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Effect of maturity stage and fertilizer on yield and grain quality of sorghum (*Sorghum bicolor*)

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ABSTRACT

A field experiment conducted on the deep Vertisol during 1988 and 1989 at Bhopal indicated that 'CSH 5' sorghum [*Sorghum bicolor* (L.) Moench] may be harvested between 112 and 121 days after sowing for getting the maximum yield. The optimum moisture content of grain at harvest was 11–17%. The milling quality, germination, viability and storability also touched the optimum level during this period. Nitrogen fertilization @ 80 kg/ha significantly improved the grain, straw and protein yields, and also germination and seedling vigour. However, grain quality deteriorated at storage due to 120 kg N/ha.

Sorghum [*Sorghum bicolor* (L.) Moench] crop has to be harvested at an optimum stage of maturity for retaining good milling quality in the grain. Hence the identification of this harvesting stage in terms of easily measurable parameters is an important problem facing farmers. The optimum maturity period for harvesting is normally reckoned in terms of average moisture content of grains, which ranges between 13 and 18% (Singh, 1983). This stage can be judged in terms of number of days after sowing or heading which is normally affected by variety, soil fertility and climatic conditions.

Nitrogen influences milling quality (Salunkhe, 1984) and results in early harvesting in N-deficient soils (Jain *et al.*, 1989). However, Kharwara and Singh (1989) report delay in maturity with N when other nutrients are limiting. Since high N doses are now in use in N-deficient deep Vertisol of Bhopal region for high-yielding and hybrid varieties of sorghum, this controversy should be resolved. The experiment was therefore conducted.

MATERIALS AND METHODS

The field experiment was conducted during the monsoon seasons of 1988 and 1989 on a deep Vertisol of Bhopal. The soil was black clayey with pH 7.9, organic carbon 0.055%, available N 172 kg/ha, available P 12 kg/ha, available K 260 kg/ha and cation-exchange capacity 45 meq/g soil. The rainfall received during the crop season of July–October was 780.5 and 689.5 in 1988 and 1989 respectively.

The treatments consisted of 6 harvesting dates (100, 105, 110, 115, 120 and 125) and 4 N levels (0, 40, 80 and 120 kg/ha). The N levels formed the main plots and dates of harvesting subplots in split-plot design with 3 replications.

'CSH 5' sorghum was sown on 3 July

1988 and 6 July 1989 with 45 cm row-to-row and 10 cm plant-to-spacing. Sowing was done by seed-cum-fertilizer drill. Half N (as per treatment) along with 60 and 30 kg/ha P and K was applied at sowing and remaining N was applied 45 days later. The harvesting was done by cutting the whole plant along with ear.

At harvest, the moisture content of the grain was determined by gravimetic method. Germination (%), seedling vigour, green and milky grains (%) and 1,000-grain weight were also determined at each harvesting date. The grain yield was determined from the whole-plot yields after the ears were dried to a uniform moisture content (10%). The seeds (1 kg from plot yields) were size graded at each harvesting date using 10/64", 9/64" and 8/64" round hole sieves with peruser width of 3.9 mm, 3.57 mm and 3.18 mm respectively. The seed recoveries (%) retained in each sieve were calculated on weight basis and evaluated for germination and seeding vigour. Seedling vigour was measured from the dry weight of 15-day-old seedlings. The crop was stored for 8 months at 10% moisture content in gunny-bags and changes in the grain quality were evaluated (ISTA, 1976).

Prediction equations were developed from the grain-yield data for days after sowing by fitting the equation parabola by least-square method as:

$$Y = a + bx - cx^2$$

In order to determine the theoretical day of biological maturity of the crop, the above equation was differentiated with respect to X (days after sowing) as:

$$\frac{dy}{dx} = 0 = b - c.2x \quad \text{or}$$

$$x = \frac{b}{2C}$$

RESULTS AND DISCUSSION

Effect of harvesting time

The grain yield, moisture content and green and milky grains (%) of sorghum as influenced by harvesting time are shown in Fig. 1. The grain yield of sorghum in 1988 was lower than that in 1989, because of damage to the crop by heavy rains in July 1988 (481.4 mm). In 1989, the rainfall was low but was well distributed over the growing season, enabling higher production of 'CSH5' sorghum.

