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RESEARCH ARTICLE

Sustainable forage-grain ratoon rice production: interactions between planting density and mowing time on forage and grain attributes

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SUPPLEMENTARY MATERIALS

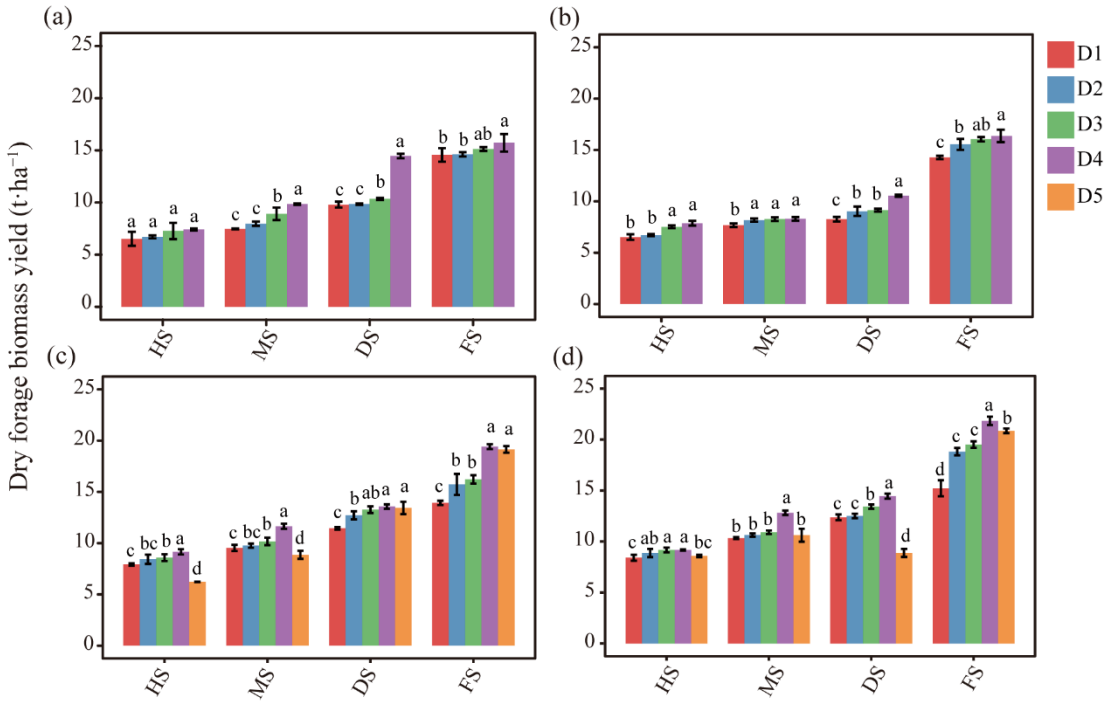

Fig. S1 Dry forage biomass yield of LY6326 and TYXZ under different planting density and mowing time treatments in 2021 and 2022. (a) LY6326 in 2021; (b) TYXZ in 2021; (c) LY6326 in 2022; (d) TYXZ in 2022. HS, Heading stage; MS, Milk-ripening stage; DS, Dry-ripening stage; FS, Full maturity stage. D1, Planting density set to 17.2 × 10^4 hills ha^{-1}; D2, Planting density set to 22.76 × 10^4 hills ha^{-1}; D3, Planting density set to 25.34 × 10^4 hills ha^{-1}; D4, Planting density set to 28.82 × 10^4 hills ha^{-1}; D5, Planting density set to 34.52× 10^4 hills ha^{-1}. Different lowercase letters above the bars indicate significant differences between treatments at the $P < 0.05$ level.

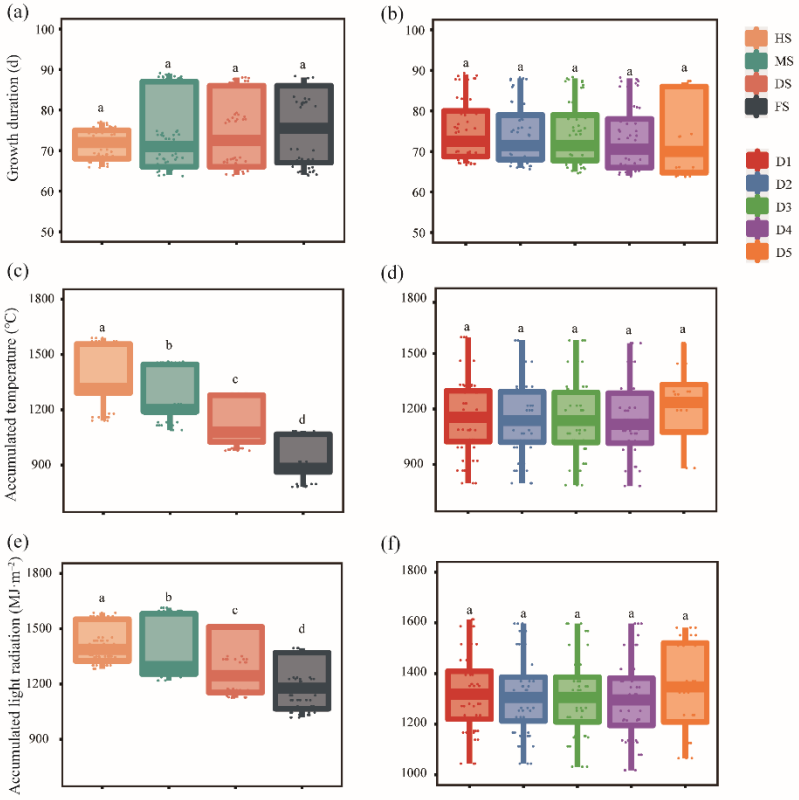

Fig. S2 Growth duration, temperature and light radiation parameters for difference mowing time and planting density treatments. (a) Different mowing time treatments during growth duration of two varieties; (b) different planting density treatments during growth duration of two varieties; (c) different mowing time treatments at accumulated temperature of two varieties; (d) different planting density treatments at accumulated temperature of two varieties; (e) different mowing time treatments at accumulated light radiation of two varieties; (f) different planting density treatments at accumulated light radiation of two varieties. HS, Heading stage; MS, Milk-ripening stage; DS, Dry-ripening stage; FS, Full maturity stage. D1, Planting density set to 17.2×10^4 hills ha^{-1}; D2, Planting density set to 22.76×10^4 hills ha^{-1}; D3, Planting density set to 25.34×10^4 hills ha^{-1}; D4, Planting density set to 28.82×10^4 hills ha^{-1}; D5, Planting density set to 34.52×10^4 hills ha^{-1}. Different lowercase letters in the box within each panel indicate significant differences between treatments at the $P < 0.05$ level.

