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Effect of precision land levelling on microenvironment and sorghum productivity in water scarce Deccan region

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ABSTRACT

Effect of favourable soil and canopy microenvironment, achieved through precision laser land levelling, on *rabi* sorghum (*Maldandi 35-1*) productivity was assessed for water deficit regions of Deccan Plateau of India. Laser levelled (0-0.1% grade) and adjoining unlevelled field plots (0.5-2% slope) located at six different experimental sites (silty clay soil) were selected for study. Germination percentage, weed control, temporal soil moisture depletion (SMD), canopy temperature depression (CTD) and water productivity were monitored. SMD ranged 0.46-0.60 for levelled plots indicated no impact of water stress at Panicle emergence stage i.e. 75 day after sowing (DAS). However, grain yield was reduced maximum by 62% when SMD increased from 0.68 to 0.88 for unlevelled plots. Lowering of CTD values by 0.7 to 3.2ºC, in levelled plots indicated the ability of plants to maintain cooler canopy compared to unlevelled plots. Grain yield was reduced by 0.47 t ha^{-1} with every increase in 0.5% of slope in unlevelled plots, whereas it was negatively correlated with SMD and CTD values in both cases. Laser land levelling showed significant improvement in uniform soil moisture distribution, seed germination, weed control, initial crop establishment and irrigation water productivity. Precision levelling significantly improved soil and canopy microenvironment which favoured to increase the sorghum yield by 27-73% and substantially saved irrigation water (30.9%) compared to unlevelled fields.

Keywords: Laser land levelling, sorghum, water stress, soil moisture depletion, canopy temperature depression

Sorghum [*Sorghum bicolour* (L.)Moench] is fifth most important coarse cereal crop grown under diversified rainfed and irrigated conditions worldwide for food, feed and fodder with immense potential of biomass and bio-fuel generation (Rooney and Waniska, 2000). Rise in temperature, heat wave events and shifting in precipitation pattern as result of global climate change significantly increases the chances of lowering productivity in many high input crops (Dahlberg *et al.,* 2011). In these situations, sorghum cultivation can be an efficient alternative in water deficit regions where the water and heat stress are major problems (Berenji and Dahlberg, 2004). Moreover, sorghum being C_4 plant responds positively to elevated CO_2 concentrations and has a potential for substantial increase in grain yield (Reeves *et al.,* 1994).

Levelling of uneven soil surface is a precursor to efficient soil, water and crop management practices and it improves the germination, establishment and yields of crops due to homogeneous rain/irrigation water distribution and soil moisture availability (Cooper, 2009; Jat *et al.,* 2006). The cost and time are major limitations in traditional levelling methods and varied with environmental factors, topography, volume and type of soil and levelling equipment (Kaur*et al.*, 2012). Recognizing these limitations, precision laser land levelling technique has emerged as an effective method to level the fields in shortest possible time with higher level of accuracy (± 2 cm). Under similar fertility levels and land configurations, laser land leveling enhanced 37-39% water productivityand 34% water-use efficiency for rice–wheat cropping system in Indo-Gangetic Plain of South Asia (Choudhary *et al.,* 2002). The conventional surface irrigation practices in unlevelled field resulted in excessive loss of irrigation water through evaporation and deep percolation by reducing application efficiency up to 25 per cent (Sattar*et al.,* 2003). Laser land levelling helps in even distribution of soluble salts in salt-affected soils (Khan, 1986), increases 3-5% cultivable land area (Choudhary *et al.,* 2002), reduces weed intensity, improves crop etablishment and microclimatic conditions (Rickman, 2002), and results in saving of 20-30% irrigation water (Khattak *et al.*, 1981).

Application of precision levelling technology for sorghum crop offersa great potential for creating favourable microclimatic alterations which may help in water saving, improving yield level and grain quality, particularly in water deficit Deccan Plateau of India and other countries in the world facing similar abiotic stress conditions. The crop tolerance to water deficit can be assessed in terms of canopy temperatures depression as water stress indicators (Jackson *et al.,* 1981; Bahar*et al.,* 2008). Therefore, the present investigation was carried to study the effect of precision laser land levelling on altering the soil and canopy microenvironmentand its impact on sorghum (*Maldandi 35-1*) productivity generally cultivated under water stress conditions on medium black soil.

