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Laser land levelling increases rice productivity and saves water

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Abstract: Rice is a major food crop globally, but yields are threatened by inefficient production practices. Laser land levelling is a technology that can enhance rice cultivars through optimised field conditions and water use efficiency. This study evaluated the effects of laser versus traditional land levelling on productivity and water savings of three rice cultivars in Egypt using a two-year split-plot field experiment with three replications. The land levelling methods (laser levelling, normal levelling, no levelling) were assigned to the main plots, and three Egyptian rice cultivars ('Sakha 108', 'Giza 177', 'Giza 178') were grown in the sub-plots. Data was collected on crop yield parameters, grain production, water use, and water use efficiency. Results showed that laser levelling increased plant height, flag leaf area, panicles per plant, filled grains per panicle, seed setting percentage, 1000-grain weight, and grain yield compared to traditional practices. The highest yields were obtained with laser levelling of 'Sakha 108' (12.22–12.31 Mg·ha^{-1}) and 'Giza 178' (12.20–12.29 Mg·ha^{-1}), while recorded 9.12–10.30 Mg·ha^{-1} in control fields. Laser levelling reduced total water use by 1793 m^3·ha^{-1} without reducing yields. Among cultivars, 'Sakha 108' had the highest water use efficiency under laser levelling. Overall, laser land levelling increased rice productivity by enhancing yield components and water productivity. Adoption of laser levelling could increase rice yields sustainably with less water usage in Egypt and similar regions. These findings demonstrate the benefits of laser levelling for enhancing rice cultivation through improved agronomic performance and water savings.

Keywords: grain yield, laser land levelling, water productivity, water saving

INTRODUCTION

More than 3.5 billion people depend on rice as their main food source every day (GRiSP, 2013), and it will continue to play a significant role in world diets (Lenaerts and Demont, 2021). The entire global food consumption is anticipated to rise by between 2010 and 2050, by 35–56% (Dijk van *et al.*, 2021), with the world population predicted to surpass nine billion by 2050 (UN, 2019). As a response, there are numerous significant obstacles to the production of rice, such as the loss of agricultural area due to urbanisation (Pandey and Seto, 2015), excessive input consumption (Nguyen *et al.*, 2022), and adverse consequences of climate change (Rehmani *et al.*, 2021). As there is a greater focus on the necessity of sustainably producing food in the remaining agricultural areas (Tilman *et al.*, 2011), there is also a greater understanding of the advantages of flora and fauna biodiversity at the landscape level (Shuman-Goodier *et al.*, 2019). In order to obtain accuracy in land levelling, drag buckets fitted with lasers are used to flatten the land surface (2 cm) from its average elevation. Precision land levelling allows for the fields to be modified to maintain a consistent slope of 0 to 0.2%. To move the soil either by cutting it or filling it in to create the proper slope or level, this procedure uses powerful tractors and soil movers that are outfitted with GPS and/or laser-guided equipment (Walker *et al.*, 2003).

While laser-assisted precision land levelling provides advantages like resource conservation and increased productivity, this advanced technology has not been broadly adopted by

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farmers in India (Hung *et al.*, 2022). The majority still use outdated, labour-intensive manual methods instead of laser levelling, which cannot level land as precisely. However, studies have shown laser levelling enables highly accurate levelling, and could greatly improve water utilisation, environmental conditions, and crop yields if implemented in India (Jat *et al.*, 2015).

