BRIEF COMMUNICATION

Grain yield in pearl millet in relation to source size and proximity to sink

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Abstract

Two pearl millet [*Pennisetum glaucum* (L.) R. Br. *emend.* Stuntz] hybrids GHB-30 and MH-179 were given defoliation treatments prior to anthesis comprising zero leaf to intact control. Keeping or removing even flag leaf only significantly altered the grain yield. With increasing leaf area (leaf numbers) the grain yield also significantly increased. Test mass showed more or less a similar trend. The leaves in the upper portion (nearer to sink) showed a greater contribution to the grain yield than the lower ones (away from sink). However, the highest leaf efficiency in terms of contribution per unit leaf area and the contribution by the whole leaf to the grain yield was recorded by 4th and 3rd leaf, respectively. The stem (covered with petioles) contributed to the extent of around 12 %. The existing leaves compensated to some extent for the defoliated ones.

Additional key words: defoliation; leaf area; *Pennisetum glaucum*; source size.

The importance of leaf area is signified for grain yield realisation in various crops by applying a great variety of treatments altering the balance between source and sink (King *et al.* 1967, Palit *et al.* 1979, Mayoral *et al.* 1985, Bagnall *et al.* 1988, Sawada *et al.* 1990). Feed forward effects of source on sink and feed back effects of sink on source indicate their mutual dependence (Foyer 1987, Geiger 1987). Further, crops differ greatly in the timing of competition between their various sinks. In axillary flowering crops, the vegetative and reproductive storage may overlap and compete for assimilates (Evans 1993). In groundnut, defoliation to the extent of 50 % did not affect the yield adversely and, moreover, there was an increase in the yield at a lesser defoliation level (Patel 1992). On the contrary, cereals such as pearl millet, by and large achieve their complete vegetative growth including both leaves and root, and then only enter final storage phase with their grains as predominant sink (Evans 1993). Leaves besides being the main photosynthesising organs also transpire resulting in a great water loss. In a rain fed crop like pearl millet which due to erratic rainfall usually experiences stress during post flowering stages, it is vital to know the minimum number of leaves required to sustain the maximum yield, so that transpiration water losses can be minimised by having optimum leaf area. This requires knowledge of the contribution of different leaves to grain yield in pearl millet.

Two pearl millet [*Pennisetum glaucum* (L.) R. Br. *emend.* Stuntz] hybrids GHB-30 and MH-179 grown in rainy season with recommended package of practices were given defoliation treatments prior to anthesis comprising zero leaf to intact control in a split plot design with three replications. In this split plot design the cultivars constituted the main plots while defoliation treatments the sub-plots. The plot size was 6 m^2. The row to row and plant to plant distances were maintained carefully at 0.6 and 0.15-0.20 m, respectively, while thinning the crop, so that the differences in the plant population among the plots were not significant. All the plants including their tillers in a plot were given defoliation treatments. Thus, the leaf area presented in the Tables 1 and 2 is the total area of leaves on the respective leaf positions viz. flag or 2nd leaf, *etc.* of the main culm as well as the tillers of a plant. Obviously the differences in numbers of tillers within the cultivars were not significant.

The experiment was repeated thrice in rainy seasons. The leaf area measurements were done employing linear measurement/area relationship using a constant (Chanda *et al.* 1985) and by *Licor*'s (Lincoln, U.S.A.) portable area meter *LI-3000A*. Leaf area is presented along with

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Table 1. Grain yield and test mass as influenced by defoliation intensity in pearl millet.