MATERIALS AND METHODS

Details of field experiment

The experiment was conducted with sorghum variety (*Maldandi 35-1*) during two successive *rabi* seasons of 2012 and 2013 on medium black soil (silty clay) at six different randomly selected farmers' sites (A-F) at village Jalgaon of Baramati Tehsil under Pune District; which falls under the agro-climatic region, Western Maharashtra Scarcity Zone (MH-6), Maharashtra, India. All experimental sites were divided into two plots (i.e. precision levelled and adjoining unlevelled plot) each of size about 0.40 ha. Thus, total 12 experimental plots were formed consisting of six precision lasers levelled (0-0.1% grade) and adjoining six unlevelled plots (0.5-2% slope), which were presumed as control. The average land slopes of 2, 0.8, 0.6, 0.5, 1 and 1.5% were observed for unlevelled plots located at A, B, C, D, E and F site, respectively. The sowing was done in all plots on the same day using bed method (18 m × 2 m) with 28.6-31.2 % residual soil moisture content (wet basis) as result of average rainfall of 17.3 cm during respective years. Unlevelled field plots adjacent to respective precisely laser levelled plots were selected for comparison to reduce the effect of inherent soil variability. Irrigation water was applied as per the requirement of laser levelled plots (i.e. 7.9 cm (I_1) at seedling elongation (30 DAS) and 9.6 cm (I_2) at panicle emergence stages(70 DAS) through two surface irrigations. The same amount of water was applied to adjoining unlevelled fields and consequent soil moisture and water stress were monitored. As the crop in unlevelled fields suffered the severe water stress condition at grain development stage, additional 7.8 cm (I_3) of irrigation water was applied to unlevelled plots only as life-saving irrigation. Total rainfall of 8.4 cm and 2.7cm were received during the crop growing period(September-January) due to returning monsoon in the years 2012 and 2013, respectively. The average crop water requirement (ETc) during crop period was estimated using CROPWAT 8.0 (FAO, Rome) based on two years weather data collected from nearest agrometeorological observatory at NIASM, Baramati. The standard crop cultivation practices for *rabi* sorghum viz. seed rate (8 kg ha^{-1}), fertiliser application (80 kg N and 40 kg P_2O_5) etc., were followed.

Soil properties

The soil samples were collected at three randomly selected locations up to depth of 0-25 cm and soil analysis was carried at Soil Testing Laboratory, KVK, Baramati. The soil properties like pH, EC, N, P, K and organic carbon were measured using standard procedures available in the literature. The average values of soil properties for six selected sites at different geographical locations are given in the Table 1.

Measurement of soil and canopy microenvironment parameters

The average soil moisture content (wet basis) was measured using standard gravimetric method (105ºC, 24h) by randomly collecting soil samples at 0-25 cm depth from three representative portions (i.e. upper, middle and lower) within the plot (Black, 1965). The procedure was repeated for every 15 days interval prior to sowing and just before start of next irrigation during entire cropping period to determine the temporal changes in soil moisture distribution for all experimental plots. The germination percentage was counted in terms of numbers of seedling per unit area (m^2) at 14 days after sowing (DAS) with constant seed rate (8 kg ha^{-1}) from above defined portion of both laser land levelled and unlevelled plots.. Similarly, the total number of weeds per unit area (m^2) was counted at 30 days after sowing for all experimental plots. Soil moisture depletion (SMD) was determined at different growth stages of sorghum to assess the impact of the water deficit. The SMD is basically function of the moisture content at field capacity, permanent wilting point and actual moisture content recorded at 0"25 cm for particular crop growth stage and it is defined Eq. (1).

$$SMD=\frac{FC-\frac{\sum_i^n x}{n}}{FC-WP} \qquad (1)$$

Where, SMD= Soil moisture depletion

FC = Moisture content at field capacity of black (silty clay) soil, 35% (wb)

WP= Moisture content at wilting point of black (silty clay) soil, 15% (wb)

$\frac{\sum_i^n x}{n}$ = Mean of three observed moisture contents at particular growth stage within plot

The SMD values determined by Eq. (1) lies between 0 to 1 where lowest value 0 indicates no stress condition and 1 indicates that crop is under severe stress condition.

