Pak. j. sci. ind. res., vol. 33, no. 11, November 1990

EFFECT OF GAMMA RAYS ON THE CANOPY STRUCTURE OF PEARL MILLET (*Pennisetum americanum* L.) Leeke

R.M. Aslam, K.A. Siddiqui* and A. Sharif

Department of Botany, University of Sindh, Jamshoro, Pakistan

(Received March 18, 1989; revised November 15, 1990)

The magnitude and direction of change induced through mutagenesis in the decisive components of canopy structures of four contemporary varieties of pearl millet (*Pennisetum americanum* L. Leeke. *viz.* Awn selected, ex-Bornu, Japan Bajra and B-18 were treated with different doses (0,5,10,15,20,25,30 and 35 kR) of gamma rays and were investigated. Their differences amongst varieties were significant (P = 0.05) whereas differences amongst different doses of gamma rays were highly significant (P=0.01). The effects on the components of canopy structure i.e. leaf size, number of leaves on plants and number of spikes were studied. The rate of reduction in leaf length was highest in Japan Bajra followed by B-18, ex-Bornu and Awn-selected at 15 kR (29.50) with control. In variety ex-Bornu at 5 kR (12.75) at 20 kR (14.05) compared with control (9.50) and variety B-18 at 15 kR (18.25) at 25 kR (12.50) at 30 kR (18.75) and 35 kR (22.25) compared with control (9.75). The implications of results are discussed with reference to the developmental allometry of pearl millet and feasibility of construction of new ideotypes for increasing productivity in selected macrodiameters.

Key words: Gamma rays, Canopy structure, *Pennisetum americanum*.

Introduction

Pearl millet (*Pennisetum americanum* L.) Leeke is gaining renewed attention as a crop to meet the food needs of the increasing population in arid regions of the world [1]. This renewed attention has prompted many recent investigations aimed at the genetic improvement of pearl millet by conventional [2,3] and unconventional [4,5] methods of plant breeding [4,6]. Yet scanty information is available on pearl millet incomparison to cereals, such as, wheat [7] barley [8] and maize [9], through, the genetic constitution of pearl millet offers unique possibilities of exploitation of induced genetic variation [5]. The present paper reports on the effect of gamma rays the effective components of canopy structure in some contemporary varieties of pearl millet. Such studies are needed to alter the developmental allometry [10,11] of pearl millet to suit different ecological niches [1].

Materials and Methods

The seed of four cultivars (Awn-selected, ex-Bornu, Japan Bajra and B-18) of pearl millet *Pennisetum americanum* L. Leeke was obtained from Millet Botanist Yousif-Wala, Punjab and Dadu, Sindh.

The seeds of above varieties treated with gamma rays were sown in four replications in the fields of Botany Department, Sindh University, Jamshoro and Agronomy Section, Agricultural Research Centre, Tandojam in the well prepared plots of dibling method. Spacing were 1 foot from plant to plant and 11/2 feet from row to row. Sowing was done after 4 P.M. Just after sowing the plots were irrigated by fine showers. The individual plots were visited 3 days after planting. Observation on seed germination, No. of plants, height of the plant in cm, No. of nodes, length between internodes, tillers, No. of leaves B/L. of leaves, colour of mid rib, No. of spikes, B/L. of spikes colour of the pollens and time of anthesis were recorded.

The method of crossing technique [27] was followed emusculating the flowers i.e. the spikelet was prepared on the previous evening by removing all other flowers except those which were likely to open on the next day. Their anthers were removed by opening the glumes with a pair of fine forceps. The emasculated flowers were covered with polythene bag, the mouth of which was plugged with cotton and tied with thick thread. Next morning the pollens of the selected male were brought and dusted on the protruding stigma between the glumes. The crossed flowers were covered again with butter paper bag. Crossed flowers were checked on the third day for seed setting.

Results and Discussions

Leaf number. Data of induced genetic variability for leaf number is recorded in Table 1 and the results of analysis of variance for number of leaves in four varieties of pearl millet after gamma irradiation revealed that the differences among varieties were significant (P=0.05, Table 2) whereas differences amongst different doses of gamma rays were highly significant (P=0.01, Table 3). The effect of different doses of gamma rays on number of leaves has shown reduction at 30 and 35 kR in varieties Japan Bajra. Awn-selected and B-18, whereas variety ex-Bornu has shown very little reduction (Table 4).

