubramaniam *et al*. 2018). Sheath blight is a major soil borne disease which is caused by the fungus *Rhizoctonia solani* and threat to rice productivity (Wu *et al*. 2014). According to the IRRI knowledge bank (2020), Sheath blight is one of the most economically important diseases in any parts of the world. Infested leaves tend to make senesce or dry out and die off rapidly where as young plant tillers also destroy very easily. As a result, the leaf area of the plant canopy can considerably lost by the infection. The decline of leaf area, along with the infestation cause to make the senescence of leaves and premature infected tillers primarily influence for grain yield reduction. The direct seed broadcasting practice of rice offers a beneficial option to decline the restrictions of transplanted rice. Direct seed broadcasting is being practiced in many countries of the world where labour force is scarce (Pingali *et al*. 1994). Direct seeding of rice occupies 26 % of the whole rice area in the South Asian region of the world (Gupta *et al*. 2006). Direct seeding of rice escapes the puddling, it does not need constant submergence, and thus declines the overall water requirement for the rice culturing system. When rainfall pattern at plant establishing time is highly variable, direct seed broadcasting may help to decrease the production risk with crop damage (Singh *et al*. 2006). Direct seed application can also decrease the risk by escaping lethal drought which affecting to depresses the yield of transplanted rice, particularly if the latter is established late due to the hindered of rainfall pattern. Having most of the advantages of the direct seeding technique it has become the favourite establishment practice of Sri Lankan rice farmers. In addition, farmers tend to apply high seed rates exceeding the Department of Agriculture (DOA) recommendation (100 kg h^{-1}) expecting high yield outcomes and suppressed weed growth which may lead to an extra cost on cultivation and finally becomes an unproductive practice. Considering the above situations, an experiment was designed to find out the best seed rate to inspect the impact of the different seed broadcasting rates on the grain yield and growth performance of the two most popularly cultivated rice varieties At 362 (Long grain) and At 307 (Intermediate grain).

MATERIALS AND METHODS

Field level experiments were conducted in *Maha* 2019/20 and *Maha* 2020/21 seasons at the Rice Research Station (RRS), Ambalantota, Sri Lanka (latitude 6.12^o N and longitude 81.02^o E). Parallel to it, farmer field experiments were conducted at Mamadala, Bolana in *Maha* 2019/20 season and at the Beragama, Mamadala and Koggalla in *Maha* 2020/21 season. Completely Randomized Design (CRD) had applied for the experiment with four replicates (plot size 18 m^2) and three seed rates. Soils in the experimental areas were imperfectly drained Reddish Brown Earth (RBE) and Low Humic Gley (LHG). Three seed rates tested in the experiment in Rice Research Station, Ambalantota were 100, 150 and 200 kg ha^{-1} for rice variety At 362 and 75, 112.5 and 150 kg ha^{-1} for At 307. In the farmers' fields, two seed rates, viz. 100 and 150 kg ha^{-1} were tested with advanced rice accession At 362. Rice variety At 362 was used as the most dominant variety in farmer field cultivations in the low county dry zone. In each experiment, pre-germinated seeds were broadcast and fertilizer application was done according to the Department of Agriculture recommendation (DOA, 2013). Supplementary irrigation was done when rain water was not sufficient to fulfill the water demand. Growth parameters such as plant height, tillers count per unit area, panicle count per unit area, number of filled and unfilled grains count per panicle, 1000 grains weight (moisture level 14 %) and grain shattering were measured. Plant tiller count per unit area was counted at the different times (2, 4, 6, 8 and 10 weeks) and the number of active panicles count was counted at the harvesting. Weeds were sampled and separated into broad leaves, grass and sedges and the number of weed seedlings and dry weight of each were determined at biweekly intervals. After harvesting, grain yield (moisture level at 14 %) and yield components were measured. Diseases infected (Sheath Blight) plant count (No. / m^2) was recorded as index. Cost evaluation was done by referring the local market paddy price of variety At 307 and At 362 in each season. Percentage income losses and ratios were calculated considering the amount of seed materials broadcast in the field farmer field level which determined according the market values of the year 2021. All the data were analyzed by latest STAR software for Windows version 2.0.1 (IRRI 2014).

RESULTS AND DISCUSSION

Results of the experiment done in RRS, Ambalantota during *Maha* 2019/2020 show a significant increment in rice tiller count when the seed broadcasting rate was augmented by 50 kg ha^{-1} ie. 100 to 150 kg ha^{-1} (Table 1). But the aggregation of the seed broadcasting rate up to 200 kg ha^{-1} has not to increased tiller number of variety At 362 further and reachable yield has become stagnant even after the increase of seed rate beyond 150 kg ha^{-1} in At 362. However, this pattern was observed throughout the growth until 10 week of the period as illustrated in table 1. Similarly variety At 307 performed with more tillers when seed rate was raised to 112.5 kg ha^{-1} and remained with the same amount of tillers even at the elevated seed rate to 150 kg ha^{-1}. By 10 weeks of field progression, both varieties had reduced their tiller number compared to the initial growth stages due to the lack of spacing among the individual plants. Similar results were observed by Ilangakoon *et al.* (2020).

