Short Communication

Received: 29 May 2024 | Accepted: 30 April 2025 | Published online: 30 April 2025

DOI: 10.53550/ijsc.v53.i1.192

ORIGINAL ARTICLE

Indian Journal of Soil Conservation

Laser land levelling and double row planting improves productivity, water use efficiency and profitability of post monsoon sorghum in black soils

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Handling Editor:

Dr Ram Avatar Jat

Key words:

Bed planting

Black Soils

Irrigation management

Laser land levelling

Sorghum WUE

ABSTRACT

A field experiment was carried out in the winter season of 2017-18 at the engineering farm of navsari agricultural university in navsari, india, to assess how land leveling and configuration techniques affect sorghum (Sorghum bicolor L.) productivity, water usage, and economic returns in heavy-textured black soils (58% clay) with poor physical properties and limited rainfall during the crop period (37 mm). The study employed a factorial randomized block design with three replications, examining three land leveling methods: an unleveled control (0.05% slope), conventional land leveling, and laser-guided land leveling. It also evaluated three land configurations: ridge and furrow, double-row bed planting (90 cm), and triple-row bed planting (150 cm). Results indicated that laser-guided land leveling significantly enhanced growth attributes, yield components, and resource-use efficiency compared to the control. This method achieved the highest grain yield (4000 kg ha^{-1}), fodder yield (16,998 kg ha^{-1}), and water use efficiency (WUE) of 17.0 kg ha^{-1} mm^{-1}. Among the land configurations, double-row bed planting yielded the highest grain (3367 kg ha^{-1}), fodder (16,717 kg ha^{-1}), and WUE (16.1 kg ha^{-1} mm^{-1}), outperforming both ridge and furrow and triple-row systems. Laser leveling also led to reduced irrigation time and depth, improving irrigation efficiency. Economic analysis indicated the highest net return (₹ 70,492 ha^{-1}) and benefit-cost ratio (3.4) with laser leveling, while double-row bed planting yielded the highest net return among configurations (₹ 69,163 ha^{-1}). The findings suggest that integrating laser-guided land leveling with double-row bed planting can significantly improve sorghum productivity, irrigation efficiency, and profitability in the heavy black soils of south gujarat.

1 | INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) ranks fifth most important crop globally, primarily cultivated in Africa and Asia as a staple food. It occupies 40.25 M ha of cultivated area, producing 58.70 M t, averaging 1458 kg ha^{-1}. The USA leads production at 15%, followed by Nigeria, Ethiopia, Sudan and India. India ranks as the second-largest cultivator of sorghum globally; however, its productivity remains relatively low at 1250 kg ha^{-1}. Maharashtra and Karnataka are the top-producing states. However, sorghum cultivation in India has significantly declined from 18.6 M ha and 9.72 M t in 1970 to just 4.50 M ha and 4.25 M t in 2021-22 (USDA, 2023).

The suboptimal productivity of *rabi* sorghum can be attributed to several interrelated factors. Primarily, this crop is predominantly cultivated under residual soil moisture conditions, which limit water availability during critical growth stages. Additionally, applying chemical fertilizers is often minimal or inadequate, resulting in nutrient deficiencies that adversely affect plant growth and yield. Furthermore, the prevailing soil management practices are generally suboptimal, contributing to diminished soil health and fertility. Inter alia, these are the main factors that hinder the overall productivity of *rabi* sorghum.

Laser land leveling enhances the precision of farmland leveling, significantly improving micro-topographical conditions and facilitating precision seeding. This technology is associated with increased crop yields and improved efficiency in fertilizer and water utilization, ultimately leading to enhanced economic returns (Ashraf *et al.*, 2017). However, concerns have been raised regarding the impact of laser land leveling on soil salinity and fertility, as this process involves the removal of topsoil from crests and its redistribution into troughs. Therefore, the development of superior soil management technologies is essential to optimize water and fertilizer use efficiency.

Resource conservation technologies, such as improved sowing patterns and laser land leveling, enhance agricultural efficiency by optimizing soil moisture retention and reducing erosion, thereby promoting sustainable farming practices (Behera *et al.,* 2019). Land configuration is an agronomic practice recognized as a key resource conservation technology, as noted by Sharma *et al*. (2015b). It optimizes spatial arrangement of crops to enhance resource use efficiency and improves overall crop productivity. It also offers opportunities for intercultural operations and is a cost-effective choice due to the straightforward field access provided by the crop row orientation on the beds. Additionally, water management is more efficient and requires less labor when using furrows than conventional tillage.