Harvesting the crop at different times resulted in significant yield variations. The yield increased significantly from 100 to 110 days after sowing. There was no significant increase thereafter, but the maximum yield was attained at 115 days after sowing. It started declining, as the harvesting was delayed further. Early harvesting at 100 days after sowing reduced the yield by 16.7% in 1988 and by 19.6% in 1989 compared with that of the crop harvested at 115 days after sowing. This was due to the presence of high percentage of green and milky grains (59–63) and high percentage of moisture content of grains (35–37). It was also due to fewer filled grains/ear and poor grain weight/ear (Table 1). There was a gradual increase in the number and weight of filled grains, but rapid decrease in the moisture content of grains and percentage of green and milky grains was recorded up to 115 days after sowing. The moisture content and green and milky grains continued to decrease even up to 125 days after sowing, due to over-ripening and grain-shedding during harvesting operation.

The optimum harvesting stage as determined from Fig. 1 and also from the differential equations, indicated that the crop reached its biological maturity at 119 days after sowing in 1988 and 115 days after

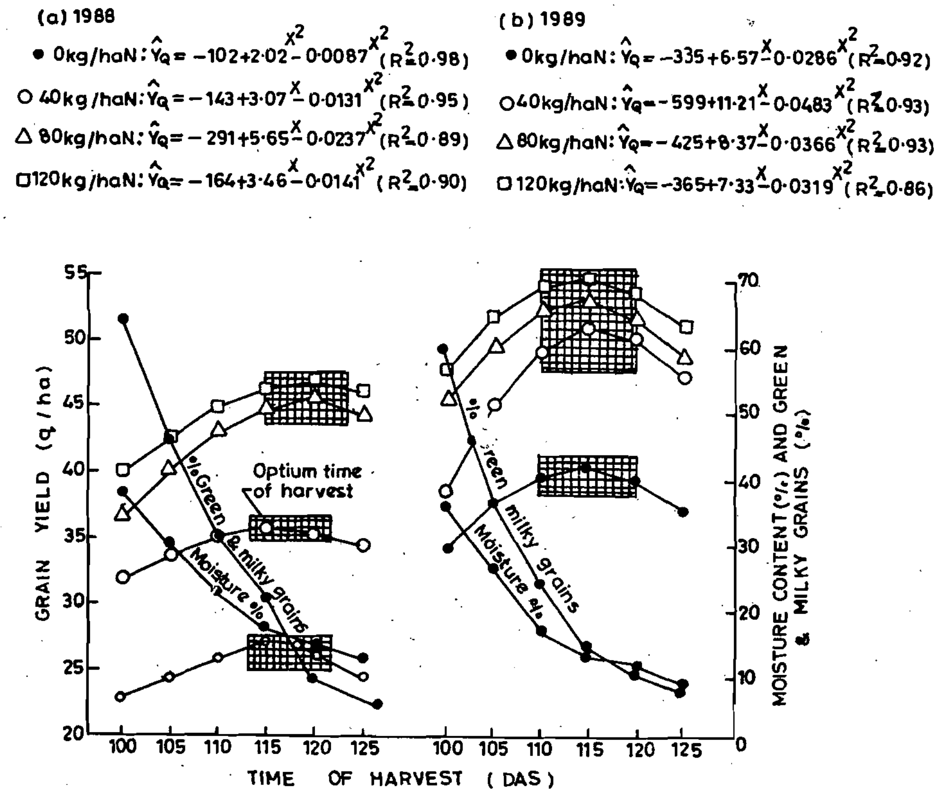

Fig. 1. Effect of harvest time and nitrogen levels on grain yield and optimum time of harvest in 'CSH 5' sorghum [CD (P = 0.05) for harvest time, N levels and interaction 1.78, 3.86 and NS in 1988, and 4.30, 3.94 and NS in 1989 respectively]

sowing in 1989, which coincided with the maximum grain yield. However, the optimum range for harvesting without significant yield reduction was observed between 114 and 122 days after sowing in 1988 and 110 and 120 days after sowing 1989 (Singh, 1983). The average optimum moisture content during both the years was 17–11%. The average percentage of green and milky grains was 24–8%. Delaying harvesting by 10 days from the optimum time caused reduction in the grain yield (4.5%) due to grain-shedding during harvesting and transportation (Belle and Hosmani, 1983; Krishnasamy *et al.*, 1989). Thus, it was evident that a close relationship exists between moisture content and percentage of green and milky grains (r = + 0.98**), moisture content and grain yield/plant (r = + 0.97**) and moisture content and 1,000-grain weight (r = — 0.99**).

