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Growth and Yield of Rabi Sorghum as Influenced by Soil and Water Conservation Structures

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Abstract Investigation carried out to know the impact of soil and water conservation structures on soil moisture, growth and yield of rabi sorghum revealed that the soil moisture was more in levelled portion of zingg terrace, graded zingg terrace and contour border strip treatments. Plant height, total dry matter production and its distribution into leaf, stem and reproductive parts, leaf area index (LAI), leaf area duration (LAD), crop growth rate (CGR), net assimilation rate (NAR) and specific leaf weight were significantly higher in contour border strip, zingg and graded zingg terrace and increased the grain yield by 103.6, 105.0 and 94.8 % during the first and 101.8 and 112.4, 110.5% during the second years over the control.

Key words Conservation structures, Soil moisture, Rabi sorghum, Growth parameters

The most efficient and cheapest way of conserving rainwater is to hold it *in situ*. Mechanical measures involve creating barriers across the direction of flow of water and thus, retard or retain runoff. Bunding and levelling alone or in combination provided more rainwater intake compared to the unbunded and unlevelled land (Singh & Ram 1976). Several workers have observed increased grain yield due to bunding and/or bunding and levelling (Dixit 1986).

Though work has been done relating to the effectiveness of soil and water conservation structures, their effect on crop growth and yield are limited and inconclusive. Thus, a research programme was undertaken on vertisols of the Agricultural Research Station, Bijapur with the objective of knowing the impact of different mechanical structures on soil moisture, crop growth and yield of rabi sorghum.

Materials and Methods

The experiment consisting of seven treatments (contour bund, broad base bund, graded bund, zingg terrace, contour border strip, graded zingg terrace and unbunded /control) was conducted for two seasons (1988-89 and 1989-90) and laid out in randomised block design with more than one observation per experimental unit in two replications. The land was divided into independent catchments of one hectare and the different structures were aligned by adopting vertical interval of 1 m, except for contour border strip which were constructed at 0.3m vertical interval by levelling the land breadth wise. A bund cross section of 1.49 m^2 was adopted for contour bund and zingg terrace, whereas 1.53 and 0.92 m^2 was adopted for the broad base bund, and graded bund and graded zingg terraces, respectively. In case of contour border strip, border ridge of 0.24 m^2 was adopted. In zingg terrace 1/3 rd inter-terraced area towards the upstream side of the bund was levelled to have uniform spread of runoff water in levelled area. In graded zingg terrace in addition to the above a 0.2% grade was provided along the bund for reducing excess runoff at non-erosive velocity. These structures were laidout at the beginning of rabi season 1988-89 before sowing. Rabi sorghum (cv. M-35-1) was sown on 4th October 1988 and 12th October 1989 during the first and second years' with a spacing of

60 cm between rows and 15 cm between plants. Fertilizer and plant protection measures were taken up as per the recommended package of practices for the region. Harvesting of the crop was done on 16th February, 1989 and 20th February, 1990 during first and second years.

For the purpose of recording growth and yield observations, each plot was divided into three sub-sampling plots with an area of 20 m x 3 m. Plant growth parameters were recorded after 30,60,90, days after sowing (DAS). Five plants were randomly selected and tagged for recording plant height and five plants were uprooted and separated into leaf, stem and reproductive parts. The samples were air dried and then oven dried at 65°C, till a constant weight was observed and the average was recorded as total dry matter (DM) plant $^{-1}$ and its distribution into leaf, stem and earhead. The leaves of uprooted plants were used for calculation of leaf area (LA) plant^{-1} as per Stickler et al. (1961) method. From LA and total DM (LA1) leaf area index, (Sestak et al. 1971), and (LAD) leaf area duration (power et al. 1967), (CGR) crop growth rate (Watson 1952), (NAR) net assimilation rate (Gregory 1926), and (SLW) specific leaf weight (Yoshida et al. 1972) were calculated. The air dried ears from each plot were threshed, cleaned and the weight of grains was recorded.