The land levelling produces a smoother soil surface, a reduction in the time and water required to irrigate the field, more uniform water distribution throughout the field, a more uniform moisture environment for crops, more uniform crop germination and growth, a reduction in the amount of seed weight, fertiliser, chemicals, and fuel used during cultivation, and an improvement in field trafficability (for subsequent operations) (Jat *et al.*, 2006). The expensive equipment/laser instrument, the requirement for a professional operator to set/adjust laser settings and run the tractor, and the restriction to fields with regular shapes are all drawbacks of laser levelling. Entrepreneurial farmers are hesitant to accept new technologies unless they can immediately and visibly increase agricultural profitability (Anuraja *et al.*, 2013). Theoretically, a farmer would choose a new technique if evidence was shown that it would result in a net profit. Before farmers would contemplate adopting, according to some economists, the net returns for the alternative technology must be at least 30% higher. According to estimates, the number of laser levellers in rice-growing regions has sharply increased from just 24.000 ha (in 2018) to 480.000 ha (in 2022) (Kumar, Chaudhary and Arya, 2022). Technologies for conserving resources on farms in various governorates where rice is grown have an advantage over other technologies (Dlamini, 2005). One such tested technique that is very helpful in irrigation water conservation and increasing production is land levelling with a laser leveller (Lohan, Sidhu and Singh, 2014). Considering this, a study was carried out to ascertain the volume of water saved because of laser or precision land levelling and to evaluate the impact of laser land levelling on the productivity of different rice kinds by contrasting it with the traditional method.

MATERIALS AND METHODS

On May 1 of the summers of 2021 and 2022, a field experiment was carried out at the Farm of Experimentation of the Sakha Research Station to ascertain the extent of water savings because of laser or precision land levelling and to estimate the effect of land levelling (traditional and laser land levelling) on the water productivity and the productivity of some rice cultivars. A split plot design experiment was carried out with three replications. Three different rice cultivars, 'Sakha 108', 'Giza 177', and 'Giza 178', were grown on the sub-plots while the main plots were used for land levelling using the traditional and laser methods.

It is clear from the soil characteristics that the clay percentage is high, about 55% in both years, which indicates the clay texture of the soil. The key parameters were pH (8.2–8.35), organic matter (1.39–1.40%), and *EC* (0.60–0.68) in the years 2021 and 2022.

It is clear from Figure 1 that in 2022, air temperatures were generally higher than in 2021, with maximum temperatures in 2022 exceeding those in 2021 by 0.5–2.9°C for most months. Relative humidity levels have also been slightly higher in 2022 for

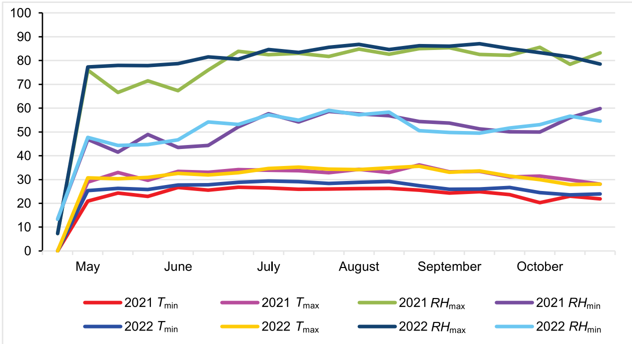

Fig. 1. The monthly minimum and maximum air temperature (T_{min}, T_{max}, °C) and relative humidity (RH_{min}, RH_{max}, %) at Sakha Agricultural Research Station during the 2021 and 2022 rice growing seasons; source: own study

several months. However, rainfall remained at 0 mm·d^{-1} throughout both seasons.

The Rice Research and Training Center (RRTC) advised the establishment and preparation of a permanent field and bed nursery. During the land preparation process, phosphorus fertiliser in the form of mono super phosphate (15%) was administered at a rate of 86.4 kg P_2O_5·ha^{-1} and potassium fertiliser in the form of potassium sulphate (48% K_2O) was applied at a rate of 136.8 kg K_2O·ha^{-1}. Urea, which contains 46.5% nitrogen, was applied at 240 kg·ha^{-1} in two splits, i.e., before flooding, applying two-thirds as a base treatment that is integrated into the soil, then applying the final third 30 days later, 25 days after seeding, seedlings were moved from the nursery to the permanent field. Three or four seedlings per hill and a 20 × 20 cm gap between hills and rows were the typical transplantation spacing used. The plot was 12 m^2 (3 × 4 m) in size.