The study's hypothesis was that laser land levelling and double row planting improve sorghum yield, water use efficiency, and economic returns. The objective was to assess the impact of various land management techniques on the yield and profitability of sorghum production in south gujarat, india.

2 | MATERIALS AND METHODS

2.1 | Experimental details

The experiment took place during the winter of 2017-18 at the engineering farm of navsari agricultural university in navsari, India. This area is known for its heavy-textured soils containing 58% clay, which display poor physical attributes like low infiltration rates, restricted permeability, and insufficient drainage. Navsari is classified under Agro-Ecological Situation-III of the south gujarat heavy rainfall Zone-I. Throughout the cropping season, total recorded rainfall was merely 37 mm. The study employed a factorial randomized block design with three replications, evaluating three land leveling methods: an unleveled control (slope 0.05%), conventional land leveling, and laser-guided land leveling. These were paired with three land configurations: Ridge and furrow (25 cm depth), Double-row bed sowing (90 cm bed width), and Triple-row bed sowing (150 cm bed width). The layout of these sowing methods is shown in *Fig. 1*.

HIGHLIGHTS

- Laser-guided land leveling significantly improved sorghum grain yield and its water use efficiency.
- Double-row bed planting (90 cm) outperformed other configurations, achieving the highest yield and irrigation efficiency.
- The combination of laser leveling and double-row bed planting resulted in the highest net returns (₹ 70,492 ha^{-1}) and B:C ratio (3.4), confirming its economic viability.

Sorghum (var. GJ-42) was planted during the first week of December, spaced at 60 cm, and harvested in the first fortnight of April. The recommended seed rate of 15 kg ha^{-1} was adhered to. Fertilization involved applying an N:P dose of 80:40 kg ha^{-1}, with 50% of nitrogen and all phosphorus applied at the start, while the remaining nitrogen was top-

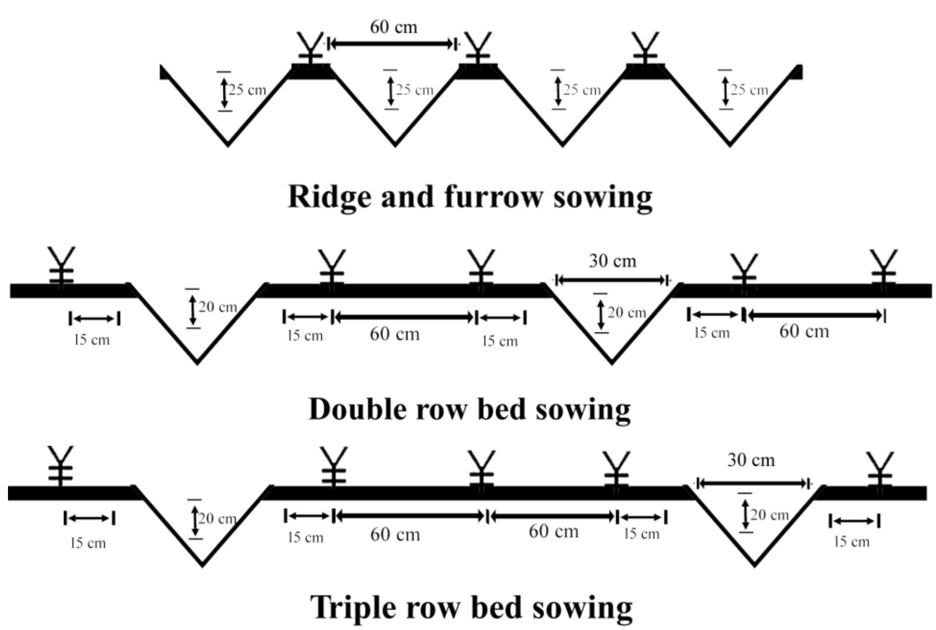

FIGURE 1 Layout of land configurations of sorghum

dressed one month post-sowing. Additionally, 10 t ha^{-1} of farmyard manure (FYM) was mixed into the soil before planting. Standard agronomic practices were followed for crop management. Four irrigations were carried out, starting with a light irrigation right after sowing, followed by additional irrigations at monthly intervals. For growth and yield assessments, five representative plants per plot were selected. Crop yield was recorded from an area of 3.6 × 3.6 m in each plot, and the results were extrapolated to estimate productivity per hectare.