Length of leaves. Data for length of leaves is given in (Table 5). Reduction in leaf length was observed in all the four

*Atomic Energy Agriculture Research Centre, Tandojam.

TABLE 1. INDUCED GENETIC VARIABILITY FOR LEAF NUMBER IN FOUR VARIETIES OF *PENNISETUM AMERICANUM* IN M_1 GENERATION.

Variety	Dose kR	Mean	Standard deviation	Coefficient variability	Variance
Awn-selected		12.75	± 3.50	27.45	12.25
control	5	14.50	± 4.47	30.84	20.00
	10	13.83	± 4.17	30.17	17.42
	15	13.95	± 4.06	29.97	15.52
	20	13.95	± 4.43	31.75	19.62
	25	14.25	± 4.31	30.28	18.63
	30	14.14	± 4.10	29.03	16.86
	35	13.82	± 3.89	28.14	15.14
ex-Bornu		13.44	± 3.91	29.13	15.34
control	5	13.34	± 3.84	28.83	14.81
	10	13.37	± 3.83	28.66	14.70
	15	13.17	± 3.80	28.90	14.50
	20	13.40	± 4.05	30.27	16.47
	25	13.36	± 4.03	30.19	16.29
	30	13.39	± 3.98	29.73	15.85
	35	13.47	± 4.13	30.66	17.08
Japan Bajra		13.41	± 4.08	30.43	16.66
control	5	13.37	± 4.07	30.48	16.61
	10	13.32	± 4.04	30.32	16.34
	15	13.38	± 4.09	30.61	16.34
	20	13.23	± 4.06	30.73	16.55
	25	13.10	± 4.03	30.81	16.30
	30	12.96	± 4.01	31.01	16.15
	35	12.81	± 4.00	31.27	16.07
B-18 control		12.77	± 3.94	30.90	15.59
	5	12.81	± 3.88	30.32	15.09
	10	12.76	± 3.82	29.98	14.66
	15	12.69	± 3.80	29.97	14.48
	20	12.72	± 3.81	29.97	14.55
	25	12.69	± 3.78	29.82	14.33
	30	12.63	± 3.75	29.72	14.11
	35	12.56	± 3.72	29.62	13.86

varieties of pearl millet (Table 6). The rate of reduction was highest in Japan Bajra (b= - 2.1190) followed by B-18 (b= -1.8810) ex-Bornu (b= -0.5471) and Awn selected (b=-0.5357, Table 6).

Leaf width . Data of induced genetic variability for leaf width is recorded in (Table 7). Gamma rays seem to have promoted leaf width (Table 6) in two varieties namely ex-Bornu (b=0.7143) and B-18 (b=1.3690).

TABLE 2. EFFECT OF GAMMA RAYS ON NUMBER OF LEAVES IN FOUR VARIETIES OF *PENNISETUM AMERICANUM*.

Varieties	Averages	Signi-ficance	S.E.	LSD1	LSD2
V2	8.31	a	0.2061	0.58	0.77
V1	7.88	ab	—	—	—
V3	7.72	b	—	—	—
V4	7.47	b	—	—	—

V1 = Awn-selected, V2 ex-Bornu, V3 = Japan Bajra, V4 = B-18.
Means not followed by the same letter are statistically significant. Capital and small letters indicate significance at 0.05% and 0.01% levels of probability respectively.

TABLE 3. EFFECT OF DIFFERENT DOSES OF GAMMA RAYS ON NUMBER OF LEAVES OF FOUR VARIETIES OF *PENNISETUM AMERICANUM*.

Doses	Average varietal response	Significance 5%	Significance 1%	S.E.	LSD1	LSD2
D1	8.69	a	A	0.2914	0.82	1.08
D2	8.19	ab	AB			
D6	8.06	ab	ABC			
D4	7.81	bc	ABC			
D5	7.81	bc	ABC			
D3	7.75	bc	ABC			
D7	7.38	bc	ABC			
D8	7.06	c	C			

Means not followed by the same letter are statistically significant, small and capital letters indicate significance at 0.05% and 0.01% levels respectively.

TABLE 4. EFFECT OF DIFFERENT DOSES OF GAMMA RAYS ON NUMBER OF LEAVES AND NUMBER OF SPIKES IN THE FOUR VARIETIES OF *PENNISETUM ANERICANUM*.