Fodder yield of sorghum was recorded after complete sun drying the stalks from each plot and from this stover yield ha^{-1} was worked out. In zingg and graded zingg terraces the grain and fodder yield from levelled portion and both from levelled and unlevelled portion was used to express grain and fodder yield on levelled area basis and on whole area basis, respectively. Soil moisture determinations were made gravimetrically from the soil samples collected from 0-90 cm soil depth before sowing.

Results and Discussion

Soil Moisture and Yield

The soil moisture stored in different treatments at sowing was superior to control. The mean values of two seasons with respect to total soil moisture indicated the highest soil moisture in levelled portion of zingg terrace followed by levelled portion of graded zingg terrace and contour border strip (39.6 cm) The substrantial higher moisture in these treatments appear to be due to increased opportunity time for the rainwater to stand *in situ* and infiltrate into the deeper layers of soil profile.

The grain yield showed a large variation ranging from 1393 kg^{-1} ha^{-1} in unbunded control to 2869 kg ha^{-1} in levelled portion of zingg terrace during first year. During the second year it varied from 1253 Kg^{-1} ha^{-1} in unbunded control to 2662 kg^{-1} ha^{-1} in levelled portion of graded zingg terraces. When the grain yield on whole area basis for the treatment was considered it was highest in contour border strip. The per cent increase in grain yield over control in zingg and graded zingg terrace treatments was 105 and 94.8 during the first year and 110.2 and 112.5 in second year.

The increase in grain yield in zingg terrace, contour border strip and graded zingg terrace could be attributed to the decreased runoff and the increased soil moisture storage . Thus, the comparison of yield on whole area basis clearly shows that higher the percentage of area levelled, more is the yield advantage, than simple bunding. As little or no rains are received after sowing of rabi crops and the crops grew on stored soil moisture. The conservation structures which help to retain more rainwater in the soil profile have resulted in increased yields. This hypothesis has further been confirmed by the significant positive correlation observed between grain yield and moisture stored at sowing.

Growth and Drymatter Production

The plant height at harvest was the highest in zingg terrace followed by contour border strip and graded zingg terraces (Table 1). The reduced runoff and increased soil moisture in zingg terrace, contour border strip and graded zingg terrace treatments appear to be the major factors for increased plant height. Vegetative growth was found to be particularly sensitive to moisture stress as