The suggested cultural conventions were followed. The standard evaluation system (SES) of International Rice Research Institute (IRRI) was used to calculate grain yield and agronomic traits (IRRI, 2013). The following data were collected from each plot at the maturity stage: plant height (cm), flag leaf area (cm^2), flag leaf angle (x), number of panicles per plant, number of panicles per clumps filled, seed setting (%), weight of 1000 seeds (g), grain productivity (Mg·ha^{-1}) and harvest index (%). While water use efficiency (*WUE*) was calculated as the weight of grain yield (kg·ha^{-1}) per unit of water used on m^3·ha^{-1} according to Israelsen and Hansen (1962). All morphological data, productivity, and yield components obtained were put through analysis of variance (ANOVA), and significant means were separated using a least significant difference plot ($LSD_{0.05}$) for the CoStat program. According to Gomez and Gomez (1984), an analysis of variances was performed on the acquired data.

RESULTS

The effects of rice variety land levelling on plant height, flag leaf area, and flag leaf angle were shown by the results in Table 1. Results indicated that ground levelling during two seasons had a significant impact on plant height, flag leaf area, and flag leaf angle. While the unwanted values for the same traits were recorded using the control (non-levelling) treatment, the desirable values for the same attributes were recorded using the laser approach. Additionally, the findings in Table 1 showed that the

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Table 1. The effects of land levelling techniques and rice variety selection, as well as their interaction, on measured variables during the 2021 and 2022 rice growing seasons

Specification	Plant height (cm)	Flag leaf area (cm^2)	Flag leaf angle (°)	No. of panicle per plant	No. of filled grains per panicle	Seed set (%)	1000-grain weight (g)	Grain yield ($Mg \cdot ha^{-1}$)	Harvest index (%)
2021									
WL	98.11 ±1.72c	30.96 ±1.61c	28.33 ±2.35b	17.11 ±0.89c	123.11 ±2.89c	86.94 ±1.88b	22.78 ±1.7c	9.17 ±0.17c	41.44 ±1.66c
NL	100.44 ±1.42b	36 ±0.77b	29.67 ±2.08a	20.33 ±0.91b	132.22 ±2.84b	89.92 ±1.58a	25.22 ±1.44b	10.30 ±0.27b	44.89 ±1.88b
LL	103 ±1.22a	41.34 ±1.09a	30.78 ±2.1a	26.22 ±2.06a	138.78 ±3.09a	90.61 ±1.65a	26.78 ±1.11a	11.50 ±0.26a	47.67 ±0.91a
F-test	**	**	**						
‘Sakha 108’	97.33 ±1.53c	35.59 ±3.62b	31.78 ±0.48b	23.78 ±3.12a	134.44 ±3.1a	87.45 ±0.84b	27 ±0.82a	11.11 ±0.25a	44.89 ±1.77b
‘Giza 177’	102.67 ±1.08a	35.57 ±2.18b	32.33 ±0.82a	19 ±1.87c	125.44 ±3.61b	91.54 ±1.24a	26 ±0.96b	9.07 ±0.19c	41.78 ±2c
‘Giza 178’	101.27 ±1.23b	36.86 ±2.47a	26.01 ±0.87c	20.98 ±2.07b	133.44 ±5.48a	88.67 ±2.45b	22.64 ±1.38c	10.66 ±0.3b	46.61 ±1.22a
F-test	**	**	**	**	**	**	**	**	**
L×V	NS	**	**	**	**	**	**	**	**
2022									
WL	99.78 ±1.65c	30.73 ±1.12c	29.11 ±2.26c	17.78 ±0.99c	125.89 ±3.19c	87.09 ±1.78b	23.67 ±1.76c	9.29 ±0.17c	42 ±1.71c
NL	102 ±1.63b	36.82 ±0.87b	30.89 ±2.15b	21.44 ±0.77b	133.56 ±3.68b	90.55 ±1.44a	25.56 ±1.58b	10.34 ±0.28b	45.33 ±1.78b
LL	104.33 ±1.35a	43.36 ±1a	31.56 ±2.04a	26.33 ±2.35a	141.33 ±2.61a	91.33 ±1.56a	27 ±1.41a	11.69 ±0.23a	48.78 ±0.69a
F-test	**	**	**						
‘Sakha 108’	98.56 ±1.36b	36.16 ±3.99b	32.78 ±0.38a	24.44 ±2.95a	137.11 ±2.57a	88.42 ±0.57b	27.67 ±0.96a	11.18 ±0.25a	45.44 ±1.71b
‘Giza 177’	103.78 ±1.15a	36.87 ±2.54b	33.11 ±0.98a	19.78 ±1.68c	127.11 ±3.95b	90.68 ±1.28a	26.67 ±0.58b	9.22 ±0.23c	42.67 ±2.31c
‘Giza 178’	103.3 ±1.07a	37.63 ±3.16a	26.99 ±0.87b	21.47 ±2.27b	135.75 ±5.42a	89.81 ±2.92a	22.85 ±1.13c	10.78 ±0.3b	47.28 ±1.26a
F-test	**	**	**	**	**	**	**	**	**
L×V	NS	**	**	**	**	**	*	**	**