The results of the experiments are given in figure 1. After 4 weeks of broadcasting the tiller count was significantly high in plots broadcast with 150 kg ha^{-1} compared to 100 kg ha^{-1} of seed rate in the Mamadala farmer field but the significant difference disappeared after 6 weeks and thereafter. Dissimilarly in the Bolana farmer field the tiller counts were higher at the seed broadcasting rate of 150 kg ha^{-1} in each measured week till 10 weeks after the sowing (WAS).

Table 2 shows variation in filled and unfilled grain count per panicle of rice varieties At 362 and At 307. The filled grain count per panicle of variety At 362 was significantly (α = 0.05) low at the seeded rate of 200 kg ha^{-1}. Irrespective of the variety elevated seeded application with the broadcasting rate of 200 kg ha^{-1}or 150 kg ha^{-1} beyond the current recommendation (100 kg ha^{-1}) has negatively affected the grain filling components such as filled grains,

Table 1: Tiller count (No. / m^2) of rice varieties during the growth period, broadcast under three different seed rates at RRS - Ambalantota (*Maha* 2019/20)

Age (WAS)	Variety	Tiller count per 1 m^2 under different seed broadcasting rates		
		100 kg ha^{-1}	**150 kg ha^{-1}**	**200 kg ha^{-1}**
4	At 362	652.17^b	726.52^a	739.13^a
6	At 362	579.08^b	641.30^a	717.39^a
8	At 362	554.37^b	755.31^a	737.55^a
10	At 362	579.08^b	630.43^a	652.17^a
		75 kg ha^{-1}	112.5 kg ha^{-1}	150 kg ha^{-1}
4	At 307	586.95^b	739.13^a	750.00^a
6	At 307	510.86^b	652.17^a	673.93^a
8	At 307	597.82^b	697.47^a	662.17^a
10	At 307	579.08^b	641.30^a	586.95^a

Note: In each row mean values with the same letters (at least) are not significantly different (α = 0.05) in LSD