The effect of water stress was monitored at panicle emergence stage (75 DAS) in sorghum where the minimum soil moisture content was recorded during crop growing period for all experimental plots. Hence, impact of water stress was expected to be reflected in terms of the canopy temperature depression (CTD) at this critical stage. The CTD was calculated using average canopy temperature of crop minus corresponding ambient air temperature (Bahar*et al.,* 2008). The average canopy temperature of the sorghum was recorded during cloudless period (12.00 AM - 1.00 PM) on 75 DAS for all levelled and unlevelled plots individually using infrared thermal imaging system (Model: Variocam hr-575, Infratech, Germany) just before start of 2nd irrigation. Three observations from the top of the canopy at upper, middle and lower portion of the same plot were taken at an angle of approximately 30° to horizontal covering maximum area of interest (Fischer *et al.,* 1998). The corresponding ambient temperature was measured using glass thermometer (calibrated from IMD). The amount and depth of water applied during eacsh irrigation was determined by measuring discharge volume at field outlet using water meter (Model: Kranti-100 mm, B.M. Meters Pvt. Ltd., India). The quantity of water saved was determined by the difference between water applied to precisely levelled and corresponding adjoining unlevelled experimental plots. The grain yield was taken from a sample area of 1 m^2 from all the three portions defined above of the plot. The water productivity for grain was calculated by dividing the sorghum grain yield (kg) to the total quantity of irrigation water applied (m^3) for given plot.

Statistical analysis

All soil and crop microclimatic parameters were measured in triplicate and the data presented in the figures are the means of three independent observations. The one way ANOVA was applied to determine the level of significance within and between the experimental plots using SPSS 16.0 statistical software (SPSS, Inc., Chicago, IL, USA). Critical difference ($p \leq 0.05$) and standard error of means (SEm±) were tabulated. Mean separations were calculated based on the mean rankings at $p \leq 0.05$ using Duncan's Multiple Range Test. Coefficient of variation was also determined to measure the variability within and between experimental plots.

RESULTS AND DISCUSSION

Sorghum germination percentage and weed control

The variations in germination percentage of sorghum after 14 days of sowing under laser levelled and unlevelled plots at six different experimental sites (A-F) are given in Table 2. The germination of sorghum in a laser levelled plots was 6.2–8.9% higher as compared to unlevelled plots presumed as control. Statistical analysis showed that no significant difference in germination percentage was observed within precision levelled and unlevelled plots. Further, variability in germination percentage between plots reduced significantly with precision land levelled plots (CV=19.1%) as compared to unlevelled plots (CV=26.5%). The uniform moisture distribution to the entire field as result of laser land levelling might have promoted even germination of sorghum and better crop stand. The unlevelled plots exhibited low germination and patchy growth indicating water stress on crop due to non-uniform soil moisture distribution. These results were supported by previous studies for pea, wheat and rice (ASG GoI, 2011; Khan, 1986; Fischer *et al.,* 1998)evaluating influence of moisture stress on germination percentage. Total 23.4 39.3% reduction in weed population in case of sorghum crop after 30 days of sowing was recorded under precisely laser leveled plots in comparison to unleveled plots (Table 2). The wide variability in weed population within and between the plots was recorded for both levelled (CV=22.7%) and unlevelled (CV=29.1%) plots located at six different experimental sites. In laser levelled plots, uniform crop stand and growth helped to minimise the weed infestationsubstantially. Also the shifting of inherent weed seeds from top soil to sub soil layers during precision land levelling might have reduced weed population whereas sparsely sorghum population in water deficit unlevelled plots might have augmented higher weed seed germination present in top soil (ASG GoI, 2011).

Soil moisture distribution and crop evapotranspiration (ETc)

The temporal variations in soil moisture at root zone depth (0 25 cm) at different sites as influenced by applied irrigation and root water uptake are given in Table 3. Higher values of moisture content were recorded during initial crop growth period (up to 15 DAS) due to lower rate of soil evaporation and root water uptake. It ranged between 27.2–28.9% and 26.1–27.2% for levelled and unlevelled plots at 15 DAS, respectively. These values were reduced to 24.7–27.3% and 23.5–23.8% for levelled and unlevelled plots at 30 DAS, respectively. To maintain available moisture content, first irrigation (I_1) of 7.9 cm was applied by surface method at this stage for both cases. Thereafter, soil moisture content decreased with time and reached the lowest value at 75 days i.e. 23.1–25.8% for levelled plots and 17.4–21.5% for

Table 1: Black soil (Silty clay) properties for different sites (both laser levelled and adjoining unlevelled plots)