Table S1 Unit price of various inputs and outputs used to evaluate economic benefits in 2022

Item	Unit	Price (USD)
Inputs		
1. Seed	$kg \cdot ha^{-1}$	6.85
2. Fuel	$L \cdot ha^{-1}$	0.81
3. Machinery	$kg \cdot ha^{-1}$	12.33
4. Electricity	$kWh \cdot ha^{-1}$	0.08
5. Fertilizer	$kg \cdot ha^{-1}$	1.51
6. Pesticides	$kg \cdot ha^{-1}$	488.90
7. Labor	$h \cdot ha^{-1}$	2.05
8. Groundwater	$m^3 \cdot ha^{-1}$	0.09
Outputs		
1. Fresh forage of MC	$kg \cdot ha^{-1}$	0.05
2. Grain of RC	$kg \cdot ha^{-1}$	0.49

Table S2 Comparison of average economic benefits based on different planting densities and mowing times of LY6326 and TYXZ in 2022

Mowing time	Planting density	Seed cost (USD·ha^{-1})	Other cost (USD·ha^{-1})	Fresh forage of MC (USD·ha^{-1})	Grain of RC (USD·ha^{-1})	Economic benefits (USD·ha^{-1})
HS	D1	104.6	2725.65	1571.17	3427.07	2167.99
	D2	138.45	2725.65	1678.37	3740.09	2554.36
	D3	154.13	2725.65	1735.75	3807.96	2663.93
	D4	175.29	2725.65	1796.08	3999.74	2894.88
	D5	209.95	2725.65	1710.43	3235.97	2010.79
MS	D1	104.6	2725.65	1702.54	3756.93	2629.23
	D2	138.45	2725.65	1768.78	3867.29	2771.97
	D3	154.13	2725.65	1783.96	4013.94	2918.13
	D4	175.29	2725.65	1813.63	4173.40	3086.08
	D5	209.95	2725.65	1710.43	3332.47	2107.30
DS	D1	104.6	2725.65	1740.64	2235.01	1145.40
	D2	138.45	2725.65	1823.86	2566.35	1526.11
	D3	154.13	2725.65	1882.32	2761.77	1764.31
	D4	175.29	2725.65	1932.05	3068.07	2099.18
	D5	209.95	2725.65	1789.25	2565.54	1419.19
FS	D1	104.6	2725.65	2019.77	1599.59	789.11
	D2	138.45	2725.65	2091.58	1818.14	1045.62
	D3	154.13	2725.65	2164.21	1869.29	1153.73
	D4	175.29	2725.65	2268.09	2117.06	1484.20
	D5	209.95	2725.65	1824.72	1911.62	800.74

Note: The other cost includes fuel, machinery, electricity, fertilizer, pesticides, labor and groundwater. D1, Planting density set to 17.2 × 10^4 hills ha^{-1}; D2, Planting density set to 22.76 × 10^4 hills ha^{-1}; D3, Planting density set to 25.34 × 10^4 hills ha^{-1}; D4, Planting density set to 28.82 × 10^4 hills ha^{-1}; D5, Planting density set to 34.52× 10^4 hills ha^{-1}. The cost difference caused by the mowing time was negligible.

Table S3 Permutational multivariate analysis of variance analysis based on fresh forage biomass yield

Source	2021		2022	
	pseudo-F	R^2	pseudo-F	R^2
D	30.919**	14.88%	11.2535**	17.05%
M	92.832***	43.92%	10.6788**	16.18%
D × M	1.072	0.52%	0.0799	0.12%
Residuals		40.68%		66.65%

Note: M, Mowing time; D, Planting density. *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S4 Analysis of variance for yield and quality of forage and ratoon rice

Year	Source	NDF	ADF	Crude protein	Starch	Fresh forage biomass yield	Dry forage biomass yield	Ratoon rice yield
2021	V	**	**	**	**	NS	**	NS
	M	**	**	**	**	**	**	**
	D	**	**	**	**	**	**	**
	V × M	**	**	**	**	NS	**	**
	V × D	NS	NS	NS	NS	NS	**	**
	M × D	*	**	*	**	NS	*	NS
	V × M × D	**	NS	NS	NS	NS	**	NS
2022	V	**	**	**	**	NS	**	**
	M	**	**	**	**	**	**	**
	D	**	**	**	**	**	**	**
	V × M	**	**	*	**	**	**	**
	V × D	NS	**	*	**	NS	**	**
	M × D	NS	**	**	**	NS	*	NS
	V × M × D	NS	NS	NS	**	NS	**	**

Note: V, Variety; M, Mowing time; D, Planting density. NS indicates not significant ($P > 0.05$). *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S5 Permutational multivariate analysis of variance analysis based on ratoon rice yield

Source	2021		2022	
	pseudo-F	R^2	pseudo-F	R^2
D	69.163***	28.25%	45.123***	7.93%
M	89.838***	36.69%	90.783***	15.95%
E	41.964***	17.14%	138.955***	24.42%
D × M	0.817	0.33%	2.369	0.42%
D × E	3.657	1.49%	3.538	0.62%
M × E	0.255	0.10%	208.243**	36.87%
D × M × E	0.174	0.07%	30.054**	6.77%
Residuals		15.93%		7.02%

Note: M, Mowing time; D, Planting density; E, Env including accumulated temperature and light radiation. *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S6 Yield-related traits of ratoon rice under different planting density and mowing time treatment in 2021–2022