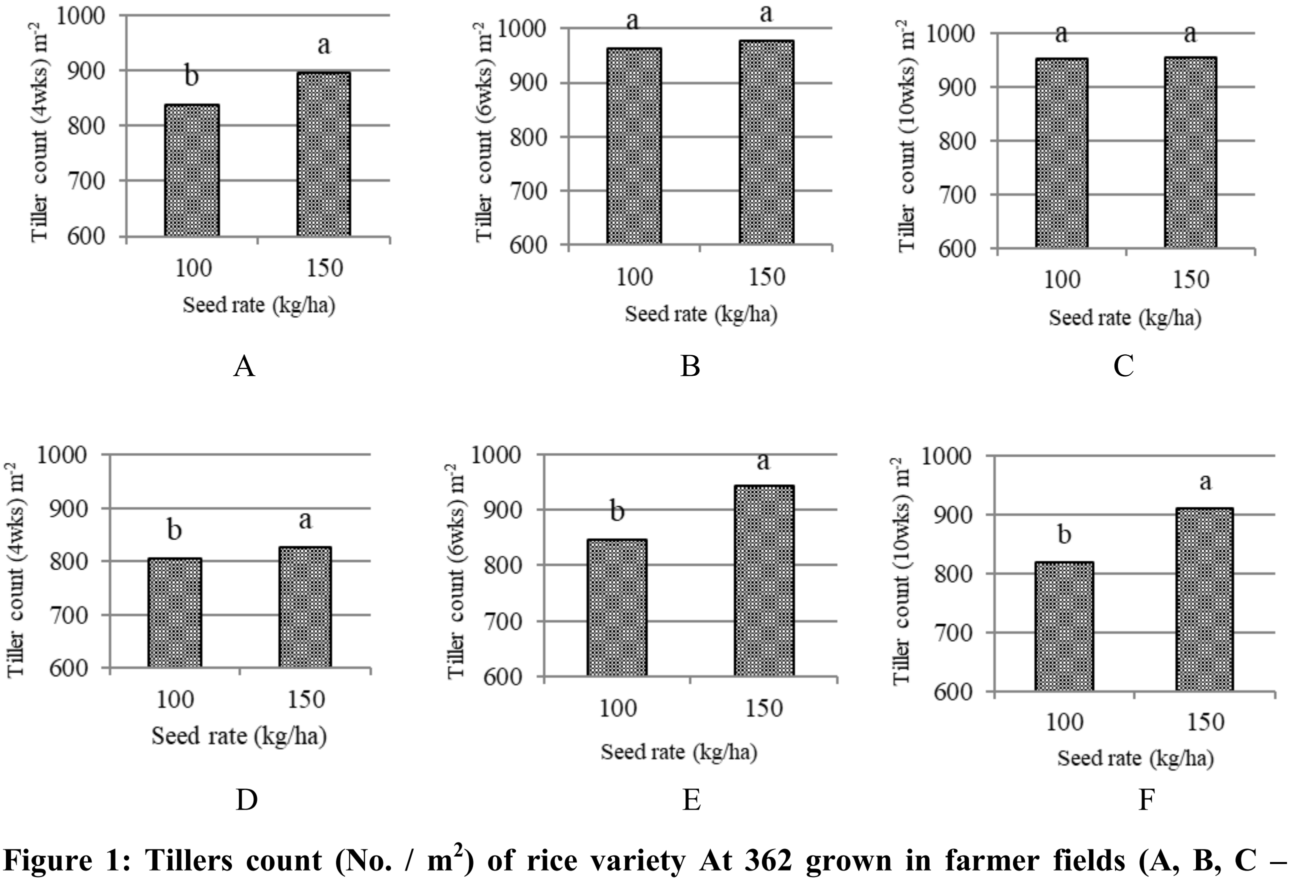

Figure 1: Tillers count (No. / m^2) of rice variety At 362 grown in farmer fields (A, B, C – Mamadala and D, E, F – Bolana farmer field) during *Maha* 2019/20

1000 grain weight and filled grain shattering of variety At 362 or At 307, respectively.

Similarly, the unfilled grain count per panicle was significantly high at the seeded rate of

200 kg ha^{-1}. Low seeding rates were affected by the relatively low unfilled count impacting to decrease in the competition for nutrients and sunlight (Baloch *et al*. 2002). Filled grain and unfilled grain shattering and 1000 grain weight of both rice varieties At 362 and At 307 are illustrated in table 2. Filled grain shattering percentage and 1000 grains weight of rice variety At 362 and At 307 were not significantly different with 100 kg ha^{-1} and 150 kg ha^{-1}. But further increasing of seed rate up to 200 kg ha^{-1} had shown the reduction of the grain shattering and 1000 grains weight. However, the unfilled grain shattering percentage was significant at the highest seed broadcasting rate of 200 kg ha^{-1} (Table 2). A relatively lower unfilled shattering percentage was observed under the 100 and 150 kg ha^{-1} seeding rate. Baloch *et al*. (2002) pointed out a similar behavior of grain shattering and 1000 grain weight with different seeding rates. Also tendency of these outcomes concerning the number of filled grains per panicle, the number of unfilled grains per panicle and infertility percentage was completely comparable with those reported by Metwally *et al*. (2010).

Table 2: Yield and grain quality parameters of rice variety At 362 and At 307 with three different seed broadcasting rates at RRS - Ambalantota (*Maha* 2020/21)

Yielding and quality parameters	At 362 seed rate (kg ha^{-1})			At 307 seed rate (kg ha^{-1})		
	100	150	200	75	112.5	150
Filled grains count per panicle	101.42^{a}	95.08^{a}	79.33^{b}	105.08^{a}	90.08^{b}	96.67^{b}
Unfilled grains count per panicle	34.25^{b}	33.58^{b}	39.25^{a}	35.58^{b}	29.67^{c}	43.25^{a}
1000 grains (filled) weight (g)	24.87^{a}	24.41^{a}	22.38^{b}	21.55^{a}	21.78^{a}	20.88^{b}
Filled grain shattering (%)	6.92^{a}	6.58^{a}	5.21^{b}	5.42^{a}	5.62^{a}	4.81^{b}
Unfiled grain shattering (%)	2.17^{b}	2.21^{b}	2.50^{a}	5.31^{b}	5.92^{b}	7.11^{a}

Note: In each row mean values with the same letters (at least) are not significantly different (α = 0.05) in LSD

Table 3: Plant count, tiller count and number of active panicles count (No. / m^2) of At 362 performed under different seeded rates at Beragama, Koggalla, and Mamadala farmer fields in *Maha* 2020/21

Location	Seed rate (kg ha^{-1})	Plant count (No. /m^2)	Tiller count (No. /m^2)	Number of active panicles (No. /m^2)	1000 grains weight (g)
Beragama	100	191.50^{a}	318.9^{a}	315.70^{a}	25.92^{a}
	150	155.60^{b}	317.80^{a}	313.50^{a}	25.12^{a}
Koggalla	100	147.00^{a}	332.50^{a}	298.10^{a}	25.19^{a}
	150	127.02^{a}	312.00^{a}	297.10^{a}	25.16^{a}
Mamadala	100	253.31^{a}	337.23^{a}	347.80^{a}	25.82^{a}
	150	221.41^{b}	311.21^{b}	339.60^{b}	25.67^{a}

Note: In each column mean values with the same letters (at least) are not significantly different (α = 0.05) in LSD

Table 3 shows the variation of plant count, tiller count, active panicle count and 1000 grain weight at the Beragam, Koggalla and Mamadala farmer field where tiller count, number of active panicles per unit area (No. / m^2) and 1000 grain weight was not significantly different under 100 and 150 kg ha^{-1}. However, the number of plant counts per unit area was significant at 100 kg ha^{-1} rate due to optimum spacing.

Figure 2 A and B show significant variations in active panicle count per unit area (1 m^2) in *Maha* season 2019/20 at rice research field RRS, Ambalantota where the number of panicles was lower at seed broadcasting rate of 100 kg ha^{-1} and 75 kg ha^{-1} in At 362 and At 307, respectively. Rice variety At 362 has given a relatively high active panicle count compared to variety At 307. Contrastingly different interpretations were found during *Maha* 2020/21.