Site	Geographical location Latitude, Longitude, Altitude	Soil properties					
		pH	EC (dSm^{-1})	N ($kg\ ha^{-1}$)	P ($kg\ ha^{-1}$)	K ($kg\ ha^{-1}$)	Organic carbon (%)
A	18°12'51.2"N, 074°28'43"E, 572 m	8.72	0.47	159.8	31.2	303.2	0.66
B	18°12'58.5"N, 074°28'29.2"E, 571m	8.37	0.83	120.9	27.1	337.5	0.40
C	18°12'50.1"N, 074°28'28.6"E, 570 m	8.47	0.93	166.5	27.6	310.7	0.69
D	18°12'51.5"N, 074°28'25.2"E, 571.2m	8.40	0.71	122.9	21.3	292.1	0.51
E	18°12'59.1"N, 074°28'26.6"E, 571.5m	8.42	0.51	130.1	36.5	257.8	0.54
F	18°12'51.1"N, 074°28'28.2"E, 571.2m	8.72	0.53	159.2	40.3	303.2	0.66

Table 2: Average of number of sorghum seedling germinated (m^{-2}) at 14 DAS and weed population (m^{-2}) in sorghum at 30 DAS under precision levelled and unlevelled plots

Site	No. of sorghum seedling m^{-2} (at 14 DAS)		No. of weeds. m^{-2} (30 DAS)		Increase of sorghum germination (%)	Reduction of weed population (%)
	Levelled	Unlevelled	Levelled	Unlevelled		
A	18.7 a	17.3 a	19.3 bc	29.0 ab	7.7	33.3
B	20.3 a	18.7 a	13.3 cd	21.3 bc	8.9	37.5
C	19.0 a	17.7 a	7.3 d	10.0 c	7.5	26.7
D	22.7 a	21.3 a	22.3 ab	32.7 ab	6.2	31.6
E	19.7 a	18.3 a	27.3 a	35.7 a	7.3	23.4
F	19.3 a	18.0 a	18.7 bc	28.0 ab	7.4	39.3
SEm±	2.19	2.83	2.37	4.38		
CD(*P=0.05*)	6.76	8.74	7.30	13.51		
CV (%)	19.1	26.5	22.7	29.1		

unlevelled plots (Table 3). This might be due to higher rate of root water uptake by crop during this period matched with panicle emergence stage. Almost similar trend of soil moisture content was observed for both cases with comparatively lower values for unlevelled plots up to 75 DAS (Fig. 1 illustrates the pattern for site A). As values in unlevelled plots were closer to wilting point (15%), crop in those plots were under severe water stress at 75 DAS. At this stage irrigation water of 9.6 cm (I_2) was applied in both levelled and unlevelled plots. At 90 DAS, moisture content in levelled plots varied 23.8–26.6%, however, it varied between 21.4 to 22.9% for unlevelled plots as a result, additional life-saving irrigation (I_3) of 7.8 cm was applied only in the unlevelled plots. Though soil moisture content at 105 DAS was lower in case of levelled plots, it had no significant effect on crop yield as crop was already at maturity stage.

The root water uptake is directly proportional ETc. The root water uptake and applied irrigation water influenced the temporal changes in moisture content. The average ETc based on two years' weather data (2012 and 2013) is given in Fig. 1. Total amount of ETc was 38.5 cm and total amount rainfall and irrigation water for levelled and unlevelled plots were 40.3 and 48.1 cm, respectively. Thus, applied irrigation water was more efficiently used by the crop in levelled plots.

In general, it was also observed that soil moisture content decreased with increase in slope (%) of the unlevelled plots. For example at 75 DAS, moisture content of 17.4, 19.2, 21.1, 21.5, 18.7 and 18% were observed at site A, B, C, D, E and F, respectively, representing 2.0, 0.8, 0.6, 0.5, 1.0 and 1.5% slope. It clearly indicated that there was an uneven distribution of applied irrigation water and higher runoff losses due to increase in slope in case of unlevelled plots. A significant difference in moisture distribution pattern was observed with time and slope for both levelled and unlevelled plots ($p \leq 0.05$). This result is in good agreement reported by Zin El-Abedin (2006).