Year	Mowing time	Density	LY6326				TYXZ			
			Panicles (10^4 ha^{-1})	Spikelets panicle^{-1}	Seed-setting rate (%)	1000-grain weight (g)	Panicles (10^4 ha^{-1})	Spikelets panicle^{-1}	Seed-setting rate (%)	1000-grain weight (g)
2021	HS	D1	369.45a	76.60a	80.25b	26.34a	400.65b	80.82a	80.58d	29.19a
		D2	404.10a	75.66ab	84.44ab	27.97ab	409.95b	78.79b	85.68c	28.32a
		D3	419.25a	75.88ab	84.97ab	28.85b	428.40ab	76.38b	86.63b	27.86a
		D4	445.05a	73.55b	86.99a	29.38a	446.85a	75.17c	88.34a	27.80b
		average	**409.46B**	**75.42A**	**84.16B**	**28.14A**	**405.94AB**	**75.22A**	**81.17A**	**27.87B**
	MS	D1	426.30c	74.55a	87.46b	29.36a	414.30b	78.43a	84.50b	28.60a
		D2	454.20b	72.50ab	87.62b	29.54a	433.95a	76.77ab	85.39b	29.44a
		D3	471.45a	72.41ab	89.10ab	28.53a	452.55a	74.96b	89.04ab	29.63a
		D4	481.80a	71.59b	91.27a	28.72a	467.70a	73.66c	90.48a	28.54a
		average	**458.44A**	**72.76B**	**88.86A**	**29.04A**	**442.13A**	**75.96A**	**87.35A**	**29.05A**
	DS	D1	328.05b	72.60a	79.51a	28.28ab	345.30c	75.41a	77.84d	28.02a
		D2	352.35b	71.11ab	80.50a	27.85ab	379.95c	72.31ab	78.09c	28.09a
		D3	369.75ab	70.14ab	81.03a	28.06a	402.00b	70.76ab	79.47b	27.65a
		D4	389.55a	69.26b	81.79a	27.72b	419.40a	69.95b	81.88a	28.09a
		average	**359.93C**	**70.78B**	**80.71B**	**27.98A**	**386.66B**	**72.11B**	**79.32B**	**27.96B**
	FS	D1	294.45b	68.71a	63.28d	27.90a	292.20b	70.95a	76.99b	27.56a
		D2	300.15ab	67.79ab	64.31c	27.34b	300.45ab	68.58b	77.94b	27.71a
		D3	310.95ab	67.13ab	67.18b	28.29ab	327.00ab	66.95b	78.83b	27.92a
		D4	339.90a	65.01b	72.39a	28.34a	346.05a	64.54c	79.44a	28.08a
		average	**311.36D**	**67.16C**	**66.79C**	**27.97A**	**316.43C**	**67.76C**	**78.30B**	**27.82B**
2022	HS	D1	439.80c	85.58a	78.86a	26.57a	437.70d	75.05a	76.04c	27.11a
		D2	447.60c	84.61ab	79.19a	26.48a	455.40c	73.34ab	76.92c	27.08a
		D3	449.25c	83.74bc	80.79a	27.31a	472.80b	73.05ab	78.50b	27.05a
		D4	468.00b	82.99c	82.70a	26.78a	484.95a	71.67b	81.10d	27.07a
		D5	485.70a	81.05c	78.55a	26.46a	486.90a	70.73c	74.58a	27.32a
		average	**458.07B**	**83.59B**	**80.02A**	**26.72B**	**467.55A**	**72.77A**	**77.43A**	**27.13A**
	MS	D1	480.90e	91.38a	78.81a	26.74b	452.10c	69.04a	75.90b	25.80b
		D2	512.25c	91.02ab	79.72a	27.24ab	464.40c	67.43b	76.04b	26.36ab
		D3	529.80d	88.71ab	80.31a	26.76b	479.85b	66.39b	76.22b	26.66a
		D4	531.75b	86.91ab	84.06a	27.58ab	487.50a	64.44c	78.06a	26.17ab
		D5	567.45a	86.83b	81.75a	28.05a	503.70a	64.02c	74.22c	26.81a
		average	**524.43A**	**88.97A**	**80.93A**	**27.27A**	**477.51A**	**66.26B**	**76.09A**	**26.36B**
	DS	D1	354.15d	75.04a	70.55ab	27.28a	349.20d	67.60a	71.37c	27.48a
		D2	361.65d	75.01a	71.82ab	27.33a	360.75c	65.97b	72.28b	27.55a
		D3	385.20c	73.59b	73.49a	26.99a	369.00b	65.69b	73.40b	27.44a
		D4	414.90b	73.46b	75.54a	27.33a	376.35ab	64.03c	75.28a	26.95a
		D5	441.30a	72.91b	69.78b	27.41a	383.25a	63.67c	72.61b	27.35a
		average	**391.44C**	**74.00C**	**72.24B**	**27.27A**	**367.71B**	**65.39B**	**72.99B**	**27.35A**
	FS	D1	311.55d	68.13a	63.40a	26.12a	329.70c	58.41a	66.01b	25.98ab
		D2	334.20c	66.91a	65.70a	26.21a	333.60b	56.38b	66.53b	25.73ab
		D3	344.85c	64.93b	65.95a	26.38a	338.70b	56.81b	67.71ab	25.28b
		D4	359.85b	63.19b	65.99a	26.07a	346.60b	54.72c	69.21a	25.56ab
		D5	368.85a	61.60c	62.12a	26.04a	355.05a	53.64d	65.09c	26.50a
		average	**343.86D**	**64.95D**	**64.63C**	**26.16C**	**340.73C**	**55.99C**	**66.91C**	**25.81C**

Note: HS, Heading stage; MS, Milk-ripening stage; DS, Dry-ripening stage; FS, Full maturity stage. D1, Planting density set to 17.2×10^4 hills ha^{-1}; D2, Planting density set to 22.76×10^4 hills ha^{-1}; D3, Planting density set to 25.34×10^4 hills ha^{-1}; D4, Planting density set to 28.82×10^4 hills·ha^{-1}; D5, Planting density set to 34.52×10^4 hills ha^{-1}. Different uppercase letters indicate significant differences among mowing time treatments within the same year at the $P < 0.05$ level. Different lowercase letters indicate significant differences among planting density treatments under the same mowing time within the same year at the $P < 0.05$ level.