Explanations: NS = nonsignificant, WL = without levelling, NL = normal levelling, LL = laser levelling, L = laser levels, V = rice cultivars; means with the same letter are not significantly different from each other; *, ** = significant at 0.05, 0.01 levels of probability, respectively.
Source: own study.

rice cultivars varied significantly in relation to plant height, flag leaf area, and flag leaf angle, with ‘Sakha 108’ having the smallest stature. The connection between the levelling method and rice cultivars was significant for flag leaf area and angle, even though ‘Giza 178’ recorded the desirable values for both.

The relationship between land levelling and rice cultivars on morphological features was shown by the results in Figure 2. The findings demonstrated that land levelling with rice cultivars during two seasons had a significant impact on flag leaf area and angle. The desirable values for flag leaf area were 42.47 and 44.38 cm^2 with the laser method for the rice variety ‘Sakha 108’ during two seasons, while the undesirable values were 28.70 and 25.58 cm^2 without levelling for the same rice variety. Additionally, land levelling and rice cultivars had a significant impact on flag leaf angle over the course of two seasons; the ideal values were 23.00° and 24.00° without levelling of ‘Giza 178’. The unacceptable value for flag leaf angle was measured with laser technique treatment of the cultivar ‘Giza 177’ for two seasons (33.66° and 34.66°). The yield components of different rice cultivars were strongly impacted by laser levelling (Tab. 1). In comparison to the lowest values in the unlevelled field (control), the number of panicles per plant, filled grains per panicle, and seed setting percentage were all highest in the laser-levelled field. Results in Table 1 for rice cultivars revealed there were substantial variances in some characteristics, including the number of panicles per plant, the number of filled grains per panicle, and the percentage of seeds that were set. The rice variety ‘Sakha 108’ recorded desirable values for these characteristics, while ‘Giza 177’ recorded the ideal seed planting percentage values. The interaction between land levelling techniques and rice cultivars had an impact on various yield features, as evidenced by the outcomes in Figure 1. Results revealed that during the course of two seasons, land levelling methods and rice cultivars had a significant impact on the number of panicles per plant, the number of filled grains per panicle, and seed setting percentage. The laser method with the rice variety ‘Sakha 108’ produced the desired number of panicles per plant with the values of 30.66 and 31.00, while the control treatment with ‘Giza 177’ produced the lowest number of panicles per plant measurements (15.33 and 15.03).

The desired value for the number of filled grains per panicle was 143.33 and 145.66 with the laser levelling of the ‘Giza 178’ during two seasons, while the unfavourable value for the number of filled grains per panicle recorded 118.00 and 120.33 with the control (without levelling) treatment of the rice variety ‘Giza 177’ during two seasons. Land levelling treatments and rice cultivars highly affected the number of filled grains per panicle during two seasons. The desirable values for the seed setting were 92.55 and 92.73% with the laser levelling of the rice variety ‘Giza 177’ during two seasons, while the undesirable values for the seed setting were