Soil moisture depletion (SMD)

SMD was estimatedin levelled and unlevelled plots (0.5-2.0 % slope) to differentiate the impact of precision

Table 3: Temporal variation in soil moisture content (0-25 cm depth) for levelled and unlevelled plots at different sites

Time (days)	Site A Levelled	Site A Unlevelled (2%)	Site B Levelled	Site B Unlevelled (0.8%)	Site C Levelled	Site C Unlevelled (0.6%)	Site D Levelled	Site D Unlevelled (0.5%)	Site E Levelled	Site E Unlevelled (1%)	Site F Levelled	Site F Unlevelled (1.5%)
0	30.2 a	29.9 a	31.1a	30.2 a	29.2 a	28.6 a	31.2 a	29.6 a	30.1 a	29.3 a	30.2 a	30.0 a
15	27.2 b	26.2 b	28.5 b	27.2 b	26.5 abc	26.1 ab	28.2 b	27.2 ab	27.9 b	26.5 ab	28.9 b	26.8 ab
30	25.1 cd	23.5 bc	26.6 cd	25.8 bc	24.7 bcd	23.8 bcd	25.8 c	24.3 b-e	26.5 bc	24.9 bc	27.3 c	23.8 bc
45	26.2 bc	24.5 bc	27.7 bc	25.9 bc	26.7 ab	25.9 ab	26.2 bc	26.1 bc	27.9 b	25.2 bc	28.6 b	25.0 bc
60	25.1 cd	22.1 c	26.5 cd	22.9 de	24.5 bcd	23.1 be	25.1 cde	23.4 cde	26.4 c	21.7 de	26.9 c	23.0 bc
75	23.2 de	17.4 d	24.1 ef	19.2 f	23.10 de	21.1 de	23.5 de	21.5 e	23.5 d	18.7 e	25.8 d	18.0 d
90	25.1 cd	21.4 c	25.7 de	23.4 cde	23.80 cde	22.7 cde	25.5 cd	22.9 cde	26.2 c	22.7 cd	26.6 cd	22.3 c
105	22.8 e	24.2 bc	23.1 fg	25.2 bcd	21.10 ef	24.8 bc	23.2 e	25.2 bcd	23.3 d	24.9 bc	24.3 e	25.0 bc
120	20.1 f	22.9 bc	21.8 g	21.9 e	19.80 f	20.6 e	19.5 f	22.0 de	21.5 e	20.9 de	22.8 f	22.1 c
SEm±	0.66	1.19	0.54	0.85	0.94	1.05	0.70	1.14	0.50	1.04	0.30	1.35
CD ($P \leq 0.05$)	1.95	3.53	1.62	2.52	2.78	3.13	2.07	3.39	1.50	3.08	0.88	4.00

laser land levelling on availablemoisture and enhanced root water uptake. Fig. 2 shows that SMD values varied with depth of irrigation water applied, crop growth stages and slope of the fields and generally increased with time. It might be due to increase in water uptake by sorghum plants with time during crop growth period. The results revealed that values of the SMD <0.4, 0.4–0.6 and >0.6 correspond to no stress, optimal and higher stress conditions for sorghum, respectively. The maximum SMD values of 0.68–0.88 at critical stage of panicle emergence (75 DAS) indicated that there was severe water stress on sorghum crop for unlevelled plots. However, no stress impact was noticed at same stage under levelled plots and corresponding SMD values (0.46-0.6) were within range of optimal category whereas highest SMD values (0.61-0.75) were noticed at 105 DAS in case of levelled plots as crop already attained maturity. It was also observed that SMD increased with increase in slope (%) of the unlevelled plots of different sites. For example at critical stage of 75 DAS, highest value of SMD viz., 0.88, 0.85, 0.82, 0.79, 0.70 and 0.68 was reported at corresponding slope value of 2.0, 1.5, 1.0, 0.8, 0.6 and 0.5% for unlevelled plots of site A, F, E, B, C and D, respectively, indicating importance of laser levelling in water management. The same was also observed for all other crop stages.