Radiation dose kR	Number of leaves: Awn-selected	ex-Bornu	Japan Bajra	B-18	Number of spikes: Awn-select	ex-Bornu	Japan	B-18
0	9.50	8.75	8.25	8.25	12.50	9.50	12.50	9.75
5	7.50	9.50	8.25	7.50	09.00	12.75	10.25	10.50
10	7.25	7.50	8.75	7.50	7.75	14.50	10.25	8.50
15	7.50	8.25	8.00	7.50	29.50	15.50	12.00	18.25
20	8.00	8.50	7.50	7.25	13.50	14.05	11.50	9.25
25	8.00	8.75	7.25	8.25	14.25	6.25	7.00	12.50
30	8.00	7.75	6.75	7.00	7.75	9.50	13.50	18.75
35	7.25	7.50	7.00	6.50	7.75	4.00	10.00	22.25

*Denotes significance with control at 0.05% level of probability **Denotes significance with control at 0.01% level of probability.

Results of correlation and regression analysis shows reduction in leaf width following gamma irradiation was more pronounced in Awn-selected (b=-1.7143) than in Japan Bajra b= - 0.5476 (Table 6).

Number of spikes. Data for number of spikes were recorded in (Table 8). The variability data shows differences among various radiation treatments were highly significant (P= 0.01, Table 9). Similarly interaction between varieties and radiation treatments were also highly significant (P= 0.01) indicating that the varieties did not perform constantly across various doses of gamma rays with respect to number of spikes. The results (Table 10) suggests that considerable variability for number of spikes was induced in Awn- selected ex-Bornu, Japan Bajra. The magnitude induced variability was less pronounced in B-18. The results of correlation and regression analysis of the effect of gamma rays (Table 11) shows reduction in leaf length, the rate of reduction was highest in Japan Bajra, B-18 ex-Bornu and Awn-selected respectively. Whereas leaf width seem to have promoted in two varieties namely ex-Bornu and B-18 following reduction in Awn-selected and Japan Bajra.

Studies of plant canopyes assuming increasing importance in many crops [12-14] including pearl millet [1]. However, very little published information is available on the effect of different mutagens on canopy structure of pearl millet. In *Sesamum indicum* alteration of phyllotaxis has been reported through mutagenesis [15]. The alteration of phyllotaxis was accompanied by increase in the number of capsules per plant.

In cereals the decisive components of canopy structure related to grain yield are the number of spikes per unit area and the longivity of green parts [16]. Extensive efforts have been made to study the canopy structure of wheat [16-18], oats [19] and barely [20]. In comparison to these, very little published information is available on the irradiation effects on the canopy structure of pearl millet [4]. Genotypes with a smaller leaf size develop more spikes per unit area but low kernel weight and vice versa [16]. Leaf size effects the ability of plants to trap solar radiation and is reflected through differences in set assimilation rates. In tropical grasses the optimum leaf area index varies from 2 to 3 to over 15 among species and there are also extreme differencces among strains within species [21]. The present work has provided evidence of induced genetic variability for leaf number. The relationship between leaf number and the length of vegetative period has been observed in many cereal crops [22-24] found high positive linear relationship between leaf number and duration to flowering in

TABLE 5. INDUCED GENETIC VARIABILITY FOR LENGTH OF LEAVES IN FOUR VARIETIES OF *PENNISETUM AMERICANUM* IN M_1 GENERATION.

Variety	Dose kR	Mean	Standard deviation	Coefficient	Variance
Awn-Selected	0	55.25	± 8.6168	15.60	74.25
	5	58.75	±10.9902	18.70	120.78
	10	58.50	± 10.6772	18.20	113.36
	15	58.62	± 9.5907	16.35	91.98
	20	58.95	± 9.4170	15.97	88.68
	25	59.08	± 9.3897	15.89	88.16
	30	48.75	± 17.5885	36.60	309.35
	35	51.91	± 15.4887	29.83	239.90
ex-Bornu	0	52.56	± 13.5349	25.75	183.19
	5	54.15	± 12.9625	23.93	168.02
	10	55.00	± 12.1046	22.00	146.52
	15	55.96	± 11.7803	21.04	138.77
	20	56.68	± 11.1772	19.71	124.93
	25	57.55	± 11.1264	19.33	123.79
	30	57.30	± 10.9432	19.09	119.75
	35	56.96	± 11.1875	19.64	125.16
Japan Bajra	0	56.85	± 10.8156	19.02	116.97
	5	56.71	± 10.4606	18.44	109.42
	10	56.83	± 10.1368	17.83	102.75
	15	58.50	± 5.7490	9.82	33.00
	20	59.25	± 12.0439	20.32	144.92
	25	54.85	± 8.2288	15.02	67.58
	30	45.25	± 7.3226	16.18	53.58
	35	57.50	± 4.4354	7.71	19.67
B-18	0	53.25	± 9.7165	18.23	94.25
	5	54.00	± 5.4875	10.14	30.00
	10	60.00	± 8.2798	11.35	66.96
	15	61.00	± 8.2194	13.45	67.33
	20	61.75	± 2.3611	3.83	5.58
	25	53.00	± 2.0001	3.77	4.00
	30	58.75	± 9.7182	16.52	92.25
	35	55.75	± 6.1320	11.00	37.58