Protein yield (Table 1) increased significantly up to 100 days after sowing in both the years and started declining thereafter. The decrease was, however, not significant at 110 and 115 days after sowing, and at 115 and 120 days after sowing but it was so when 115 and 125 days after sowing

Table 1. Effect of stage of harvesting and nitrogen fertilization on yield attributes and yield of straw and protein in sorghum

Treatment	Grains/ear	Grain weight/ear (g)	Straw yield (q/ha)		Protein yield (q/ha)	
			1988	1989	1988	1989
Stage of harvest (DAS)						
100	3,841	30.5	56.2	72.9	3.0	3.4
105	3,959	32.2	60.0	76.2	3.3	3.9
110	4,403	37.7	64.3	79.1	3.5	4.6
115	4,474	38.6	69.2	79.6	3.6	4.6
120	4,286	35.8	72.9	81.3	3.4	4.4
125	4,105	33.6	74.3	82.8	3.3	4.3
CD ($P = 0.05$)	62	2.2	2.3	4.6	0.2	0.2
N (kg/ha)						
0	3,926	25.6	53.5	73.3	2.3	3.3
40	4,081	29.8	64.9	75.4	3.1	4.0
80	4,331	39.2	70.2	80.9	3.9	4.5
120	4,374	44.3	75.2	85.1	4.2	4.8
CD ($P = 0.05$)	408	10.6	4.4	5.1	0.5	0.3
Interaction						
CD ($P = 0.05$)	124	NS	NS	NS	NS	NS

DAS, Days after sowing

Table 2. Effect of stage of harvesting on seed recovery, germination and vigour of sorghum

Stage of harvest (DAS)	Seed recovery (%)			Germination (%)			Seedling vigour (mg/plant)		
	10/64R	9/64R	8/64R	10/64R	9/64R	8/64R	10/64R	9/64R	8/64R
100	27.1	36.4	30.5	80.6	74.5	69.7	16.6	15.5	10.9
105	34.4	42.2	21.3	92.1	84.6	71.0	17.7	16.9	11.5
110	38.9	44.5	15.1	93.4	90.5	78.5	19.3	18.7	12.2
115	40.7	48.0	11.9	95.9	91.2	78.5	20.2	19.9	16.4
120	43.2	44.4	10.4	96.4	94.4	80.7	19.8	19.4	15.3
125	45.0	43.6	10.6	96.3	95.3	81.5	18.8	17.6	16.5
CD ($P = 0.05$)									
Seed size		3.2			4.1			1.46	
Stage of harvesting		1.5			1.8			0.94	
Size × stage of harvesting		2.5			4.4			1.64	

DAS, Days after sowing

were compared. The protein content however increased significantly up to the last stage due to favourable effects on the availability of assimilates for protein conversion. The 1,000-grain weight also followed the similar pattern due to deposition of solid matter in grains up to the last stage of harvesting (Table 3).

The straw yield increased significantly up to 120 days after sowing in 1988, but only up to 105 days after sowing in 1989. This showed that the biomass accumulation reached its peak earlier in 1989 than in 1988. Milling quality of grains also improved up to 110 days after sowing and became constant thereafter.

When the bulk seed was graded for size maximum recovery was recorded in 9/64" sieve size, varying from 36.4 to 48% (Table 2). Larger the seed, more was the germination and seedling vigour. Seeds retained by 10/64" and 9/64" sieves recorded more than 80% germination. Krishnasamy *et al.* (1989) also reported higher germination and seedling vigour with large-size seeds. Time of harvesting had a beneficial influence on seed size and germination and seedling vigour. Harvesting at 115 days after sowing resulted in higher seed recovery in 10/64", followed by 9/64" sieve size, and higher germination and vigour. But 115 days after sowing, the germination became more or less constant. On the contrary, the seedling vigour decreased. Germination was highly positively correlated with 1,000-grain weight ($r = 0.87^{**}$).

Immature grains having high moisture content when harvested at 100–105 days after sowing deteriorated more quickly. During storage the grain moisture increased from 10 to 15.5% and to 14.4% in the crop harvested at 100 and 105 days after sowing respectively. The moisture provided suitable conditions for the growth of moulds and insects. Insect infestation at 100 days after sowing was 35.9%. A positive correlation between moisture content and loss of 1,000-grain weight was recorded ($r = 0.95^{**}$). Similarly, all the storage properties, such as protein content, germination, vigour and milling quality, showed a diminishing trend when compared with that before storage. However, all these properties improved with delayed harvesting.