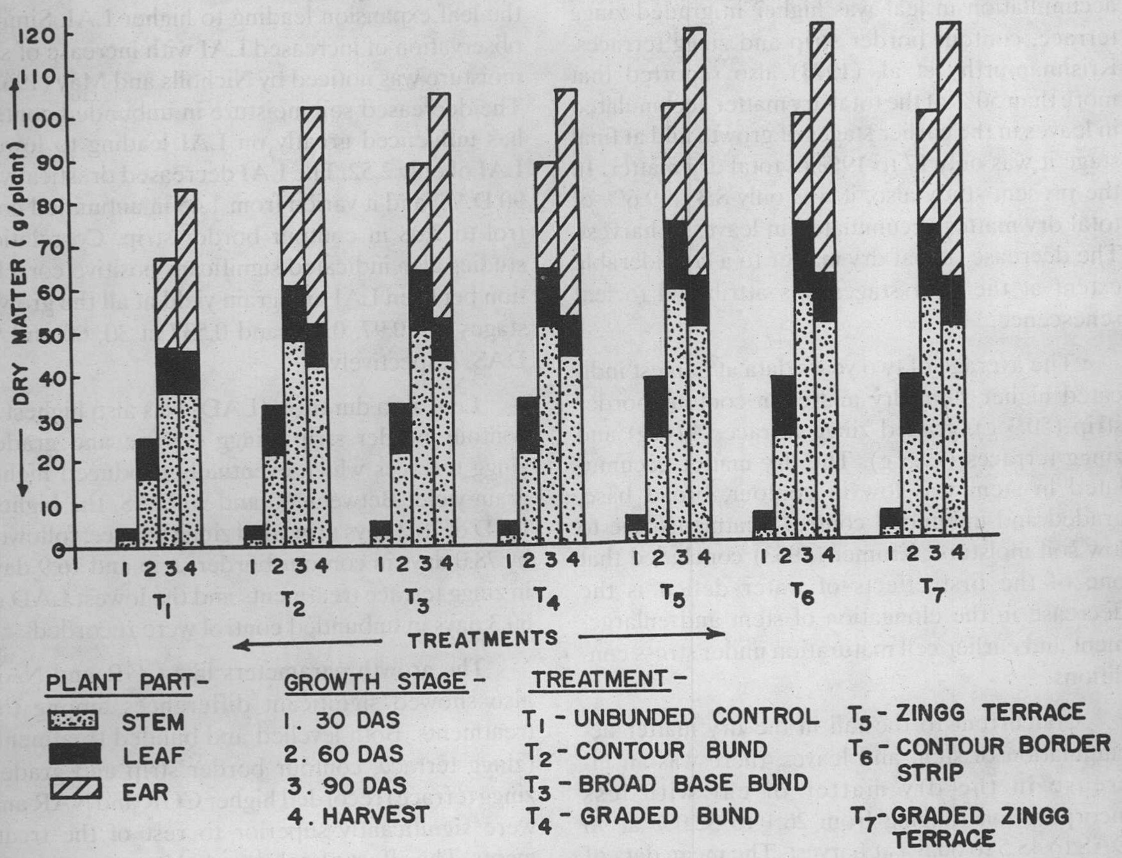

Fig 1

growth is closely related to turgor and any loss of turgidity stops cell enlargement and results in smaller plants and also change the pattern of growth (Kramer 1963). In the present investigation heavy runoff and decreased soil moisture in unbunded control may have affected cell enlargement, and hence plants height was stunted.

There was a rapid increase of total dry matter (Fig1) between 30 to 60, 60 to 90 and a steady increase from 90 DAS to harvest. It was higher in both levelled and bunded treatments viz., zingg terrace, contour border strip and graded zingg terraces, recording 119.4, 119.1 and 118.9 g, respectively at harvest. However, the dry matter accumulation in contour, broad base and graded bund treatments was also significantly higher than unbunded control. The dry matter production was more after the emergence of ears (after 60 DAS). This may be due to photosynthetic contribution of the ear, peduncle and the flag leaf. Correlation studies also indicated significant positive relationship with yield at all the growth stages ($r = 0.799$, 0.924, 0.954 and 0.965 at 30, 60 and 90 DAS and at harvest, respectively).

Although the dry matter production in general, is indicative of the efficiency of a genotype, the pattern in which it is distributed in different plant parts would give a better understanding of a genotype in question.

The dry matter accumulation in leaf increased upto 90 DAS and then started declining towards harvest. At all the growth stages the dry matter accumulation in leaf was higher in graded zingg terrace, contour border strip and zingg terraces. Krishnamurthy et al. (1973) also reported that more than 50% of the total dry matter accumulated in leaves in the earlier stages of growth and at final stage it was only 17 to 19% of total dry matter. In the present study also, it was only 8.3 to 9.6% of total dry matter accumulated in leaves at harvest. The decrease of leaf dry matter to a considerable extent at the later stages was attributed to leaf senescence.

The average of two years data at harvest indicated higher stem dry matter in contour border strip (50.3 g), graded zingg terrace (49.6 g) and zingg terraces (49.5 g). The dry matter accumulated in stem was low in contour, broad base, graded and unbunded control treatments due to low soil moisture. Kramer (1963) concluded that one of the first effects of water deficit is the decrease in the elongation of stem and enlargement and earlier cell maturation under stress conditions.