TABLE 6. CORRELATION AND REGRESSION ANALYSIS OF THE EFFECTS OF GAMMA RAYS ON LEAF LENGTH AND LEAF WIDTH ON FOUR VARIETIES OF *PEARL MILLET*.

	Leaf length			Leaf width		
Variety	r	b	c	r	b	c
Awn-Selected	–0.2865	–0.5357	64.2857	–0.5463	–1.7143	30.9643
ex-Bornu	–0.1684	–0.5476	65.9643	0.2535	0.7143	33.5357
Japan Bajra	–0.6488	–2.1190	75.4642	–0.1733	–0.5476	20.2143
B-18	–0.6710	–1.8810	70.4642	0.3200	1.3690	14.7143

Table 7. Induced Genetic Variability for Width of Leaves in Four Varieties of *Pennisetum americanum* in M_1 Generation.

Variety	Dose kR	Mean	Standard deviation	Coefficient variability	Variance
Awn Selected	0	3.16	± 0.5163	16.30	0.26
	5	3.40	± 0.5676	16.69	0.32
	10	3.60	± 0.5941	16.47	0.35
	15	3.61	± 0.5571	15.42	0.31
	20	3.70	± 0.5907	15.94	0.34
	25	4.00	± 0.5436	14.46	0.29
	30	3.82	± 0.6130	16.03	0.37
	35	3.84	± 0.5786	15.05	0.33
ex-Bornu	0	3.93	± 0.6196	15.74	0.38
	5	3.99	± 0.5957	15.04	0.35
	10	3.99	± 0.5910	14.93	0.34
	15	3.99	± 0.5898	14.78	0.34
	20	4.00	± 0.5877	14.69	0.34
	25	4.09	± 0.8610	21.04	0.74
	30	4.07	± 0.8813	21.65	0.77
	35	4.00	± 0.9060	22.65	0.82
Japan Bajra	0	3.98	± 0.8778	22.02	0.77
	5	3.98	± 0.8544	21.14	0.73
	10	4.00	± 0.8403	21.00	0.70
	15	3.98	± 0.8272	20.74	0.68
	20	3.97	± 0.8150	20.49	0.66
	25	3.97	± 0.7971	20.03	0.63
	30	3.95	± 0.7931	20.05	0.62
	35	31.96	± 0.7841	19.76	0.61
B-18	0	3.93	± 0.7929	20.15	0.62
	5	3.92	± 0.7834	19.94	0.61
	10	3.91	± 0.7791	19.91	0.60
	15	3.92	± 0.7722	19.67	0.59
	20	3.92	± 0.7622	19.44	0.58
	25	3.92	± 0.7517	19.14	0.56
	30	3.96	± 0.8272	20.84	0.68
	35	3.96	± 0.8146	20.52	0.66

Table 9. Effect of Different Doses of Gamma Rays Nnumber of Spikes of Four Varieties of *Pennisetum americanum*.

Doses	Average verietal response	Significance 5%	Significance 1%	S.E.	LSD1	LSD2
D4	18.81	a	A	2.4800	6.94	9.22
D7	12.38	b	AB	—	—	—
D5	12.13	b	AB	—	—	—
D8	11.00	b	AB	—	—	—
D2	10.63	bc	AB	—	—	—
D3	10.25	bc	AB	—	—	—
D6	10.00	bc	AB	—	—	—
D1	7.31	c	B	—	—	—

Means not followed by the some letters are statistically significant small and capital letters indicate significance at 5% level and 1% level respectively.

corn. Canopy structure is also influenced by agronomic practices for instances, increase in plant density is accompanied by a decrease in leaf number, an inncrease in the periods from planting to tassel emergence and mid-slik, and an increase in grain moisture at harvest [25].