Relationship between CTD, SMD and grain yield

The relationship of CTD and SMD with grain yield was evaluated at critical growth stage i.e. panicle emergence stage (75 DAS). The CTD values changed significantly for all experimental plots, located at six different sites (A-F) as shown in Fig. 3. CTD measurements of sorghum grown under unlevelled plots had higher values of 3.1–5.4°C than precision laser levelled plots (1.4-2.6 ºC). This clearly indicated that precision land levelling helped to keep leaf canopy cooler in levelled plots whereas unlevelled plots faced severe water stress (Fig. 4). This might be due to sufficient and uniform moisture available for plant root uptake under precision levelled plots at 75 DAS. Highest grain yield of 2.67 t ha^{1} and 1.25 t ha^{1} were recorded at lowest CTD values of 1.4ºC and 3.1ºC for precision land levelled and unlevelled plots, respectively. Similarly at highest CTD values of 2.6ºC and 5.4ºC, lowest grain yield of 1.53 t ha^{1} and 0.48 t ha^{1} were recorded for precision land levelled and unlevelled plots, respectively. The study found that at every 1ºC rise of CTD value, the grain yield decreased drastically to 0.93 t ha^{-1} ($y = 0.9342x + 3.9114$, R^2=0.94) under precision land levelling fields than 0.28 t ha^{-1} ($y = 0.2814x + 2.0501$; R^2=0.83) in unlevelled plots (Fig.5). It indicates that grain yield was more sensitive to CTD values

Table 4: Grain yield and water productivity of sorghum under precision levelled and unlevelled plots (0.5 –2.0% slope)

Site	Slope (%) unlevelled plot	Grain yield (t ha^{-1})		Irrigation water productivity (kg grain m^{-3} water)	
		Levelled	Unlevelled	Levelled	Unlevelled
A	2.0	1.75	0.48	0.100	0.019
B	0.8	1.92	1.01	0.110	0.040
C	0.6	1.53	1.11	0.087	0.044
D	0.5	1.76	1.25	0.101	0.049
E	1.0	1.85	0.96	0.106	0.038
F	1.5	2.68	0.75	0.153	0.030
SEm±		0.03	0.10	0.011	0.004
CD (P=0.05)		0.09	0.32	0.023	0.010
CV (%)		7.0	19.3	6.7	18.9

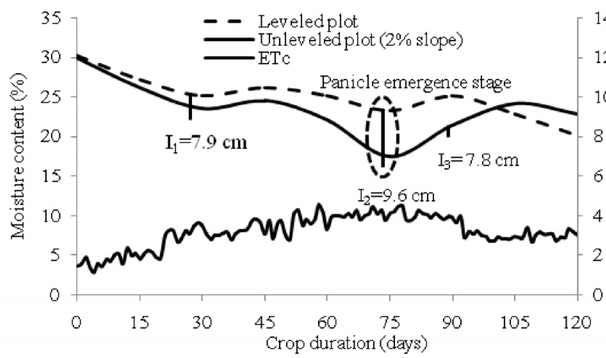

Fig. 1: Temporal moisture content for levelled and unlevelled plots (2% slope) at site A

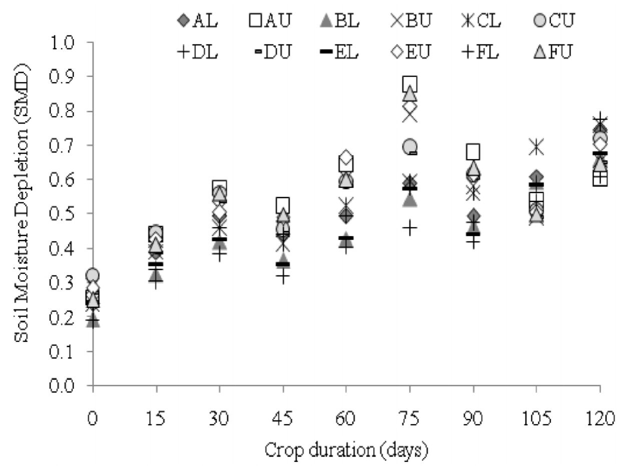

Fig.2: Temporal changes in SMD with depth of irrigation water applied, crop growth stages and slope of land (AL: Site A with Laser Land levelling plot and AU: Site A with unlevelled plot)

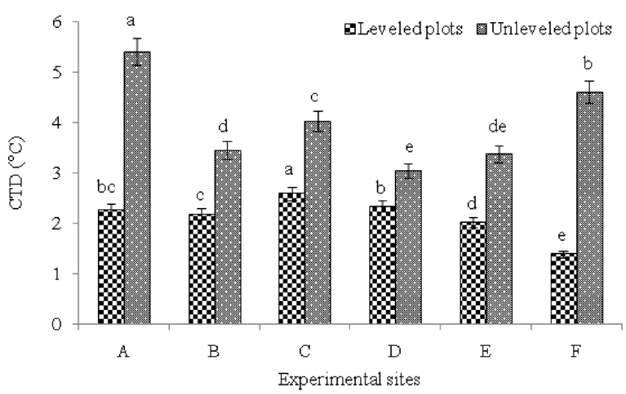

Fig.3: CTD values measured at 75 DAS for sorghum under laser levelled and unlevelled plots

(1.4-2.6 ºC) for levelled plot. Bahar *et al.* (2008) reported higher and positive CTD values for wheat grown under irrigated condition.