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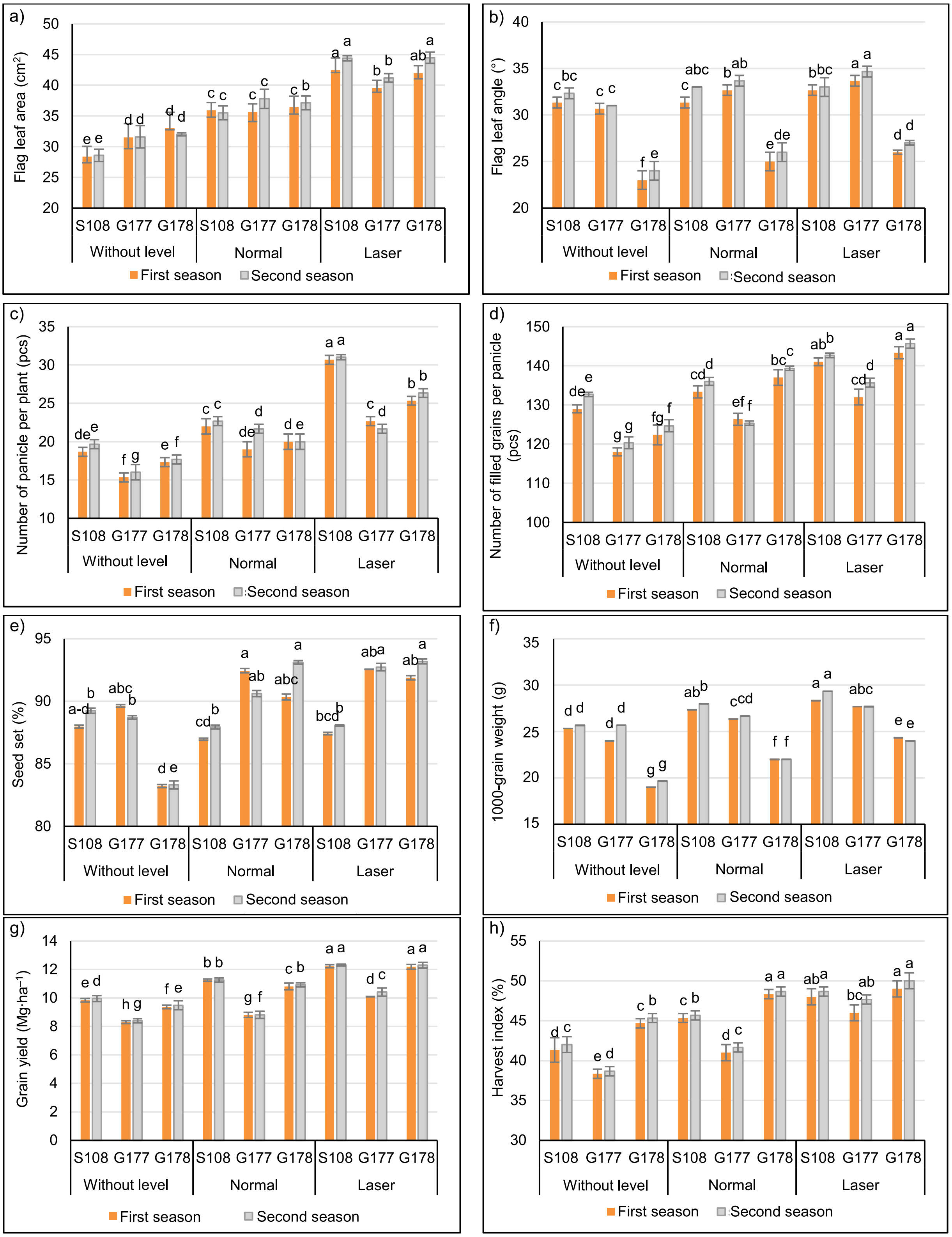

Fig. 2. The interaction between land levelling techniques and rice variety selection, on measured variables during the 2021 and 2022 rice growth period: a) flag leaf area, b) flag leaf angle, c) number of panicle per plant, d) number of filled grains per panicle, e) seed set, f) 1000-grain weight, g) grain yield, h) harvest index; means with the same letter are not significantly different from each other; source: own study

recorded with the control (without levelling) of the 'Giza 178' – 83.2 and 83.31% during two seasons (Fig. 1).