Defoliation treatment	Leaf area [cm^2 per plant]	Grain yield [$g\ m^{-2}$]	Test mass [g]
Zero leaf (naked stem)	0	30.0	3.566
One leaf (flag)	213.4 ± 23.4	53.5	3.248
Two leaves (flag + penultimate)	575.3 ± 70.5	93.1	4.345
Three leaves (flag + penultimate two)	974.3 ± 132.6	141.2	5.550
Four leaves (flag + penultimate three)	1355.3 ± 87.5	195.6	6.220
Five leaves (flag + penultimate four)	1697.9 ± 70.1	196.8	6.608
Six leaves (flag + penultimate five)	1993.2 ± 199.0	205.0	6.951
Lower 50 % (upper five leaves removed)	1153.2 ± 211.1	151.9	6.139
All leaves except flag leaf	2286.9 ± 245.3	226.7	7.437
All leaves (intact control)	2627.6 ± 486.6	251.0	7.548
CD	-	21.6	0.485
CV%	-	21.0	12.760

standard deviation while grain yield and test mass were analysed for variance, pooled over seasons (Table 1). Critical difference (CD) or least significant difference (LSD) defined as the standard error of mean difference and coefficient of variation (CV%) signifying the validity of an experiment were calculated for split plot design as per Gomez and Gomez (1984) at $p = 0.05$. The F test was significant only for the sub-plot treatments (defoliation treatments). Hence, only CD and CV% for defoliation treatments are presented (Table 1). The contribution of different leaf positions was worked out by subtracting previous treatment from the subsequent (Table 2). The individual leaf efficiency in terms of contribution per unit leaf area is computed by dividing grain yields by respective leaf area.

Table 2. Leaf area, grain yield, and per cent contribution of leaves and leaf efficiency in pearl millet.

Leaf position	Leaf area [cm^2 per plant]	Grain yield [$g\ m^{-2}$]	Percent contribution by leaves	Contribution per unit leaf area (leaf efficiency) [$kg\ m^{-2}\ m^{-2}$]
Zero leaf (naked stem)	-	30.0	12	-
Flag leaf	213.4 ± 23.4	23.5	9	1.10
2nd leaf (from apex)	361.9 ± 56.2	39.6	16	1.09
3rd leaf	399.1 ± 97.0	48.1	19	1.21
4th leaf	381.0 ± 133.0	54.4	22	1.43
Remaining lower leaves (total *minus* 4 upper leaves)	1272.6 ± 437.8	55.4	22	0.44
All leaves (intact control)	2627.6 ± 486.6	251.0	100	-

As the cultivar differences and cultivar×treatment interactions for grain yield were not significant over seasons, the grain yield and test mass as influenced by the defoliation treatments (leaf area) are presented in the Table 1. With increasing the defoliation intensity there was a significant reduction in grain yield and test mass. Keeping or removing single leaf (flag leaf) significantly altered the grain yield. If source and sink in modern cultivars are more or less in balance, it is not surprising that partial defoliation of a crop reduces yield (Evans 1993). Nevertheless, individual leaf contribution was worked out (Table 2). The contribution below 5th leaf decreased considerably hence a collective contribution of the lower leaves is given.

The contribution of stem alone (covered with petioles) was 12 %. There are many kinds of storage sinks: those that directly determine yield and those that provide temporary storage along the way, which may become sources as and when required. Wardlaw and Porter (1967) found that stem reserves of wheat contributed at most only 5-10 %, while Rawson and Evans (1971) found proportion to range from 3 to 12 % among cultivars. These proportions were rather higher in water stressed plots (Austin *et al.* 1980, Pheloung and Siddique 1991). Hall *et al.* (1990) estimated that 15 % of the C in seeds of irrigated sun-flower and 27 % of that in water stressed ones, originated from pre-anthesis assimilation. Among cereals pre-anthesis assimilates are most important as in rice (Dingkuhn *et al.* 1990).

The highest leaf area was recorded by 3rd and 4th leaf and the highest leaf efficiency (contribution per unit leaf area) and the individual leaf contribution to the grain yield were recorded by 4th and 3rd leaf, respectively. In wheat and barley, flag leaf and ear provide the major nutrient source to the grain, while in oat and rice, the flag leaf and penultimate leaf appear to be of equal importance in supplying assimilates for grain filling. In maize, sugars produced by the leaves above the ear are translocated efficiently into the kernel (see Bewley and Black 1985). In general, the upper leaves direct their assimilates mostly to the grain. Contribution of upper four leaves was more than that of the lower 50 % leaves in the present investigation. However, the total contribution by lower 50 % and upper 50 % (4 or 5) leaves exceeded that of actual yield of intact control (at least 10 leaves during grain filling). It clearly indicated the compensatory contribution by existing leaves in the absence of the other leaves.