2.2 | Water Use Efficiency (WUE)

WUE is the yield per unit area of land divided by the total amount of water applied (irrigation + rainfall) in the field (Kumari *et al.,* 2018). The amount of water applied in different treatments was measured using the Parshall flume during each irrigation (Chalodiya *et al.,* 2017).

$$\text{WUE (kg ha}^{-1}\text{mm}^{-1}) = \frac{\text{Grain yield}}{\text{Total amount of water applied in the field}}$$

2.3 | Economics

A simple economic analysis was performed, considering the cost of inputs and income from outputs (grain and fodder yield), using current market prices. The net return was calculated by subtracting the total cultivation costs (from sowing to harvesting) from the gross return for each plot, and the benefit-cost ratio was worked out by gross returns divided by the cost of cultivation.

3 | RESULTS AND DISCUSSION

3.1 | Growth Attributes

Among the land leveling treatments, laser-guided land leveling resulted in significantly greater plant height, dry matter accumulation, and total biological yield of sorghum com-

TABLE 1 Influence of land levelling and land configurations on growth attributes of sorghum

Treatment	Plant height (cm)	Dry matter accumulation (g $plant^{-1}$)	Biological weight (g $plant^{-1}$)	No. of panicle $plant^{-1}$	Panicle length (cm)	Panicle girth (cm)	Test weight (g)
Land leveling							
Control or unleveled	117.3	96.2	152.7	2.4	19.3	18.5	22.9
Conventional land leveling	129.6	104.0	170.9	2.7	21.2	21.1	25.6
Levelling with laser guided land leveler	138.1	112.3	184.4	3.0	23.1	23.3	27.2
S.Em (±)	4.3	3.5	3.6	0.1	0.7	0.9	0.9
CD (p=0.05)	13.0	10.6	10.7	0.3	2.1	2.6	2.7
Land configuration							
Ridge & furrow	125.0	96.2	156.8	2.4	19.8	19.0	23.3
Double row bed sowing	131.8	109.8	179.1	3.0	22.4	22.6	26.7
Triple row bed sowing	128.1	106.5	172.2	2.8	21.4	21.4	25.7
S.Em (±)	NS	3.5	3.6	0.1	0.7	0.9	0.9
CD (p=0.05)	NS	10.6	10.7	0.3	2.1	2.6	2.7
L×B interaction	NS*	NS	NS	NS	NS	NS	NS

**NS = non-significant*

TABLE 2 Irrigation time, depth of applied water and water use efficiency influenced by land leveling and land configurations

Treatment	Irrigation time (min $plot^{-1}$)	Depth of water applied (mm)	Water use efficiency (kg $ha^{-1}mm^{-1}$)
Land leveling			
Control or unleveled	44.6	266.0	12.0
Conventional land leveling	42.4	251.8	14.0
Levelling with laser guided land leveler	40.4	240.2	17.0
S.Em (±)	1.1	6.7	1.0
CD (p = 0.05)	3.2	19.9	3.1
Land configuration			
Ridge & furrow	47.8	284.4	11.2
Double row bed sowing	40.0	238.1	16.1
Triple row bed sowing	39.6	235.5	15.7
S.Em (±)	1.1	6.7	1.0
CD (p = 0.05)	3.2	19.9	3.1
L×B interaction	NS	NS	NS

pared to the unleveled control. The performance of conventional land leveling was statistically at par with that of laser leveling (Table 1). The superior growth under laser leveling is likely due to the uniform moisture distribution across the field, which facilitates optimal water availability and improved crop development. In contrast, the unleveled plots experienced uneven water distribution, leading to localized water stress and suboptimal crop growth (Wakchaure *et al.,* 2015).

Regarding land configurations, double row bed sowing produced significantly better growth parameters than other configurations (Table 1). This configuration likely enhanced rhizosphere drainage and soil aeration, improving nutrient availability and uptake, which contributed to enhanced vegetative growth and biomass accumulation (Schmidt and Zemadim, 2015). The interaction effect between land leveling and land configuration on growth attributes was not statistically significant.

3.2 | Yield Attributes and Yield

Land leveling techniques significantly influenced the yield attributes of sorghum. The laser-guided land leveling treatment recorded the highest values for key traits: number of panicles per plant (3.0), panicle length (23.1 cm), panicle girth (23.3 cm), and test weight (27.2 g) (Table 2). These results are consistent with earlier reports showing a 5-40% increase in crop yield through the adoption of laser land leveling technologies (Hashimi *et al.,* 2017).