Table S7 Analysis of variances for yield-related traits of ratoon rice in 2021 and 2022

Year	Source	1000-Grain weight	Grain filling	Spikelets per panicles	Panicles
2021	V	NS	NS	NS	NS
	M	*	**	**	**
	D	NS	*	*	**
	V × M	NS	**	**	**
	V × D	NS	NS	NS	NS
	M × D	NS	*	**	**
	V × M × D	NS	NS	NS	NS
2022	V	NS	NS	NS	*
	M	*	**	**	**
	D	NS	**	**	**
	V × M	NS	*	*	**
	V × D	NS	NS	NS	NS
	M × D	NS	**	**	**
	V × M × D	NS	NS	NS	NS

Note: V, Variety; M, Mowing time; D, Planting density. NS indicates not significant ($P > 0.05$). *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S8 Forage quality of silage rice under different plant density and mowing time treatments in 2021 and 2022

Year	Mowing time	Density	LY6326				TYXZ			
			NDF (%)	ADF (%)	Crude protein (%)	Starch (%)	NDF (%)	ADF (%)	Crude protein (%)	Starch (%)
2021	HS	D1	58.43a	52.24a	11.20a	11.23a	58.76a	53.05a	11.36a	12.38a
		D2	57.97b	51.22a	11.14a	10.35a	57.63a	52.22ab	11.00ab	11.28ab
		D3	57.44b	51.05a	10.89ab	9.96a	56.11a	52.05ab	10.40b	10.56ab
		D4	56.96b	50.89a	10.31b	9.48a	55.25a	51.22b	10.13b	9.71b
		average	**57.70A**	**51.35A**	**10.89A**	**10.26D**	**56.94A**	**52.14A**	**10.72A**	**10.98C**
	MS	D1	57.26a	50.07a	8.43a	27.11a	56.55a	49.79a	10.72a	32.10a
		D2	57.13ab	49.72a	10.17a	25.60ab	55.10a	49.02ab	10.34a	29.10b
		D3	56.19bc	48.77a	9.70a	23.90bc	54.93a	48.87ab	10.08a	26.35c
		D4	55.39c	49.52a	9.22a	21.85c	54.75a	48.29b	9.66a	24.31c
		average	**56.49A**	**49.52A**	**9.38B**	**24.62C**	**55.33A**	**48.99B**	**10.20A**	**27.97B**
	DS	D1	54.30a	48.33a	7.46a	37.35a	50.83a	47.51a	9.40a	37.35a
		D2	54.10ab	47.17a	7.21b	35.85a	50.06a	46.86ab	8.95b	35.85a
		D3	53.95b	41.68a	8.91b	31.73b	49.80a	46.65ab	8.90b	31.73b
		D4	46.89c	40.99b	8.83b	29.23c	49.49a	45.96b	8.19b	29.23c
		average	**52.31B**	**44.54B**	**8.10C**	**33.54B**	**50.05B**	**46.75C**	**8.86B**	**33.54A**
	FS	D1	48.87a	37.99a	7.79a	45.01a	43.14a	40.79a	7.97a	43.98a
		D2	47.94a	40.99ab	7.61a	42.98a	41.04ab	40.05a	7.84a	40.35b
		D3	46.51b	38.91b	7.46a	38.48b	40.090b	38.34b	7.68a	36.98c
		D4	46.09b	37.99b	7.79a	34.25c	38.42b	36.31c	7.62a	33.54d
		average	**47.35C**	**38.97C**	**7.66C**	**40.18A**	**40.67C**	**38.87D**	**7.78C**	**38.71A**
2022	HS	D1	58.67a	53.12a	11.21a	13.85a	59.00a	52.48a	11.30a	14.01a
		D2	57.50ab	52.04ab	11.19a	12.94a	55.52ab	51.79ab	11.22a	13.52a
		D3	56.97abc	51.52ab	11.17a	11.86ab	54.62ab	50.88ab	10.92a	12.30ab
		D4	55.74bc	50.55ab	11.04a	10.71b	53.05ab	50.52ab	10.76a	11.15b
		D5	54.96c	49.92b	10.81a	10.03b	50.66b	50.09b	10.71a	10.50b
		average	**56.77A**	**51.43A**	**11.08A**	**11.88C**	**54.57A**	**51.15A**	**10.98A**	**12.30D**
	MS	D1	56.21a	51.91a	10.90a	27.39a	52.84a	50.74a	10.02a	28.68a
		D2	55.59a	50.72ab	10.54ab	24.68b	51.51a	48.82ab	10.21a	26.28b
		D3	54.79ab	49.85abc	10.40b	20.96c	51.51a	47.69b	10.27a	24.56b
		D4	53.86ab	48.83bc	10.28b	18.25d	50.86a	47.91b	10.56a	20.61c
		D5	52.83b	47.77c	9.73c	16.64d	49.72a	46.87b	9.35b	19.38c
		average	**54.66A**	**49.82AB**	**10.37B**	**21.58C**	**51.29B**	**48.41B**	**10.08B**	**23.90C**
	DS	D1	53.70a	50.11a	10.13a	38.20a	50.52a	45.63a	10.08a	39.50a
		D2	52.94ab	48.35a	10.08a	35.35b	49.17a	45.54a	9.96a	35.65b
		D3	51.77ab	47.52a	9.90a	32.45c	48.38a	42.96b	10.13a	32.61c
		D4	50.62bc	46.33a	9.82b	24.71d	48.30a	44.86ab	9.90a	28.46d
		D5	49.22c	45.51a	9.44b	21.61e	46.80a	43.98ab	8.83b	22.08e
		average	**51.65B**	**47.56B**	**9.87C**	**30.46B**	**48.63B**	**44.59C**	**9.78B**	**31.66B**
	FS	D1	48.81a	45.28a	9.54a	45.01a	47.57a	42.44a	9.33a	48.01a
		D2	47.24ab	43.01ab	9.49a	38.74b	47.31a	40.49ab	9.26b	44.54b
		D3	45.94ab	41.54bc	9.41a	35.79c	46.64a	39.72b	9.09b	40.51c
		D4	44.85bc	39.24cd	9.29a	31.53d	44.59a	38.67b	8.88b	35.25d
		D5	43.23c	36.65d	9.18a	27.96e	42.49a	36.61c	8.64b	27.34e
		average	**46.01C**	**41.14C**	**9.38D**	**35.81A**	**45.72C**	**39.59D**	**9.04C**	**39.13A**

Note: ADF, Acid detergent fiber; NDF, Neutral detergent fiber. Different uppercase letters indicate significant differences among mowing time treatments within the same year ($P < 0.05$). Different lowercase letters indicate significant differences among planting density treatments under the same mowing time within the same year ($P < 0.05$).