Photosynthetic activity is important but leaf area may be predominant. Gamma rays seems to have prompted leaf width (Table 6 and 7) in the varieties ex-Bornu (6= 0.7143) and B-18 (b= 1.3690). Reduction in leaf width following gamma irradiation was more pronounced in Awn-selected

Table 8. Induced Genetic Variability for Number of Spikes in Four Varieties of *Pennisetum americanum* in M_1 Generation.

Varieties	Dose kR	Mean	Standard deviation	Variance
Awn-Selected	0	12.75	± 3.50	12.25
	5	14.50	± 4.47	20.00
	10	13.83	± 4.17	17.42
	15	13.56	± 4.06	16.52
	20	13.95	± 4.43	19.62
	25	14.25	± 4.31	18.63
	30	14.14	± 4.10	16.86
	35	13.82	± 3.89	15.14
ex-Bornu	0	13.44	± 3.91	15.34
	5	13.34	± 3.84	14.81
	10	13.37	± 3.83	14.70
	15	13.17	± 3.80	14.50
	20	13.40	± 4.05	16.47
	25	13.36	± 4.03	16.29
	30	13.39	± 3.98	15.85
	35	13.47	± 4.13	17.08
Japan Bajra	0	13.41	± 4.08	16.68
	5	13.37	± 4.07	16.61
	10	13.32	± 4.04	16.34
	15	13.38	± 4.09	16.78
	20	13.23	± 4.06	16.55
	25	13.00	± 4.03	16.30
	30	12.96	± 4.01	16.15
	35	12.81	± 4.00	16.07
B-18	0	12.77	± 3.94	15.59
	5	12.81	± 3.88	15.09
	10	12.76	± 3.82	14.66
	15	12.69	±3.80	14.48
	20	12.72	± 3.81	14.55
	25	12.69	± 3.78	14.33
	30	12.63	± 3.75	14.11
	35	12.56	± 3.72	13.86

TABLE 10. GENOTYPIC STUDIES OF VARIABILITY INDUCED THROUGH HYBRIDIZATION AND GAMMA IRRADIATION IN *PENNISETUM AMERICANUM*. REGRESSION AND CORRELATION ANALYSIS ON NUMBER OF LEAVES AND NUMBER OF SPIKES.

No. of leaves	r	b	c	No. of spikes	r	b	c
Awn-Selected	–0.4183	–0.1255	8.4375	Awn-Selected	–0.1439	–0.4286	14.6786
ex-Bornu	–0.5592	–0.1607	9.0357	ex-Bornu	–0.5645	–0.9613	15.1071
Japan Bajra	–0.8853	–0.2530	8.8571	Japan Bajra	–0.1684	–0.1369	11.4911
B-18	-0.4834	–0.1101	8.0268	B-18	0.7309	1.5685	6.6607

TABLE 11. CORRELATION AND REGRESSION ANALYSIS OF THE EFFECT OF GAMMA RAYS ON THE COMPONENTS OF CANOPY STRUCTURE IN *PEARL MILLET*.

Variety	Character	Correlation coefficient (r)	Regression coefficient (b)	Y. Intercept of control (c)
Awn-Selected	No. of Leaves	–0.4183	–0.1255	8.4375
	Leaf length	–0.5357	–0.5357	64.2857
	Leaf width	–0.5463	–1.7143	30.9643
	No. of Spikes	–0.1439	–0.4286	14.6786
ex-Bornu	No. of Leaves	–0.5592	–0.1607	9.0357
	Leaf length	–0.1684	–0.5476	65.9643
	Leaf width	0.2535	0.7143	33.5357
	No. of Spikes	–0.5645	–0.9613	15.1071
Japan Bajra	No. of Leaves	–0.8853	–0.2530	8.8571
	Leaf length	–0.6488	–2.1190	75.4642
	Leaf width	–0.1733	–0.5476	20.2143
	No. of Spikes	–0.1684	–0.1369	11.4911
B-18	No. of Leaves	–0.4834	–0.1101	8.0268
	Leaf length	–0.6710	–1.8810	70.4642
	Leaf width	0.3200	1.3690	14.7143
	No. of Spikes	0.7309	1.5685	6.6607

(b= -1.7143) than in Japan Bajra (b= - 0.5476). Similar results have been recorded in hexaploid wheat [18].