Thus, keeping or removing a single leaf in the upper portion of the stem, *i.e.* in the proximity of the panicle, significantly altered the grain yield of a pearl millet plant. The leaves in the upper half of the stem showed a greater contribution than those in the lower half and in the absence of some leaves the yield was compensated by the existing ones to some extent.

References

Austin, R.B., Morgan, C.L., Ford, M.A., Blackwell, R.D.: Contributions to grain yield from pre-anthesis assimilation in tall and dwarf barley phenotypes in two contrasting seasons. – Ann. Bot. **45**: 309-319, 1980.

Bagnall, D.G., King, R.W., Farquhar, G.D.: Temperature dependent feedback inhibition of photosynthesis in peanut. – Planta **175**: 348-354, 1988.

Bewley, J.D., Black, M.: Physiology of Seed Development and Germination. – Plenum Press, New York 1985.

Chanda, S.V., Joshi, A.K., Vaishnav, P.P., Singh, Y.D.: Leaf area determination in pearl millet using linear measurement-area and matter-area relationships. – Photosynthetica **19**: 424-427, 1985.

Dingkuhn, M., Schnier, H.F., De Datta, S.K., Wijangco, E., Dörffling, K.: Diurnal and developmental changes in canopy gas exchange in relation to growth in transplanted and direct seeded flooded rice. – Aust. J. Plant Physiol. **17**: 119-134, 1990.

Evans, L.T.: Crop Evolution, Adaptation and Yield. – Cambridge University Press, Cambridge 1993.

Foyer, C.H.: The basis of source sink interaction in leaves. – Plant Physiol. Biochem. **25**: 649-657, 1987.

Geiger, D.R.: Understanding interactions of source and sink regions of plants. – Plant Physiol. Biochem. **25** : 659-666, 1987.

Gomez, K.A., Gomez, A.A.: Statistical Procedures for Agricultural Research. – J. Wiley & Sons, New York 1984.

Hall, A.J., Whitfield, D.M., Connor, D.J.: Contribution of pre-anthesis assimilates to grainfilling in irrigated and water-stressed sunflower crops. II. Estimates from a carbon budget. – Field Crops Res. **24**: 273-294, 1990.

King, R.W., Wardlaw, I.F., Evans, L.T.: Effect of assimilate utilization on photosynthetic rate in wheat. – Planta **77**: 261-276, 1967.

Mayoral, M.L., Plaut, Z., Reinhold, L.: Effect of sink-source manipulation on the photosynthetic rate and carbohydrate content of cucumber cotyledons. – J. exp. Bot. **36**: 1551-1558, 1985.

Palit, P., Kundu, A., Mandal, R.K., Sircar, S.M.: Source-sink control of dry matter production and photosynthesis in rice plant after flowering. – Indian J. Plant Physiol. **22**: 87-91, 1979.

Patel, A.D.: The Source Manipulation in Response to Growth and Development in Groundnut (*Arachis hypogaea* L.) Cultivar GG-2. – Ph.D. Thesis. Gujarat Agricultural University, Junagadh 1992.

Pheloung, P.C., Siddique, K.H.M.: Contribution of stem dry matter to grain yield in wheat cultivars. – Aust. J. Plant Physiol. **18**: 53-64, 1991.

Rawson, H.M., Evans, L.T.: The contribution of stem reserves to grain development in a range of wheat cultivars of different height. – Aust. J. agr. Res. **22**: 851-863, 1971.

Sawada, S., Usuda, H., Hasegawa, Y., Tsukui, T.: Regulation of ribulose-1,5-bisphosphate carboxylase activity in response to changes in the source/sink balance in single-rooted soybean leaves: the role of inorganic orthophosphate in activation of the enzyme. – Plant Cell Physiol. **31**: 697-704, 1990.

Wardlaw, I.F., Porter, H.K.: The redistribution of stem sugars in wheat during grain development. – Aust. J. biol. Sci. **20**: 309-318, 1967.