There were no significant differences between active panicle counts in both rice varieties broadcast with different seeding rates. Dongarwar *et al*. (2015) observed the yield response to different seed broadcasting rates as 50, 75, 100, 125 and 150 kg seeds ha^{-1} with two rice varieties as Sye- 2001 and PKV HMT. Significantly higher grain yield was given by advanced rice accession Sye - 2001 which recorded as 3.2 t ha^{-1}. Conversely, rice variety PKV HMT was recorded 2.6 t ha^{-1} grain yield. Among the different seed broadcasting rates, 75 kg seed ha^{-1} showed the significant grain yield (3.5 t ha^{-1}).

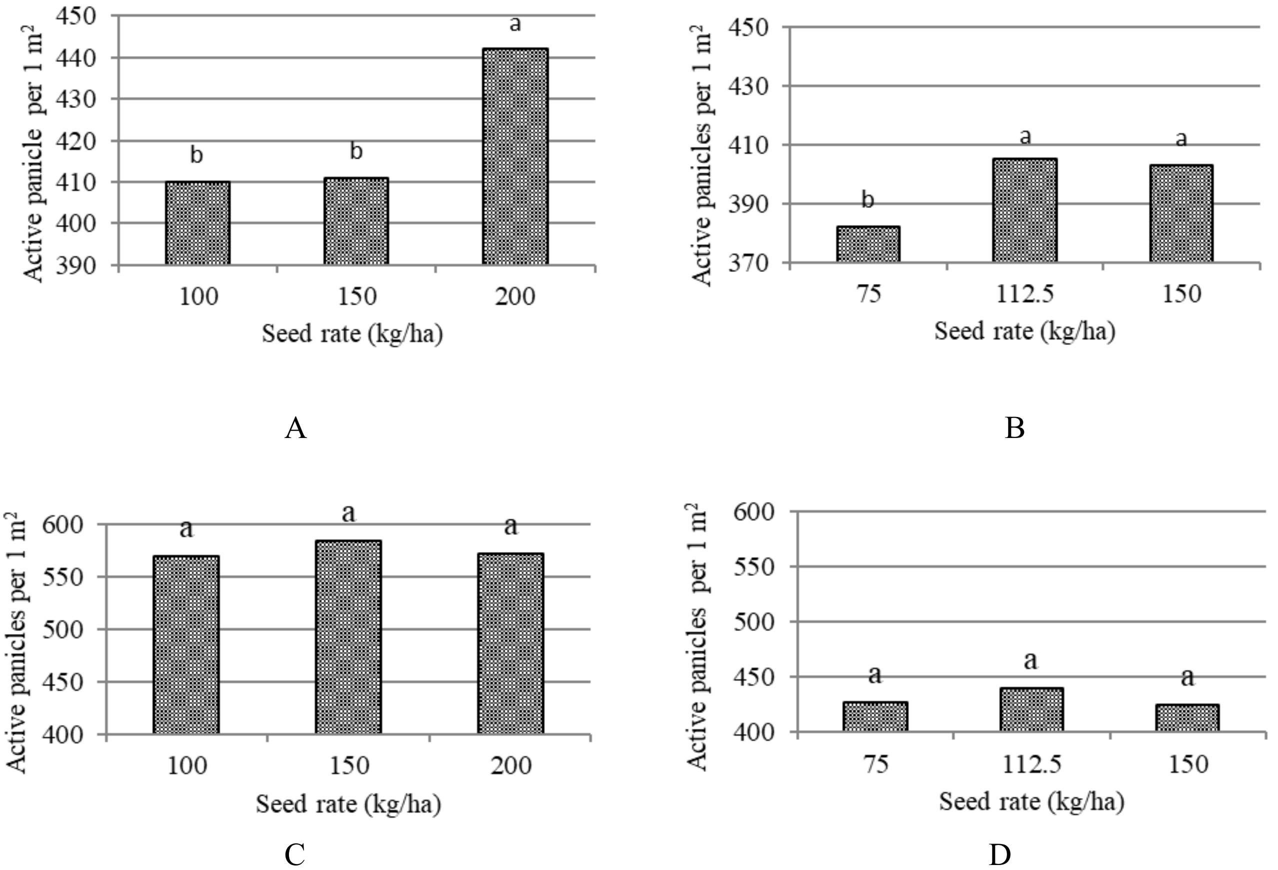

Figure 2: Active panicles count (No. / m^2) affected by different seeding rates at RRS Ambalantota (A - At 362, B - At 307 2019/20 *Maha* season and (C - At 362, D - At 307) 2020/21 *Maha* season)

Table 4 shows the variation of grasses, sedges and broad leaves counts and dry weights (g) per unit area (1 m^2). Broad leaves, sedges and grasses count and dry weight were significantly high at the 100 kg ha^{-1} rate due to relatively wider spacing. However, further increasing of seeding rate, spaces between rice plants were minimized which cased to reduce the weeds such as grasses, sedges and broad leaf with both rice verity At 362 and At 307. At different seed broadcasting rates (100, 150 and 200 kg ha^{-1}) sedges and broad leaves count and dry weight were relatively very low. Anchal *et al*. (2017) showed that the weed controlling capacity using different seed rates which was most effective with high seed rates.