Effect of N

Nitrogen fertilization to sorghum crop significantly increased the grain, straw and protein yields, the increase being basically owing to significantly higher number and weight of grains/ear and 1,000-grain weight. The effects were significant up to 80 kg/ha in 1988 and only up to 40 kg/ha in 1989 (Fig. 1, Table 1). The lower response to N in the second year may be due to the build up of N residues in the soil. Straw yield however increased significantly, as the higher doses of N increased the biomass yield more than the grain.

The germination and seedling vigour and protein content of grains significantly improved by N levels up to 120 kg/ha. Germination was increased from 80 to 91% and vigour of 15 day-old-seedlings from 16 to 18.5 mg/plant

Nitrogen application did not influence the milling quality of grain (Salunkhe, 1984). Similarly, grain-moisture content at harvest was not significantly influenced but was increased from 10 to 113.5% at 120 kg N/ha. This resulted in the deterioration of the grain quality in storage (Table 3). All the grain properties like 1,000-grain weight, protein content, milling (%) and germination and vigour after storage were deteriorated more at 120 kg N/ha level. The highest values of

Table 3. Effect of stage of harvesting and nitrogen fertilization on sorghum-seed quality at harvest and after storage for 8 months in sorghum

Treatment	At harvest						After storage for 8 months						
	Moisture (%)	1,000-grain weight (g)	Protein (%)	Milling (%)	Germination (%)	Seedling vigour (mg/plant)	Moisture (%)	1,000-grain (g)	Protein (%)	Milling (%)	Germination (%)	Seedling vigour (mg/plant)	Insect infestation (%)
Stage of harvest (DAS)													
100	36.2	8.6	8.7	95.8	75.0	14.3	15.5	8.5	8.1	94.6	72.5	12.0	35.9
105	27.3	8.8	8.9	97.2	82.6	15.3	14.4	8.7	8.4	95.3	78.9	12.6	32.4
110	20.9	8.9	9.1	98.3	87.8	16.7	13.2	8.8	8.6	96.1	86.1	13.1	29.5
115	15.7	9.2	9.3	98.5	90.2	18.8	12.3	9.0	8.8	96.5	86.2	14.7	26.4
120	11.9	9.5	9.4	99.0	91.2	18.2	11.4	9.2	9.0	97.2	87.4	14.1	22.4
125	8.8	9.6	9.6	99.1	92.7	17.6	11.1	9.3	9.2	97.5	88.2	13.8	16.9
CD (P = 0.05)	2.3	0.07	0.10	1.76	2.11	0.5	1.0	0.2	0.3	0.4	6.1	0.4	2.3
N (kg/ha)													
0	19.3	8.8	8.9	97.1	80.5	16.0	12.2	8.6	8.4	94.8	79.8	12.0	24.2
40	19.9	9.0	9.2	97.7	86.5	16.3	13.0	9.1	8.9	97.1	85.2	14.8	25.3
80	20.5	9.3	9.2	98.3	88.0	16.5	13.3	9.0	8.7	96.6	84.0	13.7	28.2
120	20.8	9.4	9.4	98.6	91.7	18.5	13.5	8.9	8.7	96.2	83.4	13.0	31.2
CD (P = 0.05)	NS	0.13	0.15	NS	5.52	1.5	0.7	0.3	0.4	1.3	3.2	0.7	2.8

Moisture content of grain at storage, 10%

all these properties were recorded at 40 kg N/ha. The insect infestation in storage was significantly increased with N application at higher levels.

Effect of N on time of harvesting

The effect of N on the time of harvesting was evaluated from the interaction effects between the two. The grain, protein and straw yields of sorghum were not significantly influenced by the interaction of N levels and time of harvesting (Fig. 1; Table 1). Thus the time of harvesting was the same at all the N levels. The crop reached its biological maturity stage (as determined from differential equation) in 116, 117, 119 and 122 days after sowing in 1988 and 115, 116, 114 and 115 days in 1989 at 0, 40, 80 and 120 kg N/ha levels respectively. It was also evident from Fig. 1 that optimum date of harvesting in 1988 at 0–40 kg N/ha was between 113 and 122 days and at 80–120 kg N/ha between 115 and 123 days after sowing. However, in 1989 the optimum date was common for all the N levels, which was between 110 and 120 days after sowing. Similarly, the interaction effects of N levels and time of harvesting were not significant for the grain characters and various storage properties. It showed that the N fertilization did not significantly affect the time of harvesting of sorghum, confirming the earlier findings of Brady (1990).

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