Among land configurations, double row bed sowing produced the most favorable yield attributes, followed by triple row bed sowing, both of which significantly outperformed ridge and furrow planting (Table 2). The improved performance is attributed to enhanced root development and better soil nutrient mineralization under bed planting systems. Du *et al.* (2021) similarly reported that raised bed planting systems enhance wheat growth relative to flat bed systems.

The interaction effects between land leveling and land configuration were not significant for yield attributes.

In terms of actual yield, laser-guided land leveling resulted in the highest grain yield (4000 kg ha^{-1}) and fodder yield (16,998 kg ha^{-1}), significantly outperforming the unleveled treatment and being at par with conventional leveling (Fig. 2). These gains are primarily attributed to more uniform soil moisture throughout the crop's growth stages, supporting better vegetative and reproductive performance (Ramya *et al.,* 2022).

Among land configurations, double row bed sowing also produced the highest grain yield (3791 kg ha^{-1}), statistically similar to triple row bed sowing, and significantly higher than ridge and furrow planting. A similar trend was observed for fodder yield, where double row bed sowing recorded the highest value (16,717 kg ha^{-1}), and ridge and furrow the lowest. Kumari *et al.* (2022) reported comparable findings, suggesting that double row planting of sorghum under limited water conditions enhances yield performance. In contrast, Sharma *et al.* (2015a, b) noted better performance of pearl millet under ridge planting, highlighting that crop responses to configurations can vary. Again, the interaction between land leveling and land configuration was not statistically significant for grain and fodder yield.

3.3 | Irrigation Time, Water Use, and Water Use Efficiency (WUE)

Land leveling techniques had a significant effect on the irrigation time, total water use, and WUE of the sorghum crop. The shortest irrigation time was recorded under laser-guided land leveling (40.4 minutes), followed by conventional land leveling (Table 2). The depth of irrigation water applied under laser leveling was 240.2 mm - 4.62% and 9.70% lower than that of conventional leveling and the unleveled control, respectively. This reduction is attributed to the uniform distribution of irrigation water achieved under laser leveling, which minimizes water losses and ensures efficient application across the field (Rajkumar *et al.,* 2019). As a result, laser land leveling recorded the

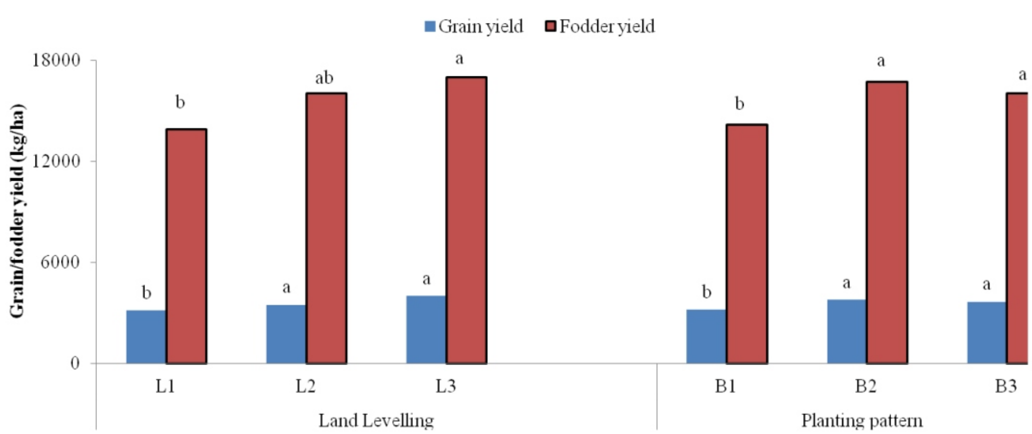

FIGURE 2 Influence of leveling and land configurations on yield of sorghum

highest WUE (17.0 kg $ha^{-1}mm^{-1}$), indicating more efficient use of water in producing grain yield. This aligns with findings by Naresh *et al.* (2014), who reported improved WUE in laser-leveled fields compared to both conventional and unleveled fields. The interaction effect between land leveling and land configuration on water use and WUE was not statistically significant.

Among the land configurations, the minimum irrigation time was observed under triple row bed sowing (39.6 minutes), closely followed by double row bed sowing (Table 2). Triple row bed sowing also resulted in the lowest depth of irrigation water applied, statistically similar to double row bed sowing. This can be attributed to the reduced open surface area for water infiltration in raised bed systems, which leads to faster irrigation and lower water requirement compared to the ridge and furrow method (Kumari *et al.,* 2022). In terms of WUE, double row bed sowing achieved the highest value, followed by triple row bed sowing, both significantly better than the ridge and furrow configuration. These results are consistent with previous studies showing that bed-furrow planting systems enhance soil water retention and irrigation efficiency (Zhao *et al.,* 2014). As with leveling, the interaction effects between land leveling and land configuration were non-significant.