Table 4: Grass, sedges and broad leaves count (No. / m^2) and dry weight (g / m^2) at the different growth stage with different seed broadcasting rates at RRS - Ambalantota (*Maha* 2020/21)

Age (WAS)	Grass count (No. / m^2)			Sedges count (No. / m^2)			Broad leave count (No. / m^2)		
At 362 (kg ha^{-1})	100	150	200	100	150	200	100	150	200
4 wks	2.72^c	10.78^a	5.43^b	NR	NR	NR	NR	NR	NR
6 wks	28.80^a	22.64^b	2.72^c	NR	NR	NR	NR	NR	NR
8 wks	28.07^c	60.68^a	37.12^b	1.01^c	5.43^a	2.72^b	NR	NR	NR
10 wks	41.47^c	50.71^a	46.17^b	11.72^a	5.43^b	5.43^b	NR	NR	NR
At362	Grass dry weight (g / m^2)			Sedges dry weight (g / m^2)			Broad leave dry weight (g / m^2)		
4 wks	1.77^b	4.24^a	1.74^b	NR	NR	NR	NR	NR	NR
6 wks	24.54^a	10.90^b	2.20^c	NR	NR	NR	NR	NR	NR
8 wks	1.36^c	6.60^b	9.59^a	0.86^b	1.09^a	0.39^c	NR	NR	NR
10 wks	10.82^c	13.49^a	12.88^b	2.31^a	0.87^c	1.30^b	NR	NR	NR
	Grass count (No. / m^2)			Sedges count (No. / m^2)			Broad leave count (No. / m^2)		
At 307 (kg ha^{-1})	75	112.5	150	75	112.5	150	75	112.5	150
4 wks	5.43^c	19.02^a	13.59^b	NR	NR	NR	NR	NR	NR
6 wks	17.12^b	87.85^a	19.59^b	NR	NR	NR	NR	NR	NR
8 wks	172.09^a	146.74^b	39.84^c	19.02^a	13.59^b	19.02^a	5.93^b	5.43^b	29.89^a
10 wks	107.74^b	107.66^b	172.07^a	15.38^a	5.08^c	9.05^b	18.02^b	14.48^c	23.23^a
At 307	Grass dry weight (g / m^2)			Sedges dry weight (g / m^2)			Broad leave dry weight (g / m^2)		
4 wks	12.61^a	6.03^b	6.58^b	NR	NR	NR	NR	NR	NR
6 wks	8.40^c	11.60^a	9.13^b	NR	NR	NR	NR	NR	NR
8 wks	22.88^b	26.82^a	6.53^c	2.93^b	4.96^a	4.35^a	0.78^b	0.24^c	0.97^a
10 wks	8.91^c	31.60^a	18.42^b	1.14^b	1.47^a	0.33^c	2.64^a	2.47^c	2.55^b

Note: NR – weeds not recorded, WAS - weeks after sowing. N.B: Note: In each row mean values with the same letters (at least) are not significantly different ($\alpha = 0.05$) in LSD