Table S9 Permutational multivariate analysis of variance analysis based on fresh forage quality.

Source	2021		2022	
	pseudo-F	R^2	pseudo-F	R^2
D	3.9106*	1.88%	1.8867	1.27%
M	10.7039**	6.92%	5.7214*	3.85%
D × M	0.0319	0.02%	0.1016	0.07%
Residuals		91.18%		94.81%

Note: M, Mowing time; D, Planting density. *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S10 Quality of ratoon rice under different planting density and mowing time treatments in 2021 and 2022

Year	Mowing time	Density	LY6326							TYXZ						
			Brown rice rate (%)	Milled rice Rate (%)	Head rice rate (%)	Chalkiness (%)	Chalkiness degree	Protein content (%)	Amylose content (%)	Brown rice rate (%)	Milled rice Rate (%)	Head rice rate (%)	Chalkiness (%)	Chalkiness degree	Protein content (%)	Amylose content (%)
2021	HS	D1	80.39a	70.58a	61.12a	5.60b	0.80d	6.65a	10.52a	78.58a	67.92a	57.34a	0.53b	0.19a	6.82a	9.79d
		D2	80.01b	69.91b	59.31b	5.97ab	1.20c	6.36a	10.01a	77.45b	67.48b	56.42ab	0.70b	0.20a	6.72a	10.32c
		D3	79.76b	68.57b	57.88c	6.40a	1.60b	6.21ab	9.23b	76.48c	67.41b	54.35c	0.93b	0.23a	6.63a	10.97b
		D4	79.68b	68.23b	57.78c	6.53a	1.93a	6.16b	8.50c	76.29c	67.28b	53.95d	1.57a	0.30a	6.38a	11.72a
		average	**79.96A**	**69.32AB**	**59.02A**	**6.13B**	**1.38B**	**6.35C**	**9.57C**	**77.20AB**	**67.52A**	**55.52A**	**0.93B**	**0.23C**	**6.64C**	**10.70B**
	MS	D1	80.08a	71.97a	63.97a	2.80d	0.53c	7.56a	10.66a	79.36a	68.82a	58.95a	0.50b	0.10a	7.82a	12.93a
		D2	79.99ab	70.64b	61.83b	3.40c	1.10bc	7.43a	10.10ab	78.05b	67.53b	58.78ab	0.63b	0.13a	7.80a	11.58b
		D3	79.81bc	69.73c	61.41b	4.53b	1.17b	7.24ab	9.93b	77.74c	67.48b	57.16b	0.73b	0.17a	7.78a	11.16b
		D4	79.76c	68.41d	61.09b	5.30a	1.37a	6.97b	8.67c	77.60c	67.41b	55.86c	1.33a	0.27a	7.28a	10.38c
		average	**79.91A**	**70.19A**	**62.08A**	**4.01C**	**1.04B**	**7.30B**	**9.84C**	**78.19A**	**67.81A**	**57.69A**	**0.80B**	**0.17C**	**7.67B**	**11.51B**
	DS	D1	78.04a	69.36a	45.69a	7.40b	1.63c	7.23a	12.59a	77.54a	67.03a	47.27a	0.67b	0.30b	7.25a	15.34a
		D2	77.80ab	68.39b	43.86b	7.45b	2.40b	7.15a	11.95b	76.82b	65.94b	46.75b	0.77b	0.33b	7.23ab	13.82b
		D3	77.16bc	67.74c	40.80c	7.77b	2.80b	6.88ab	11.53b	76.32b	65.63b	46.11b	1.20ab	0.38b	7.02b	13.18c
		D4	76.72c	66.39d	39.18d	9.53a	3.17a	6.58b	10.10c	75.66c	64.80c	45.63c	1.77a	0.47a	6.92b	12.11d
		average	**77.43B**	**67.97B**	**42.38B**	**8.04A**	**2.50A**	**6.96B**	**11.54B**	**76.59B**	**65.85B**	**46.44B**	**1.10B**	**0.37B**	**7.11C**	**13.61A**
	FS	D1	76.89a	64.78a	35.49a	7.57c	2.13c	9.61a	14.75a	75.42a	62.73a	32.33a	1.47b	0.50b	9.24a	15.25a
		D2	75.76b	64.37ab	30.70b	8.57bc	2.53bc	9.35a	13.82b	75.14ab	61.48b	30.98b	1.60b	0.55b	9.10a	14.88ab
		D3	75.58bc	63.20b	28.71c	9.77b	2.93ab	8.74b	13.26b	74.27b	61.38b	26.04c	2.87a	0.63a	8.38a	14.53b
		D4	75.47c	61.98b	28.48c	11.13a	3.40a	8.64b	12.42c	73.74c	60.24c	25.70d	2.00ab	0.73a	8.16a	13.35c
		average	**75.93C**	**63.58C**	**30.85C**	**9.26A**	**2.75A**	**9.09A**	**13.56A**	**74.64C**	**61.46C**	**28.76C**	**1.99A**	**0.60A**	**8.72A**	**14.50A**
2022	HS	D1	80.52a	71.35a	59.13a	3.37c	0.63c	7.03a	9.67a	79.45a	71.00a	49.94a	0.93a	0.10b	6.95a	10.57a
		D2	80.10b	71.32a	57.07ab	3.83b	0.67bc	7.01a	9.33bc	79.12a	70.77a	47.55ab	0.97a	0.17ab	6.75b	10.14b