The impact of water stress on the grain yield at 75 DAS with maximum SMD values is shown in Fig. 6. In general, grain yield decreased with increase in SMD values. SMD values >0.6 obtained under unlevelled plots indicated that crop under water stress condition resulted lower grain yields of 0.48-1.25 t ha^{-1}. The higher grain yield of 1.53-2.67 t ha^{-1} wasobtained under precision land levelling for no water stress condition (SMD <0.6). The highest reduction of 61.9% in grain yield was measured between highest (0.88) and lowest (0.68) values of SMD indicating the severe impact of water stress under unlevelled condition. Further, it could be stated that precision land levelling enhanced grain yield by 26.5-72.8% compared to unlevelled plots.

Water productivity and profitability

The results revealed that significant improvement in grain yield and irrigation water productivity was achieved due to precision land levelling compared to traditional unlevelled plots (Table 4). The average grain yield and

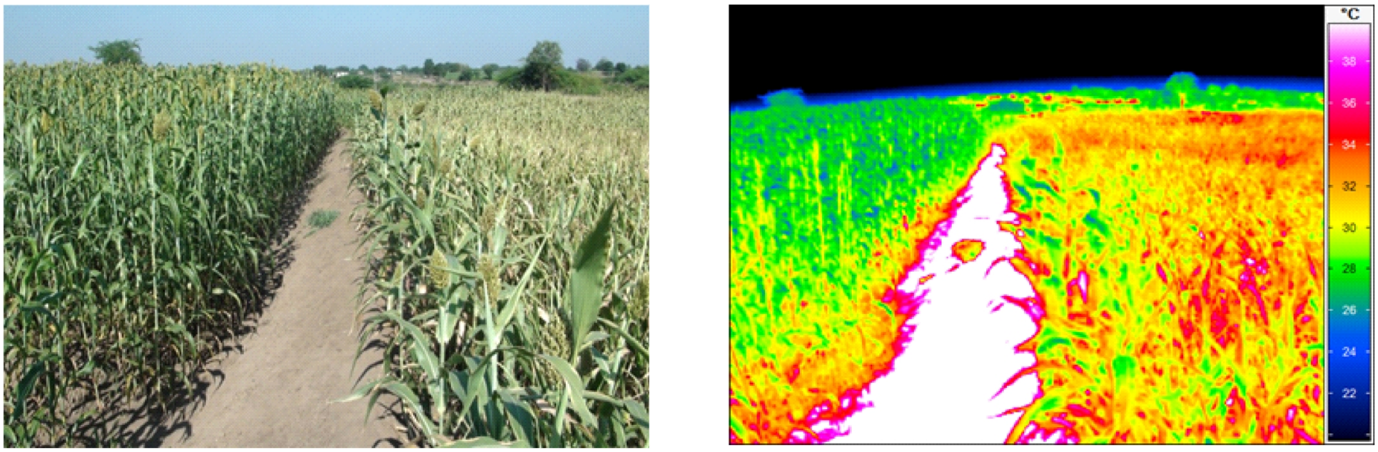

Fig.4: Infrared thermal image representing intensity water stress in leaf canopy temperature of sorghum between levelled and unlevelled plots

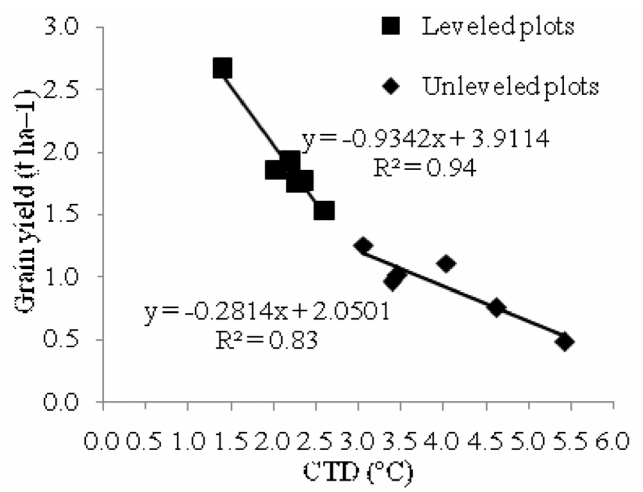

Fig.5: Effect of CTD at 75 DAS on sorghum grain yield for levelled and unlevelled plots

