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SEED RADIOSENSITIVITY OF SOME CROPS*

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Abstract

Radiosensitivity estimations utilizing the morphological criterion; Germination count X Seedling height (both percent of control) x 100—seedling performance; were made for *Allium cepa* L., *Pisum sativum* L. cv. Laxton Superb and Alaska, *Lycopersicon esculentum* Mills cv. Glamour, *Euphorbia lagascae* S. 2n and 4n, *Citrullus vulgaris* S. cv. Crimson sweet, and *Cucumis sativus* L. cv. MR 17. The extrapolated field performance yielded D50 values (in Kiloroentgens) of 40.5, 12.0 and 15.3, 40.0, 17.3 and 16.0, 16.0 and 55.0 for the respective crops. Diploid *E. lagascae* was more radioresistant than its tetraploid. Growth phases (seedling performance) for all crops were negatively correlated with ascending dosage. This, and the goodness of fit of the respective data to regression lines were highly significant.

Introduction

The occurrence and type of mutation are determined not only by dosages and nature of the mutagenic factor but also by the biological characteristics of the specimen, that is, its radiosensitivity. This knowledge has a direct bearing on the problem of irradiating seed before planting and the possibility of using ionizing radiation to control plant activity and mutability.

The usual tests of plant sensitivity to mutagens in X_1 are lethality, mitotic/meiotic chromosome aberrations, seedling growth reduction, and sterility (Ehrenberg et al, 1961; Gaul 1963). In this study sensitivity of some crops has been estimated using germination and seedling height as an index of seedling performance according to the technique of Osborne & Lunden (1961).

Materials and Methods

Year old seeds of *Allium cepa* L. cv. Yellow Sweet Spanish; *Pisum sativum* L. cv. Laxton Superb, and Alaska; *Lycopersicon esculentum* Mills cv. Glamour; *Euphorbia lagascae* S. 2n and 4n; *Citrullus vulgaris* S. cv. Crimson Sweet; and *Cucumis sativus* L. cv. MR 17: were used.

Varying number of seed lots each of 40 seeds were prepared for acute gamma radiation exposures from a ^{60} Co 4500 Ci source. Dosages in kiloroentgens were:

A. cepa 2.5., 5, 7.5. 10, 12.5, 15, 20, 25, 30, 40, 50

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P. sativum (both cultivars)	2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 24
L. esculentum	2.5., 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60
E. lagascae (2n and 4n)	2.5., 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60, 70
C. vulgaris	2.5., 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60
C. sativus	2.5., 5, 7.5, 10, 15, 20, 25, 30, 40, 50, 60

An extra seed lot of each served as the control. Seed moisture content prior to irradiation was 8.7;10.8, 10.8; 9.3; 7.6, 7.6; 12.4; and 11.9 percent respectively.

The seeds were planted immediately after irradiation in flats filled with a steam sterilized soil mixture of 2 parts soil, 1 part sand, and 1 part peat. For each crop a randomized complete block design with 4 replications was used, with 10 seeds per treatment per replication.

The factors for seedling performance (seedling height and germination) were recorded 15 days after 50 percent germination in controls. Following graphic (reversed log) representation of the seedling performance and extrapolation to field performance, D_{50} dosages were determined. Such data also served for conducting the analysis of variance for each crop, on which correlations, regression equations, and goodness of fit were also calculated.

Results

The rapid germination in the lower dosages for all crops was not better than control when final observations were made. Growth stimulation was completely lacking. The seedling performance was significantly reduced with increased radiation dosages for all crops (Tables 1 and 2). *P. sativum* cv. Alaska was more radioresistant and taller than cv. Laxton Superb, with D_{50} estimated at 15.3 KR. for cv. Alaska and 12.0 KR. for cv. Laxton Superb. The diploid *E. lagascae* were taller than the tetraploids and more radioresistant. D_{50} estimations were 17.3 KR. for diploids compared to 16.0 KR. for tetraploids.

L. esculentum and *A. cepa* were more radioresistant than others (except *C. sativus*) with D_{50} of 40.0 and 40.5 KR. respectively. These values for *C. vulgaris* and *C. sativus* were 16.0, and 55.0 KR. (Table 2).

Table 1. Seedling performance and D_{50} values for *Pisum sativum* cultivars.

Cultivars	Dosages in kiloroentgens (KR.) 0	2	4	6	8	10	12	14	16	18	20	24	LSD 0.05	D_{50}
Laxton	1.00	.99	.99	.97	.91	.86	.78	.19	.11	.06	.04	0	.01	12.0
Alaska	1.00	.99	.98	.98	.97	.88	.83	.85	.76	.71	.53	.28	.05	15.3

Table 2. Seedling performance and D_{50} values for other crops.

Crop	Dosages in kiloroentgens (KR.) 0	2.5	5	7.5	10	15	20	25	30	40	50	60	70	LSD 0.05	D_{50}
Euphorbia lagascae (2n)	1.00	.95	.96	.93	.92	.91	.50	.16	.13	.04	0	0	0	.03	17.3
Euphorbia lagascae (4n)	1.00	.94	.94	.93	.85	.83	.18	.10	.07	0	0	0	0	.01	16.0
Lycopersicon esculentum	1.00	.98	.97	.97	.96	.95	.94	.91	.88	.78	.43	.29	x	.04	40.0
Allium cepa	1.00	.99	.99	.99	.98	.98	.96	.92	.92	.89	.80	.24	x	.03	40.5
Citrullus vulgaris	1.00	.99	.98	.91	.89	.83	.36	.26	.16	.11	.07	.03	x	.08	16.0
Cucumis sativus	1.00	.98	.97	.95	.94	.92	.88	.83	.86	.85	.84	.68	x	.06	55.0

Highly significant negative correlations of dosage and seedling performance were obtained, with a similar significance for the goodness of fit of the data to respective linear regression lines (Table 3).