	D3	80.03b	70.74b	52.45ab	3.90ab	0.70bc	6.73b	9.15bc	78.78b	70.41ab	47.52ab	1.04a	0.23ab	6.54c	10.05b
	D4	79.85bc	70.67b	51.25ab	4.07ab	0.80b	6.62ab	9.08cd	77.84b	70.28ab	46.70ab	1.37a	0.27ab	6.34d	9.73c
	D5	79.71c	70.48b	51.98b	4.37a	0.97a	6.38c	8.92d	77.39c	69.66b	43.64b	1.73a	0.29a	6.12e	9.43d
	average	**80.04A**	**70.91A**	**54.38A**	**3.91C**	**0.75C**	**6.75C**	**9.23C**	**78.52A**	**70.42A**	**47.07B**	**1.21C**	**0.21BC**	**6.54C**	**9.98C**
MS	D1	80.63a	71.72a	61.86a	2.43b	0.50b	7.78a	10.09a	80.05a	71.43a	58.38a	0.83a	0.07b	7.66a	10.93a
	D2	80.24b	71.66ab	59.13ab	2.50ab	0.57b	7.48ab	9.96b	79.66b	71.28a	54.14ab	0.89a	0.13ab	7.40b	10.69b
	D3	80.16b	71.31b	57.97ab	2.80ab	0.62ab	7.28b	9.47c	79.54b	71.09ab	51.18bc	0.93a	0.20ab	7.09c	10.41c
	D4	80.13b	71.12c	56.12ab	3.03ab	0.67ab	7.20c	9.33d	79.06c	70.67b	50.38bc	0.97a	0.23ab	6.82d	10.31c
	D5	80.0bc	70.72d	53.05b	3.07a	0.70a	7.08c	9.08e	77.54d	70.40b	47.32c	1.47a	0.26a	6.56e	10.22c
	average	**80.24A**	**71.31A**	**57.63A**	**2.77D**	**0.61C**	**7.36B**	**9.59BC**	**79.17A**	**70.97A**	**52.28A**	**1.02C**	**0.18C**	**7.11C**	**10.51C**
DS	D1	78.94a	68.30a	47.36a	7.97c	4.53c	7.99a	10.86a	79.15a	68.84a	46.68a	1.23b	0.32b	7.78a	12.97a
	D2	78.54b	68.18a	46.28b	8.17c	4.60bc	7.77b	10.67a	78.19b	68.01b	45.29ab	1.47ab	0.37ab	7.47ab	12.68b
	D3	78.33b	67.81b	43.05c	8.47bc	4.80bc	7.69b	10.43b	78.06b	67.96b	44.30ab	1.70ab	0.43ab	7.23b	12.49c
	D4	78.07c	67.56b	41.46d	8.77ab	5.17ab	7.53c	9.75c	77.81bc	67.72b	41.60ab	2.23a	0.47ab	6.97c	12.20d
	D5	77.89c	66.54c	40.07e	9.13a	5.60a	7.37d	9.48d	77.30c	67.03c	40.92b	2.00ab	0.53a	6.93c	11.96e
	average	**78.35B**	**67.68B**	**43.64B**	**8.50B**	**4.94B**	**7.67B**	**10.24B**	**78.10A**	**67.91B**	**43.76B**	**1.73B**	**0.42B**	**7.28B**	**12.46B**
FS	D1	78.30a	67.89a	38.49a	8.92c	6.43c	9.38a	13.08a	77.41a	67.67a	39.89a	3.73ab	0.53b	9.86a	14.76a
	D2	78.11b	67.52b	36.19b	9.12c	6.53c	9.23a	12.78a	77.08ab	67.20b	38.70b	4.03a	0.63ab	9.30a	14.45b
	D3	77.78c	67.12b	35.06c	9.43bc	7.43b	8.81b	12.42b	76.68ab	66.35c	37.82c	4.13a	0.73ab	8.77b	14.15c
	D4	77.74c	66.81c	34.52d	9.77b	7.53ab	8.44c	12.18b	76.18ab	66.02c	37.55c	4.73a	0.83ab	8.47b	13.11d
	D5	76.55d	66.47d	33.23e	10.70a	7.77a	8.11d	11.22c	76.14b	65.03d	37.21c	4.80a	1.07a	8.07b	12.96e
	average	**77.70C**	**67.16B**	**35.50C**	**9.59A**	**7.14A**	**8.79A**	**12.34A**	**76.70B**	**66.45C**	**38.23C**	**4.28A**	**0.76A**	**8.89A**	**13.89A**

Note: Different uppercase letters indicate significant differences among mowing time treatments within the same year ($P < 0.05$). Different lowercase letters indicate significant differences among planting density treatments under the same mowing time within the same year ($P < 0.05$).

Table S11 Analysis of variances for processing quality, appearance quality, protein content and amylose content of ratoon rice

Year	Source	Brown Rice Percentage (%)	Milled rice Percentage (%)	Head rice Percentage (%)	Chalkiness (%)	Chalkiness degree	Protein content (%)	Amylose content (%)
2021	V	**	**	**	**	**	**	**
	M	**	**	**	**	**	**	**
	D	**	**	**	**	NS	**	**
	V × M	**	**	**	**	**	NS	**
	V × D	NS	**	**	**	NS	NS	
	M × D	**	NS	**	*	NS	NS	*
	V × M × D	*	NS	**	*	NS	NS	*
2022	V	**	**	NS	**	**	**	**
	M	**	**	**	**	**	**	**
	D	**	**	**	**	**	**	**
	V × M	NS	**	**	**	**	**	**
	V × D	NS	NS	NS	**	NS	**	**
	M × D	NS	NS	NS	**	**	**	**
	V × M × D	NS	NS	NS	NS	NS	**	**

Note: V, Variety; M, Mowing time; D, Planting density. NS indicates not significant ($P > 0.05$). *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S12 Permutational multivariate analysis of variance analysis based on ratoon rice quality

Source	2021		2022	
	pseudo-F	R^2	pseudo-F	R^2
D	40.52***	3.66%	12.550***	3.93%
M	362.78***	38.95%	34.037***	10.67%
E	229.76***	20.77%	119.821***	37.56%
D × M	13.47***	1.22%	0.636	0.19%
D × E	3.30	0.29%	2.301	0.72%
M × E	21.13	1.91%	14.083***	4.41%
D × M × E	3.68	0.33%	0.107	0.03%
Residuals		32.87%		42.49%

Note: M, Mowing time; D, Planting density; E, Env including accumulated temperature and light radiation. *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively.