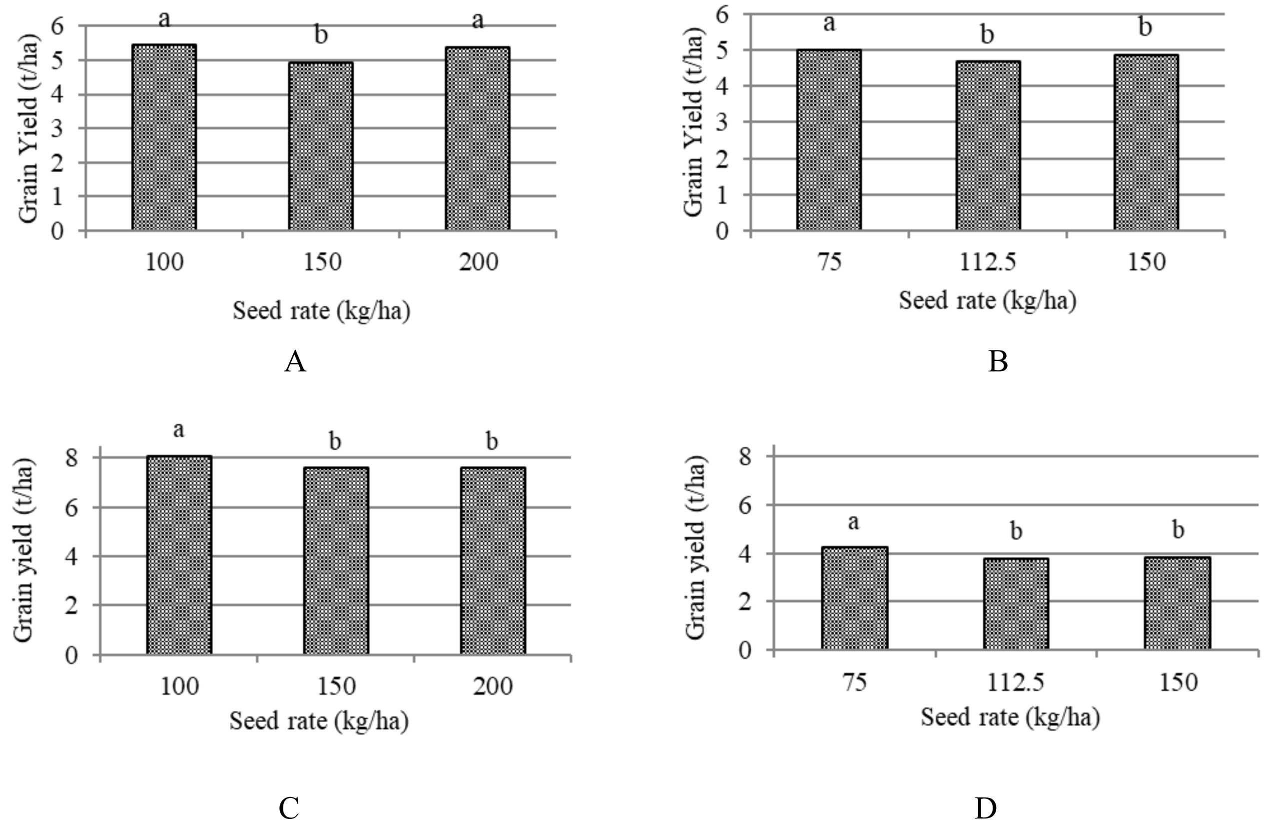

Figure 3: Grain yield of rice varieties grown in RRS, Ambalantota with different seed broadcasting rates (A - At 362, B - At 307) in *Maha* 2019/20 and (C - At 362, D - At 307) in *Maha* 2020/21

The figure 3 A and B were shown the deviation of grain yield of rice varieties grown at the rice research field Ambalantota in *Maha* 2019/20 season under the three different seeding rates ie. 100, 150 and 200 kg ha^{-1}. As denoted in the figure average grain yield was influenced by different seed broadcasting rates of At 362 and At 307 during both *Maha* 2019/20 and *Maha* 2020/21. Two seeding rates 100 and 200 kg ha^{-1} of variety At 362 have given significantly high grain yield of over 150 kg ha^{-1} during *Maha* 2019/20. However, it was relatively different during *Maha* 2020/21 and there had been no grain yield improvement for raised seed rates more than the recommended seed rate of 100 kg ha^{-1} (Figure 3C). Variety at 307 performed in a similar pattern during both *Maha* seasons in RRS, Ambalantota. Experimental results of the grain yield were confirmed by Angassa, (2017) who found that a significant grain yield was obtained under seed broadcasting rate 100 kg ha^{-1} than 75 and 125 kg ha^{-1} which is completely in agreement with the results of this study.

Deviations of grain yield in farmer fields Bolana and Mamadala established with two different seed rates were illustrated in figure 4. Figure 4 A shows the variation of grain yield of rice variety At 362 cultivated at the Bolana farmer field in *Maha* 2019/20 where at the rate of 100 kg ha^{-1} and 150 kg ha^{-1} received 7.45 and 6.97 t/ha respectively which yield levels were significant ($0.05 > p$). Thereby, a 100 kg ha^{-1} seed broadcasting rate could be considered as the best level for rice cultivation in the Bolana. However, in Mamadala farmer fields cultivated with rice variety At 362 did not give significant grain yield under two different seed rates (100 and 150 kg ha^{-1}). The yield levels for 100 and 150 kg ha^{-1} seed rates were 5.84 and 6.01 t/ha, respectively in *Maha* 2019/20 (Figure 4B). Having evidence on high recorded grain yields in research fields and farmer fields during *Maha* 2019/20 seed rate of 100 kg ha^{-1} could be used as the best rate for broadcasting of variety At 362.