3.4 | Economics

Economic analysis revealed that laser-guided land leveling resulted in the highest gross return (₹ 102,992 ha^{-1}) and net return (₹ 70,492 ha^{-1}), followed by conventional land leveling (Table 3). The benefit-cost (B:C) ratio was also highest under laser leveling (3.4), followed by conventional leveling (3.2), with the lowest economic returns observed under the unleveled control (B:C ratio 3.0). These findings are consistent with Chalodiya *et al.* (2017), who reported significantly improved economic returns with laser land leveling in castor cultivation.

Among land configurations, the maximum net return was recorded under double row bed sowing (₹ 69,163 ha^{-1}), followed by triple row bed sowing (₹ 64,782 ha^{-1}). The ridge and furrow configuration yielded the lowest economic returns, significantly inferior to the other two methods. The highest B:C ratio was observed in double row bed sowing (3.4), while the lowest was recorded in ridge and furrow (3.0) (Table 3). Similar conclusions were drawn by Ram *et al.* (2016), who found raised bed planting systems to be more profitable than flatbed or ridge planting systems. As with other parameters, the interaction effects between land leveling and land configuration on economic returns were not statistically significant.

4 | CONCLUSIONS

This study demonstrates that the combination of laser-guided land leveling and double row bed planting significantly improves the growth parameters, yield attributes, grain and fodder yield, water use efficiency (WUE), and economic returns of sorghum under the heavy-textured black soils of south gujarat. Laser leveling resulted in more uniform water distribution, reduced irrigation time and water application, and enhanced WUE (17.0 kg ha^{-1} mm^{-1}), while double row planting offered improved aeration and root zone conditions, leading to the highest grain yield (3367 kg ha^{-1}) among land configurations. Both techniques consistently outperformed conventional and control treatments in all measured parameters.

Based on these findings, it is concluded that laser land leveling and double row planting not only optimize crop productivity and irrigation efficiency but also offer higher returns on investment. These practices hold strong potential for scaling out in black soil regions of south gujarat and similar agroecological zones with poor drainage and limited water availability.

TABLE 3 Economics of sorghum cultivation under different land leveling and land configurations

Treatment	Cost of cultivation (₹ ha^{-1})*	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Land leveling				
Control or unleveled	27550	82302	54752	3.0
Conventional land leveling	28950	92073	63123	3.2
Levelling with laser guided land leveler	32500	102992	70492	3.4
S.Em (±)	-	2453.9	2453.9	0.1
CD (p=0.05)	-	7356.8	7356.8	0.3
Land configuration				
Ridge & furrow	27192	83264	54422	3.0
Double row bed sowing	28008	98821	69163	3.4
Triple row bed sowing	28850	95282	64782	3.2
S.Em (±)	-	2453.9	2453.9	0.1
CD (p=0.05)	-	7356.8	7356.8	0.3
L×B interaction	NS	NS	NS	NS

**₹ ha^{-1} = Rupees per hectare*

To support broader adoption and long-term impact, the following research gaps should be addressed:

- Assessment of long-term soil health and structural changes under repeated laser leveling.
- Detailed economic analyses across different farm sizes and resource settings to establish profitability thresholds.
- Development of crop- and region-specific irrigation schedules tailored to bed planting systems.
- Exploration of synergies with other resource-conserving technologies such as precision irrigation and nutrient management tools.

By addressing these gaps and promoting farmer-centric extension strategies, laser leveling and double row planting can become integral components of climate-resilient, water-efficient, and economically viable sorghum cultivation systems in semi-arid and resource-constrained environments.

ACKNOWLEDGMENTS

We are thankful to the Department of Agricultural Engineering, N.M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India, for providing facilities for smoothly running work.

CONFLICT OF INTEREST

We have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data will provide on request basis.

AUTHOR'S CONTRIBUTION

This research work conducted by RK; PK led the manuscript writing and BS analysed the data; All authors contributed significantly to the drafts manuscript and approved the final version for publication.

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How to cite this article: Reena Kumari, Pratibha Kumari and Babloo Sharma. 2025. Laser land levelling and double row planting improves productivity, water use efficiency and profitability of post monsoon sorghum in black soils. *Indian J. Soil Cons.,* 53(1): 83-88.