Concurrent to the fall in the dry matter accumulation of stem and leaves, there was an increase in the dry matter of ear with less incorporation ranging from 26.1 to 32.0% at 90 DAS to 48.5 to 50.5%at harvest. The mean data of two years at harvest revealed higher dry matter of 59.4, 59.1 and 58.8 g in graded zingg terrace, zingg terrace and contour border strip, respectively, as compared to only 38.9 g in unbunded control.

Growth Parameters

The LAI in the present study increased with age reaching peak at 60 DAS and declined rapidly thereafter. The difference among the treatments were too low during 30 DAS. But at 60 DAS, the highest LAI was observed in the zingg terrace and the graded zingg terrace (3.13) followed by the contour border strip (3.12). Several workers while studying the soil-plant-water relations have concluded that growth is controlled directly by plant water deficits and indirectly by soil water deficit (Stout et al. 1978). Thus, in the present study, the increased soil moisture in zingg terrace, contour border strip and graded zingg terrace increased the leaf expansion leading to higher LAI. Similar observation of increased LAI with increase of soil moisture was noticed by Nicholls and May (1963). The decreased soil moisture in unbunded control has influenced greatly on LAI leading to lowest LAI of only 2.52. The LAI decreased drastically at 90 DAS, and it varied from 1.45 in unbunded control to 2.08 in contour border strip. Correlation studies also indicated significant positive correlation between LAI and grain yield at all the growth stages ($r=0.97$, 0.916 and 0.537 at 30, 60 and 90 DAS, respectively).

Leaf area duration (LAD) was also highest in contour border strip, zingg terrace and graded zingg terraces which eventually produced higher grain yield. Between 60 and 90 DAS, the highest LAD of 78.2 days in graded zingg terrace, followed by 78.0 days in contour border strip and 76.9 days in zingg terrace treatments and the lowest LAD of 60.3 days in unbunded control were recorded.

The growth parameters like CGR and NAR also showed significant differences among the treatments. Both levelled and bunded treatments (zingg terrace, contour border strip and graded zingg terrace) recorded higher CGR and NAR and were significantly superior to rest of the treatments. The effect of only bunded treatments (contour, broad base and graded bund) on growth parameters though comparatively lower than both the levelled and bunded treatments but was far superior to unbunded control.

The reduction in grain yield of sorghum due to moisture stress was due to significant reduction in leaf area per plant, LAI, LAD, CGR and total dry matter production per plant (Krishnamurthy et al., 1973). The higher dry matter production in zingg terrace, contour border strip and graded zingg terrace was the result of significantly higher LAI, NAR and longer LAD as compared to unbunded treatment. The peak period in the rate of dry matter accumulation (60 to 90 DAS) coincided with high NAR. In this context, it is worthy to note that the treatments viz., contour border strip, zingg terrace and graded zingg terrace treatments which recorded higher CGR, NAR, LAI and LAD had

Table 1 *Total soil moisture at sowing, (cm) grain yield, fodder yield and plant height during 1988–89 and 1989–90 versus conservation structures*

Treatment	Soil moisture at sowing			Grain yield (kg/ha^{-1})			Fodder yield (kg/ha^{-1})			Plant height (Cm)		
	88–89	89–90	Mean	88–89a	89–90	Mean	88–89	89–90	Mean	88–89	89–90	Mean
Unbunded control	30.9	29.1	30.0	1393	1253	1323	2336	2504	2420	141.2	170.7	156.0
Contour bund	35.0	32.9	33.9	1858	1665	1762	2682	3037	2861	154.0	192.9	173.5
Broad base bund	35.4	33.6	34.5	2055	1637	1846	2690	3063	2877	156.0	192.3	174.3
Graded bund	34.1	32.5	33.3	2109	1667	1888	2780	2963	2872	156.7	191.8	174.2
Zingg terrace	42.1	40.2	41.1	2869	2638	2754	3836	4262	4049	161.8	199.6	180.7
				(2239)	(1988)	(2114)	(3179)	(3410)	(3295)			
Contour border strip	40.8	38.5	39.6	2737	2529	2633	3694	3793	3744	162.1	198.9	180.5
Graded zingg terrace	40.6	39.1	39.9	2708	2662	2685	3718	4237	3978	156.4	200.4	178.9
					(2176)	(2002)	(2089)	(3269)	(3334)			
S Em ±	N A	N A		71.6	41.2		63.3	57.0		1.06	0.73	
				(67.3)	(38.2)		(53.4)	(60.7)				
C D at 5%				206.1	118.5		182.1	174.8		3.04	2.11	
				(193.6)	(110.1)		(153.8)	(164.1)				