Table S13 Growth dates, temperature and light resources, and ratoon ability under different mowing time and planting density treatments from 2021 to 2022

Year	Variety	Mowing time	Density	MT	HT	MT-HT (d)	Accumulated light radiation ($MJ \cdot m^{-2}$)	Accumulated temperature (℃)	Ratoon ability
2021	TYXZ	HS	D1	15-Jul	23-Sep	70	1318.07	1179.28	-
			D2	15-Jul	22-Sep	69	1301.24	1159.94	-
			D3	15-Jul	22-Sep	69	1301.24	1159.94	-
			D4	15-Jul	21-Sep	68	1282.52	1141.61	-
		average				69	1300.77	1160.19	
		MS	D1	24-Jul	1-Oct	69	1271.43	1132.61	-
			D2	24-Jul	30-Sep	68	1253.67	1115.83	-
			D3	24-Jul	30-Sep	68	1253.67	1115.83	-
			D4	24-Jul	28-Sep	66	1218.73	1090.06	-
		average				68	1249.38	1113.58	
		DS	D1	5-Aug	12-Oct	68	1166.83	991.28	-
			D2	5-Aug	12-Oct	68	1166.83	991.28	-
			D3	5-Aug	11-Oct	67	1147.83	983.89	-
			D4	5-Aug	10-Oct	66	1128.21	978.39	-
		average				67	1152.43	986.21	
		FS	D1	20-Aug	26-Oct	67	1044.47	796.89	-
			D2	20-Aug	26-Oct	67	1044.47	796.89	-
			D3	20-Aug	24-Oct	65	1032.00	786.28	-
			D4	20-Aug	23-Oct	64	1018.48	782.17	-
		average				66	1034.86	790.56	
	LY6326	HS	D1	15-Jul	2-Oct	77	1452.56	1326.06	-
			D2	15-Jul	1-Oct	76	1435.17	1308.00	-
			D3	15-Jul	1-Oct	76	1435.17	1308.00	-
			D4	15-Jul	30-Sep	75	1417.41	1291.22	-
		average				76	1435.08	1308.32	
		MS	D1	24-Jul	7-Oct	75	1318.48	1196.44	-
			D2	24-Jul	6-Oct	74	1310.16	1193.22	-
			D3	24-Jul	6-Oct	74	1310.16	1193.22	-
			D4	24-Jul	5-Oct	73	1309.14	1190.78	-
		average				74	1311.99	1193.42	
		DS	D1	5-Aug	23-Oct	79	1350.96	1033.22	-
			D2	5-Aug	22-Oct	78	1334.47	1029.33	-
			D3	5-Aug	22-Oct	78	1334.47	1029.33	-
			D4	5-Aug	21-Oct	77	1317.63	1026.11	-
		average				78	1334.38	1029.50	
		FS	D1	20-Aug	11-Nov	83	1235.32	865.44	-
			D2	20-Aug	10-Nov	82	1227.53	864.22	-
			D3	20-Aug	10-Nov	82	1227.53	864.22	-
			D4	20-Aug	9-Nov	81	1214.82	862.72	-
		average				82	1226.30	864.15	
2022	TYXZ	HS	D1	12-Jul	21-Sep	69	1358.08	1331.29	1.38b
			D2	12-Jul	20-Sep	68	1349.36	1321.20	1.42b
			D3	12-Jul	20-Sep	68	1349.36	1321.20	1.44b
			D4	12-Jul	19-Sep	67	1345.94	1310.68	1.50a
			D5	12-Jul	18-Sep	66	1325.02	1294.35	1.52a
		average				**68**	**1345.55**	**1315.74**	**1.45A**
		MS	D1	21-Jul	28-Sep	67	1280.46	1230.34	1.23d
			D2	21-Jul	27-Sep	66	1264.22	1218.24	1.28d
			D3	21-Jul	27-Sep	66	1264.22	1218.24	1.37c
			D4	21-Jul	26-Sep	65	1252.56	1206.39	1.51a
			D5	21-Jul	25-Sep	64	1236.34	1193.15	1.45b
		average				**66**	**1259.56**	**1213.27**	**1.37A**
		DS	D1	3-Aug	10-Oct	67	1173.41	1087.75	0.64d
			D2	3-Aug	9-Oct	66	1153.76	1084.70	0.73cd

		D3	3-Aug	9-Oct	66	1153.76	1084.70	0.84bc
		D4	3-Aug	8-Oct	65	1136.47	1081.43	1.07a
		D5	3-Aug	7-Oct	64	1125.85	1076.82	0.93b
	average				**66**	**1148.65**	**1083.08**	**0.84B**
	FS	D1	15-Aug	25-Oct	70	1138.68	918.44	0.62c
		D2	15-Aug	23-Oct	68	1112.69	902.39	0.61c
		D3	15-Aug	23-Oct	68	1112.69	902.39	0.66bc
		D4	15-Aug	21-Oct	66	1079.36	886.02	0.73a
		D5	15-Aug	20-Oct	65	1065.56	878.79	0.68b
	average				**67**	**1101.80**	**897.61**	**0.66C**
LY6326	HS	D1	8-Jul	30-Sep	76	1586.35	1589.61	1.34c
		D2	8-Jul	29-Sep	75	1568.21	1572.09	1.43bc
		D3	8-Jul	29-Sep	75	1568.21	1572.09	1.50ab
		D4	8-Jul	28-Sep	74	1551.40	1557.19	1.61a
		D5	8-Jul	28-Sep	74	1551.40	1557.19	1.43bc
	average				**75**	**1565.11**	**1569.63**	**1.46A**
	MS	D1	17-Jul	17-Oct	89	1613.71	1461.53	1.15c
		D2	17-Jul	16-Oct	88	1597.04	1456.61	1.25bc
		D3	17-Jul	16-Oct	88	1597.04	1456.61	1.34abc
		D4	17-Jul	16-Oct	88	1597.04	1456.61	1.49a
		D5	17-Jul	15-Oct	87	1581.00	1446.30	1.36ab
	average				**88**	**1597.17**	**1455.53**	**1.32A**
	DS	D1	30-Jul	28-Oct	88	1515.92	1288.83	0.83c
		D2	30-Jul	28-Oct	88	1515.92	1288.83	0.93bc
		D3	30-Jul	27-Oct	87	1513.24	1283.67	0.99b
		D4	30-Jul	27-Oct	87	1513.24	1283.67	1.24a
		D5	30-Jul	26-Oct	86	1510.12	1278.88	1.03b
	average				**87**	**1513.69**	**1284.78**	**1.00B**
	FS	D1	12-Aug	10-Nov	88	1394.89	1085.09	0.54a
		D2	12-Aug	8-Nov	86	1369.72	1067.13	0.56a
		D3	12-Aug	8-Nov	86	1369.72	1067.13	0.63a
		D4	12-Aug	8-Nov	86	1369.72	1067.13	0.67a
		D5	12-Aug	8-Nov	86	1369.72	1067.13	0.61a
	average				**86**	**1374.75**	**1070.72**	**0.60C**