The effects of land levelling on the 1000-grain weight (g), grain yield ($Mg \cdot ha^{-1}$), and harvest index (%) of several rice cultivars, in addition to their interactions, were shown in Table 1.

The results showed that land levelling techniques for two seasons had a significant impact on 1000-grain weight (g), grain production ($Mg \cdot ha^{-1}$), and harvest index (%). The highest values for these features were recorded with treatment laser levelling compared to control (without levelling) for two seasons,

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increasing by 1000-grain weight, and grain yield (Mg·ha^{-1}), and harvest index (%). The results in Table 1 also showed that, for the same traits, there were significant differences among the rice cultivars. The highest values were obtained from the rice variety 'Sakha 108' for 1000-grain weight, grain yield (Mg·ha^{-1}) traits, while the rice variety 'Giza 178' provided the highest value for harvest index over two seasons. Throughout the course of two seasons, the rice variety 'Giza 177' recorded the lowest values for the 1000-grain weight, grain yield (Mg·ha^{-1}), and harvest index (%) characteristics. There is a general consensus that the number of panicles, the number of spikelets per panicle, the rate of seed germination, and the weight of the grain at 1000 grains are the four key factors influencing rice yield.

The interaction between different rice cultivars and land levelling techniques had an impact on yield and its component features, as shown in Figure 1. The findings revealed that land levelling methods with different rice cultivars during two seasons had a significant impact on 1000-grain weight, grain yield (Mg·ha^{-1}), and harvest index. The laser levelling method produced the desired 1000-grain weight values of (28.33 and 29.33 g) for the rice variety 'Sakha 108' during the two seasons, while the 'Giza 178' rice variety recorded the lowest values (19.00 and 19.66 g) for the same period.

The desirable grain yield was 12.22, 12.31, 12.20, and 12.29 Mg·ha^{-1} by using laser levelling of the 'Sakha 108' and 'Giza 178' during two seasons, whereas the lowest grain yield value was (19.95 and 20.16 Mg·ha^{-1}) recorded without levelling for the rice variety 'Giza 177' during two seasons, as shown in Figure 1. Grain yield was also greatly influenced by land levelling methods and rice cultivars during the two seasons. Additionally, the findings demonstrated that for two seasons, land levelling, and rice variety had a significant impact on the harvest index. The 'Giza 178' rice variety's harvest index recorded the desirable values of 49.00 and 50.00% with the use of laser levelling throughout the two seasons, while the 'Giza 177' rice variety's harvest index recorded unfavourable values of 38.33 and 39.66% without land levelling.

Data showed that the grain yield of the three tested cultivars under the laser levelling method was raised as a result of the enhanced land levelling. Grain yield, total water utilised, water saved, and yield reduction as impacted by land levelling methods are reported in Table 2.

The 'Sakha 108' cultivar used 12.552 m^3·ha^{-1} of water from seed to seed and saved an average of 21.4% and the yield decreased by 30.45% during the two research seasons, which is equivalent to about 2.45 Mg·ha^{-1} of grain when laser levelling was used. When laser levelling was utilised, 'Giza 178' was placed in second place behind 'Sakha 108' cultivar, which conserved water by about 21.4%, or about 2688 m^3·ha^{-1} throughout the two seasons under investigation and reduced grain production by 30.8%, or about 2.88 Mg·ha^{-1} as shown in Table 2. According to the results, 'Sakha 108' had the best water use efficiency when laser levelling was used, followed by 'Giza 178' under the same levelling method, while 'Giza 177' had the lowest value of water use efficiency (*WUE*). This means that 'Sakha 108' could be used to produce the most grain with the least amount of water input in the conditions mentioned above.

