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Intercepted radiation as a tool to document plant population effects on leaf area and dry matter in sorghum *(Sorghum bicolor)**

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Destructive crop sampling is widely used to determine the effects of agronomic treatments on crop-growth rates. This technique is very labour-intensive (field harvesting, sample separation, leaf-area determination and dry-matter determination), which severely limits its application in crop science. On the other hand, radiation interception is relatively quick and easy to measure with modern microprocessor-based equipment, without the need for destructive harvests. Many researchers have found strong relationships between leaf area and radiation interception and between radiation interception and biomass accumulation in various crops. Terry (1990) demonstrated a direct relationship between intercepted radiation and total dry matter produced in sorghum [*Sorghum bicolor* (L.) Moench] over a number of environmental conditions. Monteith *et al.* (1989) reported that it is possible to predict both the growth and yield of sorghum and pearl millet [*Pennisetum glaucum* (L.) R. Br. L. emend. Stuntz] under moisture non-limiting situations, based on measured radiation interception and radiation-use efficiency.

The experiment was carried out to determine the relationship between percentage radiation interception, leaf-area index and total dry weight in sorghum, in different plant population treatments, to assess the possibility for using spot measurements of radiation interception to measure crop-growth response to the treatments.

The field trial was conducted at Patancheru, Andhra Pradesh, during the rainy season of 1995, on an Alfisol (*p*H 5.5, electrical conductivity 0.22 dS/m and organic carbon content 0.30%). The experiment was conducted in split-plot design, replicated 3 times, with plant populations as main plots and genotypes as subplots. Plant populations were 2.5, 5.0, 10 and 20 plants /m^2, established by hand-thinning at 16 days after emergence to plant spacings of 80, 40, 20 and 10 cm between plants within the row. The genotypes were 3 pairs of experimental near-isogenic lines (thought to differ in tillering ability, although differences were not expressed in this experiment). The plot size was 6 rows × 0.50 m × 10 m (30 m^2), with individual plots consisting of 2 broad (1.5 m) beds sown to 3 rows of sorghum each. The trial received a basal N and P_2O_5 application of 30 kg/ha each in the form of diammonium phosphate (28:28:0), through machine drilling. The crop was sown on 21 June by machine planter. Other cultural practices were kept optimum for the crop.

Sampling and radiation measurements

Destructive growth sampling was carried at 26, 41 and 57 days after emergence, using bordered areas of 4 rows × 50 cm (1 m^2). All plants in the sample area were harvested, brought immediately to the laboratory, separated into leaves and stems. Total leaf fresh weight from each plot was recorded, and a subsample of approximately 30% (fresh-weight basis) was taken for measurement of leaf area and leaf dry weight. Leaf area was measured by electronic leaf-area meter (LiCor 5000), and samples dried for 48 hr in an oven adjusted to 75^{0}C. Leaf-area index was calculated (from the subsample data) as the ratio of measured leaf area : harvested area. Stem (plus sheath) dry weights were measured on the whole samples.

Photosynthetically active radiation interception was measured during mid-day on all plots with a portable ceptometer at 5–6 days interval starting at 26 days after emergence and continuing to 61 days after emergence. The instrument was used to measure both above (incoming) and below (intercepted) canopy radiation; interception (%) was calculated as the ratio of intercepted : total incident radiation. Three measurements/plot were made above the canopy, followed immediately by 3 below the canopy (each reading below the canopy was an average of 6 individual readings, automatically calculated by the instrument). The instrument was placed diagonally in the centre of the 4 rows of each plot, covering the area under these 2 rows, the area between them was about 15 cm of the inter-row area on either side of the 2 centre rows.

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* Short note

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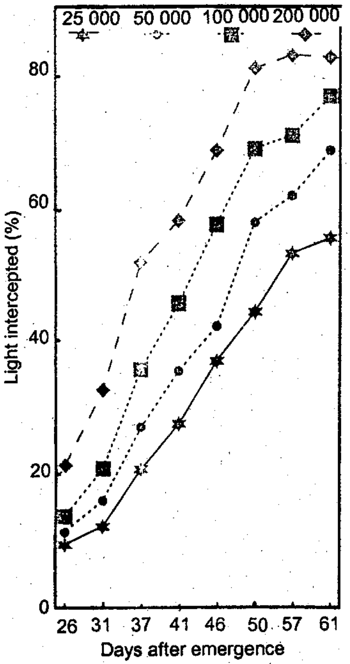