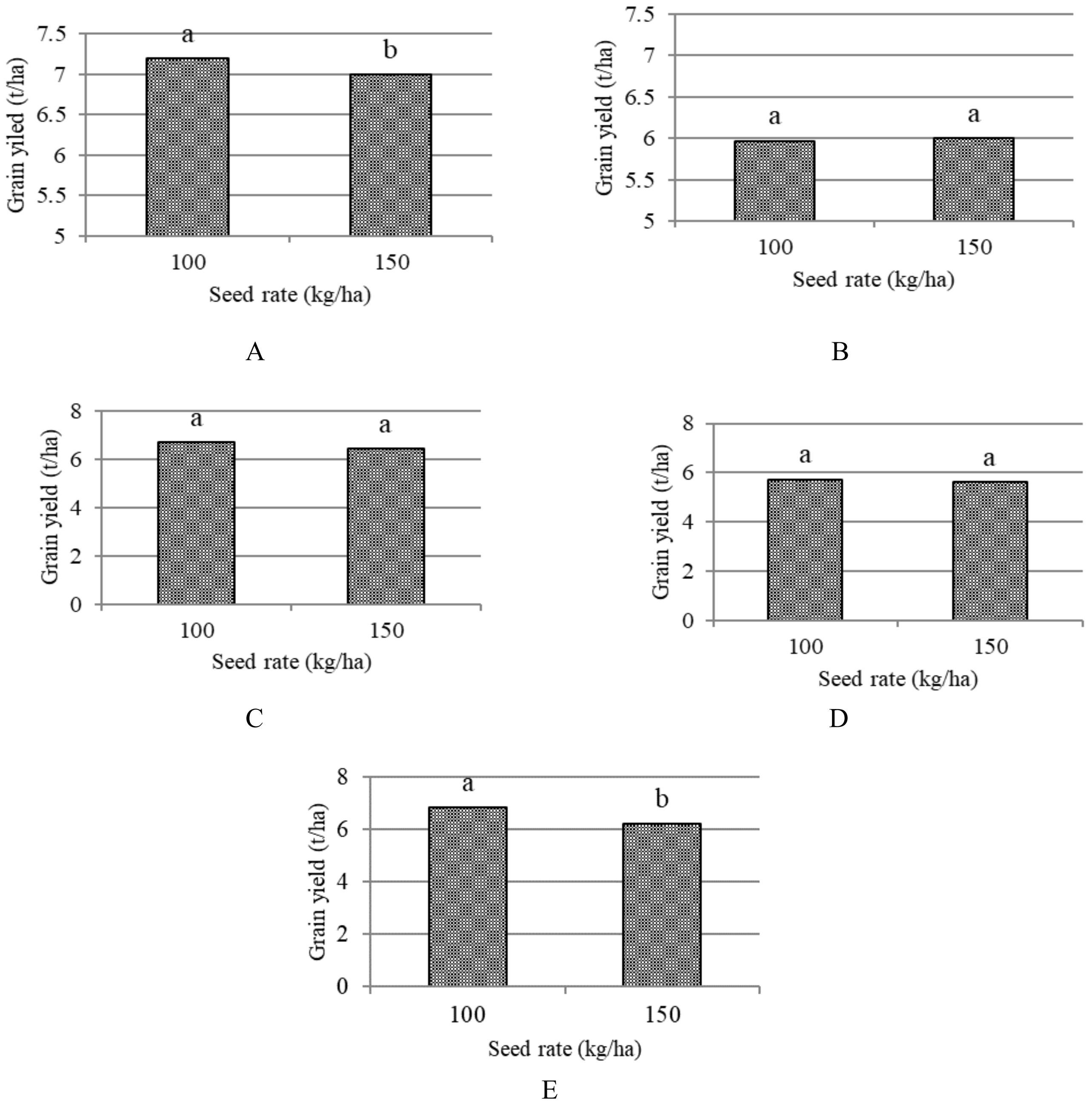

Figure 4: Grain yield of rice variety At 362 with two different seed broadcasting rates at farmer filed (A – Bolana, B – Mamadala) in *Maha* 2019/20 and (C - Beragama, D – Koggalla, E – Mamadala) in *Maha* 2020/21)

Deviations of grain yield in farmer fields Bolana and Mamadala established with two different seed rates were illustrated in figure 4. Figure 4 A shows the variation of grain yield of rice variety At 362 cultivated at the Bolana farmer field in *Maha* 2019/20 where at the rate of 100 kg ha^{-1} and 150 kg ha^{-1} received 7.45 and 6.97 t/ha respectively which yield levels were significant (0.05 > p). Thereby, a 100 kg ha^{-1} seed broadcasting rate could be considered as the best level for rice cultivation in the Bolana. However, in Mamadala farmer fields cultivated with rice variety At 362 did not give significant grain yield under two different seed rates (100 and 150 kg ha^{-1}). The yield levels for 100 and 150 kg ha^{-1} seed rates were 5.84 and 6.01 t/ha, respectively in *Maha* 2019/20 (Figure 4 B). Having evidence on high recorded grain yields in research fields and farmer fields during *Maha* 2019/20 seed rate of 100 kg ha^{-1} could be used as the best rate for broadcasting of variety At 362.

Figure 4 C, D and E indicate the grain yield variation of rice variety At 362 cultivated in the Beragama, Koggalla and Mamadala in *Maha* 2020/21, respectively. None of the Beragama or Koggalla farmer fields provide yield advantage for raised seed rates where the recorded average yields in both farmer fields were 6.7 and 5.7 kg ha^{-1}, respectively. Dissimilar yield responses were observed at the Mamadala farmer field during *Maha* 2020/21 on different seed rates. Significantly different yields of 6.82 and 6.22 t/ha were recorded in the plots done with 100 and 150 kg ha^{-1} seed broadcasting rates. The seed broadcasting rate of 100 kg ha^{-1} was repeatedly recorded as the best seed rate under farmer managed conditions. Similar results were observed by Ilangakoon *et al.* (2020) where three ultra-short age rice varieties namely Bg 250, Bg 251 and Ld 253 were cultivated under the three different seeding rates as 100, 125 and 150 kg ha^{-1} and yield response under different seeding rates was not significant. Therefore, if there is no yield advantage with higher seed rates, the lowest seed broadcasting rate which offers realistic yield would be the best for cost effective rice production.