DISCUSSION

Compared to unlevelled fields, the use of precision land levelling resulted in higher grain yields, by providing more reliable water conditions that enabled timely field preparation and sowing. The uneven distribution of water across unlevelled fields may explain the lower grain production, which severely reduces the yield and its components in lower and elevated areas (Naresh *et al.*, 2014). Under steady seed setting rate and 1000-grain weight conditions, the total amount of spikelets (number of panicles · number of spikelets per panicle) is the key to improving grain output (Pan *et al.*, 2017; Dou *et al.*, 2021).

According to Aquino *et al.* (2015), laser land levelling increases agricultural flatness, which evens out planting depth, promotes crop germination and the environment in which it grows, and increases the impact of precision seeding. Second, precision seeding guarantees homogeneity in seeding rate and row spacing (Yazgi and Degirmencioglu, 2007). This lowers the re-seeding rate and lapses seeding rate, enhances germination, optimises crop population density, and can improve the results of laser land levelling. Finally, precision sowing and laser field levelling work well together and increase crop output.

Crop grain quality is influenced by the environment and crop cultivation techniques in addition to the genotype of the crop (Souza *et al.* 2004; Otteson, Mergoum and Ransom, 2008). In another study, El-Refaee *et al.* (2011) indicated that when compared to other irrigation treatments, irrigation every six days recorded the highest values of water use efficiency. Hassan *et al.* (2015) stated that irrigation at a seven-day interval could give significantly improved water productivity (grain produced per unit of water). According to a study by Bouman and Tuong

Table 2. Average yield reduction and water saved (m^3·ha^{-1}) as affected by land levelling and rice cultivars during the 2021 and 2022 seasons

Levelling	'Giza 177'				'Giza 178'				'Sakha 108'			
	yield (kg)	YR (%)	WS (m^3)	WS (%)	yield (kg)	YR (%)	WS (m^3)	WS (%)	yield (kg)	YR (%)	WS (m^3)	WS (%)
WL–NL	0.21	6.1	1248	10	0.6	15.38	1440	9.5	0.568	13.85	1440	11.21
WL–LL	0.79	22.83	2304	17.3	1.2	30.8	2688	21.4	1.02	30.45	2688	21.4
NL–LL	0.61	16.75	1056	9.26	0.6	13.3	1248	9.9	0.452	9.68	1248	9.94
Average	0.537	15.23	1536	12.2	0.8	19.82	1792.8	13.6	0.68	17.99	1792.8	14.2

Explanations: WL = without levelling, NL = normal levelling, LL = laser levelling, YR = yield reduction, WS = water saved.
Source: own study.

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(2001), continual flooding rice had an average water productivity of 0.2 to 0.4 g of grain per kg of water in India and 0.3 to 1.1 g of grain per kg of water in the Philippines. Water-saving irrigation boosts water production up to a maximum of 1.9 g of grain per kg of water, but the yield is reduced on the productivity of water.

CONCLUSIONS

Laser land levelling presents a promising avenue for enhancing rice cultivation practices compared to traditional methods. Our study aimed to evaluate the impact of laser land levelling on rice productivity and water savings, contrasting it with traditional methods. The findings underscored significant improvements in various agronomic parameters with laser levelling, including increased plant height, flag leaf area, panicles per plant, filled grains per panicle, seed setting percentage, and grain yield compared to traditional practices. Moreover, laser levelling led to a notable reduction in total water usage without compromising yields, indicating enhanced water use efficiency.

The broader adoption of laser land levelling could bring substantial benefits to rice cultivation not only in Egypt but also in similar regions globally. By optimising field conditions and water usage, laser land levelling offers the potential to enhance rice productivity sustainably while conserving valuable water resources. However, it's essential to note that the precise numerical data presented in this study are specific to our experimental conditions and may vary in different contexts.

Furthermore, while extrapolating the potential benefits to the entire country, it's crucial to exercise caution due to potential variations in soil types, climate conditions, and agricultural practices across different regions. Thus, while laser land levelling shows promise, further research and field trials are warranted to fully understand its implications and optimise its implementation for broader agricultural benefits.

CONFLICT OF INTERESTS

All authors declare that they have no conflict of interests.

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