Fig 1 Per cent photosynthetically active radiation interception by the 4 plant population treatments from 26 to 61 days after emergence. Data points are means of 6 cultivars and 3 replications. Bar are SE of the means

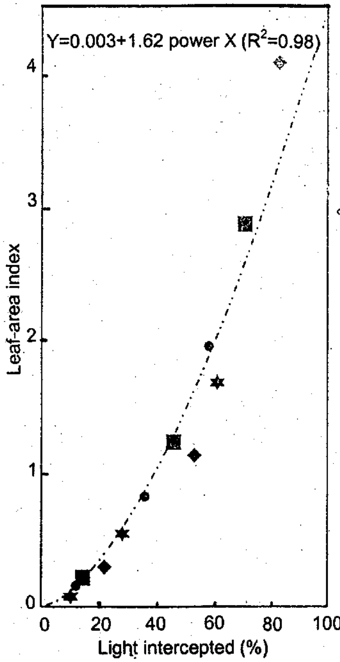

Fig 2 Relationship of leaf-area index (at the time of radiation interception measurement) and per cent photoynthetically active radiation interception measured by ceptometer. Symbols are the same as in Fig 1

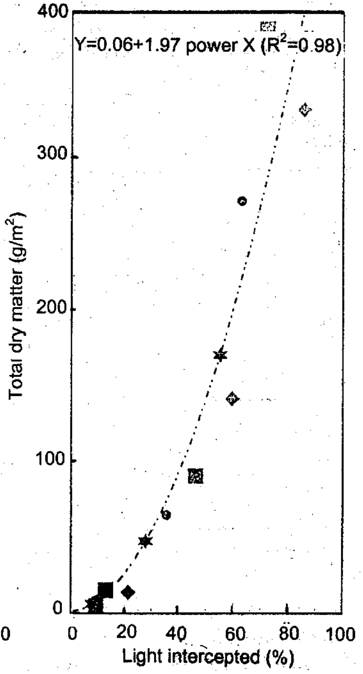

Fig 3 Relationship of total crop dry weight at the time of radiation interception measurement and per cent photosynthetically active radiation interception measured by ceptometer. Symbols are the same as in Fig 1

Treatment effects

The plant population treatments caused large and significant differences in both total dry weight and leaf-area index at all 3 sampling times (Table 1). Differences among the extreme populations in total dry weight were 4-fold in the first sampling date (26 days after emergence), similar to the differences in plant numbers. Differences among treatments declined to 2-fold at the final date (57 days after emergence), as the extra area per plant allowed a greater biomass production/plant in the lower plant populations. Differences in the leaf-area index among extreme plant populations were of similar magnitude to those in total dry weight at 26 days after emergence, but remained more than 3-fold at 57 days after emergence, indicating the increased growth (total dry weight) in the low populations was largely a function of greater radiation interception/plant. In general, the 2 lower plant populations (2.5 and 5.0 plants/m^2) were statistically similar to each other, but significantly different from the 2 higher populations (10 and 20 plants/m^2). The 6 genotypes in general did not differ among themselves in either LAI or total dry weight (data not presented).

The differences in growth among the 4 plant populations were well represented by the measured differences in radiation interception (Fig 1). Early differences in interception were similar in magnitude to differences in the populations; but by the end of the measurement period compensatory growth in the lowest population increased radiation interception to more than half (55%) of that of the highest population (83%). The highest population reached a maximum radiation interception of approximately 80% by 50 days after emergence, but the interception by lower populations continued to increase at 61 days after emergence. The differences in pre cent radiation intercepted among the plant populations were significant for the whole measured period (Fig 1). There were no statistical differences in per cent radiation intercepted among genotypes (data not presented).