Table 3. Goodness of fit to regression line (t), correlation coefficient of dosage and seedling performance (r), and equations of linear regression of dosage on the seedling performance.

Crop	"t"	"r"	n	linear reg. eq.
Lycopersicon esculentum. (Glamour)	532.3**	—0.923**	12	y = 102.8—1.171x
Allium cepa (Y.S.S.)	381.3**	—0.862**	12	y = 114.2—1.144x
Pisum sativum (Laxton)	188.0**	—0.922**	12	y = 118.6—5.451x
Pisum sativum (Alaska)	174.4**	—0.912**	12	y = 111.2—2.668x
Euphorbia lagascae (2n)	562.1**	—0.889**	13	y = 89.7—1.574x
Euphorbia lagascae (4n)	483.2**	—0.854**	13	y = 82.8—1.498x
Citrullus vulgaris (C. Sweet)	520.3**	—0.916**	12	y = 92.9—1.769x
Cucumis sativus (MR_{17})	645.7**	—0.943**	12	y = 98.9—0.452x

** = significance at $p \geqslant 0.01$

Discussion

Early germination at low dosages and inhibition at high dosages has been reported (Stein & Richter, 1961), as has inhibition of germination at high dosages (Haber & Luippold, 1959; Amer & Hakeem, 1964), and decrease in seed germination with enhancing dosages (Das & Mukherjee, 1968). Goud et al (1969), Bajaj et al (1970) and Ramulu (1970) additionally reported reduced growth characteristics with increased radiation dosages. The negative seedling performance/dosage correlation for the crops in this study provide added support to this growth trend. The D_{50}'s evaluated have ranged from 12.0 KR for *P. sativum* cv. Laxton to a comparitively resistant 55.0 KR. for *C. sativus*. The taller cv. Alaska peas and diploid *E. lagascae* are more radio-resistant than the shorter cv. Laxton Superb peas and tetraploid *E. lagascae* respectively, emphasising that cultivar and ploidy levels differ in radiation response. Variations due to these factors have been earlier suggested, Fujii (1962). Higher ploidy levels are more radioresistant than lower levels but exceptions too prevail, Sparrow & Evans (1961). Bhaskaran & Swaminathan (1961) further inferred from X-ray effects on 2x, 4x and 6x *Triticum*, that cytological abnormalities were greater in the hexaploids. The higher ploidy levels acted as a buffer for the cytological abnormalities rendering them more radioresistant than diploids. The results obtained for diploid and tetraploid *E. lagascae* based on seedling performance and 100 percent lethality indicate the tetraploids to be more sensitive than diploids. The slower and compact growth habit of the tetraploids is in accordance to earlier findings of Singh (1968). The nuclear volumes of the diploid and tetraploid were not investigated, but may be an influencing factor in the varied response obtained. In the usual situation described in tetraploid plants recently derived from diploids, the polyploid nuclei are generally considerably larger than the diploid (the DNA 2x greater) and the amount of chromosome breakage produced seemingly proportional to the chromosome number (Conger & Johnston, 1956). In certain naturally occurring polyploid species the average nuclear volume of a fairly high polyploid may be equal to that found in a closely related diploid. Sparrow et al (1961) considered it theoretically possible for a polyploid nucleus to be disproportionately larger than the diploid. If this were true, it could account for occasional cases in which a polyploid would be more sensitive than the closely related diploid. In the reverse case in which the average space occupied by a genome in a polyploid is considerably less than that in a diploid, the polyploid would be protected first by polyploidy, and then by its low nuclear volume. It is thus clear that both the degree of polyploidy and the nuclear volume would influence the radiosensitivity determinations.

The LD_{50} for *L. esculentum* cv. Glamour was estimated at 40.0 KR., and for *A. cepa* cv. Yellow Sweet Spanish at 40.5 KR. The LD_{50} for *L. esculentum* cv. Rutgers has been reported (Osborne & Lunden, 1961) at 14.0 KR., average of 2 at 37.0 KR., and of 3 at 13.0 KR. The range is suggestive primarily of the cultivar differences enhanced by influencing (modifying/suppresing) variables. The estimations for *C. sativus* cv. MR. 17 and *C. vulgaris* cv. Crimson Sweet are 55.0 KR. and 16.0 KR., contradictory to earlier findings (Osborne & Lunden, 1961), where *C. sativus* was in the sensitive (10.0-18.0 KR.) and *C. vulgaris* in the more resistant 55.0-72.0 KR. range.

The results of this investigation have presented dose estimation values that for a few fall in the earlier predicted ranges but marked variations are also apparent. Both the similarities and variations are attributed to chance as no attempts were made to precondition the seeds for making balanced comparisons. This is evidence enough that to achieve reproducibility of radiosensitivity results or for acceptance of early predicted results, experimentation techniques should aim at conducting replicated experiments under as similar conditions as prevailed during the first or allow for variability to modify the values.

For all crops the negative seedling performance and dosage correlations were highly significant as was also the goodness of fit of the data to the regression line (Table 3). Although cellulai criterion (Physiological and Cytological) are better indices for radiosensitivity estimation (Mujeeb 1970) rapid morphological assessment entities of high significance may be advantageous as is evident for these species. The latter test may additionally be used for material that does not facilitate physiological estimation (leaf stippling), or is a complicated cytological material.

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