One of the decisive components of canopy structure related to yield is the number of spikes per unit area [16]. In present investigations, pronounced variability for spike number was induced in the variety Awn-selected, other varieties did not respond readily to various gamma rays treatments (Table 4). Awn- selected behaved similarly with respect to spike length. Mother varieties also differed from spike diameter was noted in M_2 population of Japan Bajra. These result suggest that it is possible to alter the canopy structure through induced mutation.

If induced mutations are combined with hybridization and recurrent selection seems possible to constrict ideotypes of pearl millet for increasing productivity in selected macroclimates [26].

The present studies suggest that it is possible to alter the canopy structure in pearl millet through gamma irradiation, such evidence in case of wheat has been presented earlier [11,18,27]. These alterations in the canopy structure, however, are to be assessed with reference to increase in photosynthetic activity and ultimately enhancement in yield.

References

1. P. Singh and E.T. Kanemasu, Agronomy J., **75,** 497 (1983).
2. B.S. China and P.S. Phul, Seed Sci. Technol., **10**, 541 (1983).
3. C.C. Nwasike, R.B. Thakare, B.A. Oyejole and S.O. Okira. Pflanze-nzuchung Z., **90**, 259 (1983).
4. W.W. Hanna, Mut, Breed Rev., I.I (1982).
5. R.M. Aslam and K.A. Siddiqui, New Genetical Approaches to Crop Improvement, International Symposium Karachi (1986), pp. 289–296.
6. A. Prasad, K. Koduru and R.M. Krishna, Pflanzenzuchung Z., **90**, 1 (1983).
7. K.A. Siddiqui, Proc. 6th Int. Wheat Genetics Symp. Kyota, Japan (1984).
8. S.M. Vasti and J. Jones, Environmental and Experimental Bot., **24**, 9 (1984).
9. G.A. Churchill and R.H. Andrew, Crop Sci., **24**, 76 (1984).
10. K.A. Siddiqui, M.A. Rajput and K.H. Tahir, Genetica Agr., **33**, 231 (1979).
11. K.A. Siddiqui, M.A. Rajput and K.H. Tahir, Genetica Agr., **34**, 89 (1980).
12. J.S. Ahlrichs and M.E. Bauer, Agran. J., **75**, 987 (1983).
13. L.R. Reeder, D.A. Sleper and C.J. Nelson, Crop Sci., **24**, 97 (1984).
14. T.R. Sincleir, Agron. J., **76**, 141 (1984).
15. T. Kobauashi, Radian Bot., **5**, 399 (1965), *The Use of Induced Mutations in Plant Breeding,* Rome, Italy (Pergamon Press, Oxford, London).
16. S. Borjovic. Proc. 4th Int., Wheat Genet. Symp. Columbia, Missouri, 773 (1973).
17. L.T. Evans and R.L. Dunstone, Australian J. Biol. Sci., **23**, 725 (1970).
18. K.A. Siddiqui, M.I. Khan, M.A. Arain and K.A. Jaffri, I.A.E.A., Vienna, 455 (1978).
19. J.W. Turner, C.J. Gardener, N.C. Stoskopt and E. Reinbergs, Canadian J. Plan Sci., **46**, 690 (1966).

20. J.D. Berdahl, D.C. Rasmusson and D.N. Moss, Crop Sci., **12**, 177 (1970).
21. G.O. Mott and H.L. Popenoe, Trop. Crops, 158 (1977).
22. F.R. Allen, G.W.M. Kee and J.H.M. Ghen, Agron J., **65**, 233 (1973).
23. S.S. Chase and D.K. Handa, Crop. Sci., **7,** 421 (1976).
24. E.E.N.A. Bonoparte and R.I. Brown, Can. J. Plant Sci., **56**, 699 (1976a).
25. E.E.N.A. Bonoparte and R.I. Brown, Can. J. Plant Sci., **56**, 688 (1976b).
26. L.A. Wilson, *Root Crops*, ed. P. Det. Alvin and T.T. Koz Louski, (Academic Press, London), pp. 187.
27. G.N.R. Ayyangar, Madras Agric. J., **22**, 1 (1934).