Relationship of radiation interception and leaf-area index and total dry matter

There was a strong single relationship between measured leaf-area index and per cent intercepted radiation, across

Table 1 Plant population effects on total crop dry matter and leaf-area index at 3 sampling dates. Data are means of 6 genotypes for each plant population (rainy season 1995)

Population (plants/m^2)	Days after emergence 26	41	57
	Total dry matter (g/m^2)		
2.5	4.5	43.1	158
5.0	9.7	62.6	258
10	12.1	87.6	381
20	17.8	141.7	325
SE	2.5	11.9	14.9
F	**	***	***
	Leaf-area index		
2.5	0.08	0.55	1.14
5.0	0.16	0.83	1.68
10	0.30	1.95	4.06
SE	0.04	0.15	0.11
F	**	***	***

** $P < 0.01$; *** $P < 0.001$

all 3 sampling dates and across the whole range of plant populations (Fig 2). The relationship was non-linear (over the whole range of radiation interception values), however, reflecting decreases in interception per unit leaf area increased, due to both plant population differences and crop growth. Similar relationships have already been reported for both time (Gallagher and Biscoe 1978, Marshall and Willey 1983) and population effects (Leach and Beech 1988). There was a similar and equally robust relationship between crop biomass and percentage radiation interception across sampling dates and plant populations (Fig 3). Again the relationship was non-linear, probably reflecting the same competition effects that caused the non-linearity in the interception–leaf-area index relationship. This is in contrast to the linear and spacing-independent relation between dry-matter accumulation and intercepted radiation reported by McGowan *et al.* (1991), but similar to Rosenthal *et al.* (1993) for interception and leaf-area index among grain sorghum cultivars and plant densities.

The results confirm the hypothesis that treatment differences on crop growth (Table 1) can be effectively monitored by measuring radiation interception (Fig 1). Differences in radiation interception due to both plant population differences and to increasing crop growth closely mirrored differences in both crop leaf area (Fig 2) and crop biomass accumulation (Fig 3). Specific relationships between radiation interception and crop growth may vary somewhat with environment and crop species, but within experiments, radiation interception is very useful to track treatment effects on crop growth.

Radiation interception measurements required a maximum of 3 min/plot with the instrument used, compared to approximately 20 min to process a single growth sample needed for conventional crop sampling (harvest 3 min; remove leaves, 5 min; measure leaf area, 7 min; chop and weigh samples - 5 min. Thus costs of measurement of radiation interception are a fraction (< 20%) of the costs of crop sampling, and measurements can easily by carried out by a single person. The use of radiation interception to monitor treatment effects also eliminates the need for reliable electric power to operate leaf-area meters, drying ovens and electronic balances in remote areas. Further, radiation interception data can be recorded on the same plot area each time, reducing sampling error (over repeated measurements) and eliminating the need for large plots to accommodate regular destructive sampling.

SUMMARY

A study was carried out to compare weekly estimates of radiation interception to changes in leaf area and total crop biomass between 25 and 60 days after emergence in sorghum [*Sorghum bicolor* (L.) Moench] crop sown at 4 different plant populations. The weekly radiation interception measurements effectively differentiated the 4 plant population treatments, both directly and in terms of predicted leaf area and biomass, as the relationships of radiation interception to leaf area and biomass were constant across treatments and time. Thus ceptometer measurements of light interception provided an accurate and inexpensive way of estimating crop growth differences in sorghum.

REFERENCES

Gallagher J N and Biscoe P V. 1978. Radiation absorption, growth and yield of cereals. *Journal of Agricultural Science* **91**:47–60.

Leach G J and Beech J M. 1988. Response of chickpea accessions to row spacing and plant density on a Vertisol on the Darling Downs, south-eastern Queensland. II. Radiation interception and water use. *Australian Journal of Experimental Agriculture* **28** (3) : 377–83.

Marshall B and Willey R W. 1983. Radiation interception and growth in an intercrop of pearl millet/groundnut. *Field Crops Research* **7** : 141–60.

McGowan M, Taylor H M and Willingham J. 1991. Influence of row spacing on growth, light and water use by sorghum. *Journal of Agricultural Science* **116** : 329–39.

Monteith J L, Huda A K S and Midya D. 1989. A resource capture model for sorghum and pearl millet. (*in*) *Modelling the Growth and Development of Sorghum and Pearl millet*, pp 30–4. Virmani S M, Tandon H L S and Alagarswamy G. (Eds). International Crops Research Institute for the Semi - Arid Tropics, Patancheru, Andhra Pradesh, India Bulletin 12.

Rosenthal W D, Gerik T J and Wade L J 1993. Radiation-use efficiency among grain sorghum cultivars and plant densities. *Agronomy Journal* **85** : 703–5.

Terry A C. 1990. Growth and development of sorghum in relation to drought tolerance. *Dissertation Abstracts International B, Sciences and Engineering* **51 (5)** : 2131 B.