Table: 5 Sheath Blight infected plant count (No. / m^2) of variety At 362 and At 307 with different seeds broadcasting rates

Seed rate (kg/ha) (At 362)	Number of infected plants (No. / m^2) / At 362	Seed rate (kg/ha) (At 307)	Number of infected plants (No. / m^2) / At 307
100	Not detected	75	30^c
150	Not detected	112.5	100^b
200	Not detected	150	165^a

Note: Note: In each column mean values with the same letters (at least) are not significantly different (α = 0.05) in LSD

Although there were no incidences of pest infestations in the experimental plots in any of the tested seasons, variety At 307 was infected by sheath blight during *Maha* 2020/21 (Table 5). The severity of the infestations was significantly high with elevated seed rates where the highest occurrences were recorded in the plots seed broadcasted with 150 kg ha^{-1}. In dense rice cultivation Sheath blight, caused by *Rhizoctonia solani*, will be crucial because no varieties found with resistance worldwide (Wu *et al*. 2014) and Tan *et al*. 2007 have found a 40 % yield reduction with the highest inoculum density. High seed rate resulting in dense crop might have influenced the yield reduction in each seeded rate in this experiment. According to IRRI, (2022) the grain yield could be reduced due the sheath blight infections. However, as stated in table 5 no such incidences were detected in variety At 362 in any of the broadcast seed rates.

According to table 6, high income losses were found with increasing seed broadcasting rates. On the other hand, raised seed broadcasting rates have not produced significant yield advantages either. Rice variety At 362 grown at the elevated seed broadcasting rate of 200 kg ha^{-1} in *Maha* season 2019/20 has nearly doubled the income loss from 1.81 to 3.67% (table 6). Related results in income loss were observed during *Maha* season 2020/21 where the loss at 200 kg ha^{-1} was almost double compared to 100 kg ha^{-1}. Rice variety At 307 also trended losing income similarly during both seasons with raised seeded rates. Dongarwar *et al*. (2018) observed similar income losses with the high rice seed broadcasting rates of Maharashtra in India. Therefore, if there is no yield advantage with higher seed rates, the lowest seed rate which offers the realistic yield would be the best for cost effective rice production while having lowest risk of prone to pest or disease epidemics.

Table 6: Cost and income losses of with different seed broad casting rates in *Maha* 2019/20

Variety	Seed rate (kg ha^{-1})	Cost for seed paddy (Rs./ha)	Yield production (t/ha)	Income level (Rs./ha)	Income loss (%)	Income loss as ratio
2019/20 *Maha* Season						
At 362	100	9,000.00	5.50	495,000.00	1.81	1.00
At 362	150	13,500.00	5.00	450,000.00	3.00	1.65
At 362	200	18,000.00	5.45	490,500.00	3.67	2.02
At 307	75	7,500.00	5.00	500,000.00	1.50	1.20
At 307	112.5	11,250.00	4.79	479,000.00	2.34	1.56
At 307	150	150,00.00	4.82	482,000.00	3.11	1.64
2020/21 *Maha* Season						
At 362	100	13,500.00	8.00	1,080,000.00	1.25	1.00
At 362	150	20,250.00	7.51	1,013,850.00	2.00	1.60
At 362	200	27,000.00	7.47	1,008,450.00	2.70	2.16
At 307	75	10,650.00	4.12	585,040.00	1.82	1.00
At 307	112.5	15,975.00	3.92	556,640.00	2.87	1.58
At 307	150	16,875.00	9.95	560,900.00	3.00	1.64

Note: Cost and Income calculated by Sri Lankan rupees (2019/20 *Maha* At 362 seed paddy price Rs. 90 / 1 kg, At 307 Rs. 75 / 1 kg 2020/19 *Maha* At 362 seed paddy price Rs. 135 / 1 kg, At 307 Rs. 142 / 1 kg)

CONCLUSIONS

It can be concluded that increasing of seed rate does not have any positive impact on growth or yield of either long grain (At 362) or intermediate grain (At 307) rice varieties grown under irrigated conditions. Though relatively low weed density was reported under high seed rate, it has not set any considerable impact on the grain yield of rice. Densely grown rice cultivation might be affected by fungal diseases causing yield losses like sheath blight when the environment is favourable during some seasons. Considering the above results irrespective of the seed size 100 kg ha^{-1} seed broadcasting rate can be recommended as the best seed rate for farmer field cultivation where better weed management practices are adopted. Finally, the results of this experiment have reconfirmed that exceeding the recommended seeding rate of DOA (100 kg ha^{-1}) is not effective to get a higher yield response from paddy under irrigated condition. Additionally, high seeded rate application was recorded the depreciation of farmer income by two times than recommended rate of seed sowing due to extra expenditures for seed paddy. However, further studies are needed to investigate the performance of different seed rates under rain fed conditions of Sri Lanka.

AUTHOR CONTRIBUTION

RFH and KHCHK conceptualized and design the study. RFH, KHCHK and HMSH performed the experiment at Rice Research Station and farmer field experiment was performed by KHCHK, RHUG, THNS, and NTW. KHCHK and RFH analyzed and interpret the data. KHCHK and RFH contributed in drafting the manuscript.

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