Note: MT, Mowing time at MC season; HT, Harvest time at RC season. MT-HT, growth day from the mowing time at MC season to the harvest time at RC season. HS, Heading stage; MS, Milk-ripening stage; DS, Dry-ripening stage; FS, Full maturity stage. D1, Planting density set to 17.2×10^4 hills ha^{-1}; D2, Planting density set to 22.76×10^4 hills ha^{-1}; D3, Planting density set to 25.34×10^4 hills ha^{-1}; D4, Planting density set to 28.82×10^4 hills ha^{-1}; D5, Planting density set to 34.52×10^4 hills ha^{-1}. Different uppercase letters indicate significant differences among mowing time treatments for the same variety within the same year ($P < 0.05$). Different lowercase letters indicate significant differences among planting density treatments under the same mowing time for the same variety within the same year ($P < 0.05$). "-" indicates that no data were sampled in that year.

Table S14 Analysis of variance for growth-related traits, post-anthesis resource utilization efficiency and crop growth of ratoon rice

Year	Source	Ratoon ability	TUE	LUE
2021	V	-	NS	-
	M	-	*	-
	D	-	NS	-
	V × M	-	NS	-
	V × D	-	NS	-
	M × D	-	NS	-
	V × M × D	-	NS	-
2022	V	NS	NS	NS
	M	**	*	*
	D	**	NS	NS
	V × M	**	NS	NS
	V × D	NS	NS	NS
	M × D	*	NS	NS
	V × M × D	NS	NS	NS

Note: TUE, Temperature utilization efficiency; LUE, Light utilization efficiency. V, Variety; M, Mowing time; D, Planting density. NS indicates not significant ($P > 0.05$). *, **, and ***, significant at the $P < 0.05$, $P < 0.01$, and $P < 0.001$ levels, respectively. "-" indicates that no data were sampled in that year.

Table S15 Analysis of forage yield and quality, ratoon rice yield and quality, and growth-related traits, post-anthesis resource use efficiency and crop by the technique for order preference by similarity to an ideal solution (TOPSIS) with entropy weight (EW) method

Mowing time	Density	Fresh forage yield	Forage quality	Ratoon rice yield	Ratoon rice quality
HS	D1	0.080	0.101	0.037	0.000
	D2	0.068	0.094	0.031	0.002
	D3	0.061	0.086	0.026	0.003
	D4	0.054	0.081	0.019	0.002
	D5	0.064	0.070	0.019	0.004
MS	D1	0.065	0.112	0.025	0.041
	D2	0.059	0.103	0.016	0.041
	D3	0.056	0.098	0.010	0.035
	D4	0.052	0.096	0.007	0.030
	D5	0.064	0.082	0.000	0.030
DS	D1	0.061	0.063	0.085	0.108
	D2	0.051	0.052	0.080	0.107
	D3	0.044	0.046	0.072	0.097
	D4	0.039	0.038	0.062	0.090
	D5	0.055	0.033	0.056	0.083
FS	D1	0.029	0.016	0.110	0.162
	D2	0.020	0.009	0.103	0.163
	D3	0.012	0.006	0.099	0.159
	D4	0.000	0.003	0.093	0.160
	D5	0.051	0.000	0.091	0.156

Note: Forage quality includes NDF, ADF, crude protein and Starch. Ratoon rice yield includes yield and components. Ratoon rice quality includes brown rice rate, milled rice rate, head rice rate, protein content and amylose content. HS, Heading stage; MS, Milk-ripening stage; DS, Dry-ripening stage; FS, Full maturity stage. D1, Planting density set to 17.2×10^4 hills ha^{-1}; D2, Planting density set to 22.76×10^4 hills ha^{-1}; D3, Planting density set to 25.34×10^4 hills·ha^{-1}; D4, Planting density set to 28.82×10^4 hills ha^{-1}; D5, Planting density set to 34.52×10^4 hills ha^{-1}.

Table S16 The planting cost of economic benefits under different planting density and mowing time treatments in 2022

Item		Agricultural input cost (USD·ha^{-1})				
		D1	D2	D3	D4	D5
Seed cost		104.6	138.45	154.13	175.29	209.95
Other cost	Fuel	96	96	96	96	96
	Machinery	377	377	377	377	377
	Electricity	12.51	12.51	12.51	12.51	12.51
	Fertilizer	383	383	383	383	383
	Pesticides	524.62	524.62	524.62	524.62	524.62
	Labor	1115.77	1115.77	1115.77	1115.77	1115.77
	Groundwater	216.75	216.75	216.75	216.75	216.75

Note: The other cost includes fuel, machinery, electricity, fertilizer, pesticides, labor and groundwater. D1, Planting density set to 17.2×10^4 hills ha^{-1}; D2, Planting density set to 22.76×10^4 hills ha^{-1}; D3, Planting density set to 25.34×10^4 hills ha^{-1}; D4, Planting density set to 28.82×10^4 hills ha^{-1}; D5, Planting density set to 34.52×10^4 hills ha^{-1}. The cost difference caused by the mowing time was negligible.