N A : Not Analysed, Figures in parentheses are yields on whole area basis

Table 2 *Influence of conservation structures on plant growth parameters at 30,60 and 90 days after sowing (mean of two years)*

Treatments	LAI			LAD (days)		CGR (gdm^{-2} LA day^{-1})			NAR (gdm^{-2} LA day^{-1})		SLW (gdm^{-2})		
	30	60	90	30–60	60–90	30	60	90	30–60	60–90	30	60	90
Unbunded control	0.46	2.52	1.45	44.7	60.3	0.093	0.158	0.043	0.064	0.080	0.538	0.381	0.721
Contour bund	0.55	2.91	1.86	51.9	71.5	0.086	0.185	0.052	0.077	0.079	0.488	0.421	0.760
Broad base bund	0.66	2.81	1.79	52.2	69.0	0.105	0.206	0.048	0.073	0.090	0.429	0.464	0.822
Graded bund	0.64	2.18	1.77	51.0	68.1	0.103	0.203	0.053	0.076	0.091	0.442	0.479	0.839
Zingg terrace	0.81	3.13	1.99	59.1	76.9	0.113	0.233	0.053	0.072	0.091	0.424	0.510	0.859
Contour border strip	0.78	3.12	2.08	58.5	78.0	0.119	0.225	0.053	0.072	0.087	0.432	0.503	0.804
Graded zingg terrace	0.80	3.17	2.05	59.5	78.2	0.116	0.226	0.051	0.069	0.090	0.432	0.480	0.805
S Em ±	0.015	0.048	0.040	1.142	1.267	0.009	0.007	0.002	0.002	0.004	0.009	0.024	0.029
C D at 5%	0.041	0.139	0.116	3.288	3.648	0.026	0.020	0.006	0.007	N.S.	0.028	0.068	0.085

also indicated higher dry matter production and higher grain yield. Watson (1956) pointed out that variation in LAI and LAD contributed more to the variation in grain yield. However, in the present investigation, besides LAI and LAD, CGR and NAR were also higher in contour border strip, graded zingg terrace and zingg terraces, which recorded higher grain yield.

The SLW at initial growth stages (30 and 60 DAS) did not show any definit relationship with grain yield. However at 90 DAS higher SLW in all the conservation treatments especially in zingg terraces coincided with the highest grain yield. The negative and inconsistant relationship between SLW and grain yield in the early growth stages could be attributed to low amount of radiation reaching to the lower canopies due to higher LAI and more canopy coverage. The light limitation effect on SLW was clearly demonstrated by Pieters (1960) who stated that under low radiation, full light capture would be achieved by fewer layers of mesophyll, the substrate could arguably be used more efficiently to generate a larger area of thin leaves rather than a smaller area of thick leaves. It may be inferred that the higher SLW in zingg terraces at 90 DAS was an indicative of higher carbon exchange rate (CER) leading to higher grain yield.

Thus, it may be inferred that both levelled and bunded treatments (contour border, strip, zingg and graded zingg terraces) conserved more soil moisture as compared to the bunded treatments ablone (contour, broad base and graded bund). The increased soil moisture lead to increased dry matter production, plant height, LAI, LAD, CGR, NAR and SLW and the grain yield.

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