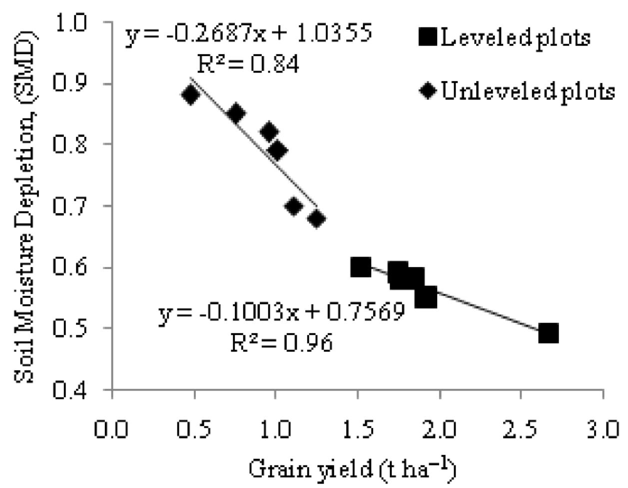

Fig.6: Relation between grain yield and SMD values at 75 DAS

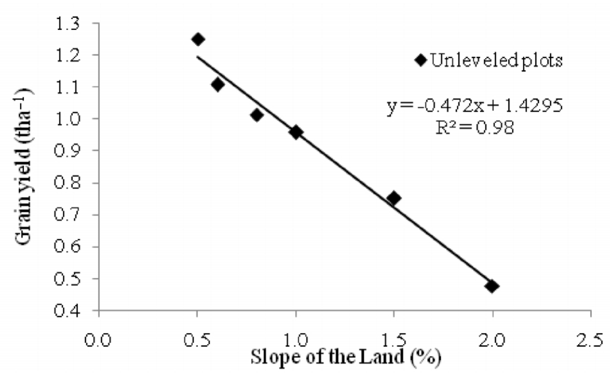

Fig.7: Variation in sorghum yield with slope in unlevelled plots

irrigation water productivity of sorghum, respectively, was recorded as 1.91 t ha^{-1} and 0.11 kg grain m^{-3} water under laser land levelling which was superior to traditional unlevelled plots being 0.93 t $ha^{-1}$and 0.037 kg grain m^{-3} water. The statistical analysis revealed that the coefficient of variation in grain yield and irrigation water productivity between the plots with laser land levelled plots was 7 and 6.7% compared to unlevelled plots value of 19.3 and 18.9%, respectively. The total 30.9% of irrigation water saving under laser land levelling was achieved as additional 7.8 cm lifesaving irrigation was applied at 90 DAS for sorghum under unlevelled plots only. The 51.6% increase in average grain yield under precision land levelling compared to unlevelled plots might be due to uniform soil moisture distribution and sufficient water availability at root zone for crop growth. The reduction in grain yield can be attributed to water stress condition appeared at 75 DAS under unlevelled plots. The wide variability in grain yield under unlevelled plots could be attributed to variation in field slope (0.5-2%) for different selected sites (Fig.7). The grain yield and slope are negatively correlated as sorghum grain yield reduced by 0.47 t ha^{-1} with every increase in 0.5% of slope in unlevelled plots (y = 0.472x+1.4295, R^2 = 0.98).

CONCLUSIONS

Rabi sorghum productivity can be significantly enhanced by altering the soil and canopy microenvironment with adoption of precision laser levelling practice under limited water available conditions in Deccan plateau regions of India. CTD and SMD can be effectively used to assess the performance of precision land levelling on improving the soil moisture and canopy microclimatic conditions. Advantages with precision land levelling are uniform soil moisture distribution, optimum seed germination, effective weed control, initial crop establishment and its ability of plants to keep leaf canopy cooler at critical stages avoiding water stresses which are otherwise experienced in unlevelled plots. The SMD values > 0.6 at critical stage indicated that water stress condition resulted in lower sorghum productivity under unlevelled plots. The study confirms that precision laser land levelling, a promising technology, can be used to significantly improve microenvironment and enhance sorghum productivity by 26.5-72.8% along with an additional saving of 30.9% irrigation water depending upon the soil type and slope of the field.

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