References and Notes

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Pollen Tube Growth in vivo as a Measure of Pollen Viability

Abstract. Observation by fluorescence of tomato pollen tubes in fixed styles clearly showed that all pollen samples grew regardless of age and fruit or seed setting potential. Methods commonly used to evaluate pollen viability, such as staining and germination, may predict growth in the style but do not always predict seed setting ability.

In the course of a study of the physiological and cytogenetic consequences of aging tomato pollen, it was discovered that older pollen lots often induce fruit setting without seed formation. Similarly induced parthenocarpy has been observed by McGuire (1) and others. Since this response suggested that fruit setting was induced as a result of pollen tube activity even without fertilization, a study was undertaken of tube growth in styles to which aged pollen had been applied. The dependable and rapid method of Martin (2) for staining pollen tubes in the style has greatly facilitated the study.

Although in vitro pollen germination has served as a useful indicator of fruit set in apples and pears under controlled conditions (3), a dependable measure of pollen viability (seed-setting ability) has been sought for a long time in

other plants. Research on pollen physiology and programs of plant hybridization would be expedited if there were available a method for estimating seedsetting potentials which would not require waiting until ripe fruits could be sectioned. The frequent failure of such methods as staining the pollen itself or germination of pollen in vitro to predict seed set or even fruit set has been repeatedly demonstrated (4); in fact, Visser cites a negative relationship between germination in vitro and fruit set in a number of crops (3).

Several series of experiments with stored and fresh tomato pollen from the various varieties in the field and greenhouse were undertaken in 1959 (5) and repeated in 1960. The pollen samples were collected in gelatin capsules and stored immediately at 0°C over CaCl₂. These conditions were found to be the best for tomato pollen storage by McGuire (1). The oldest pollen was collected in 1956 and 50 other samples were collected at various later times. Three genetically different male-sterile lines (6) were pollinated in the greenhouse with both stored pollen and control pollen which had been freshly gathered from genetically identical sources. All pollen lots were judged to be 90 to 100 percent "viable" after testing by acetocarmine staining and germination in 20 percent sucrose. Twenty or more hours after pollination, two to five styles from each group of pollinations were fixed in formalinaceto-alcohol, stained with aniline blue, and observed under ultraviolet light according to Martin's technique (2). Since pollen tubes penetrate to the ovule of the tomato in 12 to 15 hours, styles may be removed from the ovary after that time and the tubes observed without jeopardizing potential fruit or seed set. Thus information on tube growth, fruit set, and seed set can be obtained from each pollination.

Table 1. Pollination results from tomato pollen samples stored at 0°C over CaCl₂.

| Parents | | Pollen | Pollen | Flowers | Total | Total |
|---|---------------|--------|------------|---------|--------|-------|
| Female | Male | (mo) | per style* | nated | fruits | seeds |
| $m_{S_{17}}, a_1, c, d_1, l$ | Early Pak | 50 | 20-50 | 5 | 0 | 0 |
| Pearson (ms ₂) | Early Pak | 38 | 10-20 | 17 | 0 | 0 |
| Pearson (ms ₂) | Pearson | 17 | 50-100 | 12 | 0 | 0 |
| Pearson (ms ₂) | \mathbf{XL} | 14 | 150-200 | 27 | 6 | 4 |
| Pearson (ms ₂) | Pearson | 14 | 150-200 | 7 | 5 | 0 |
| ms2, a1, hl | VF36 | 6 | 75-100 | 5 | 1 | 4 |
| Pearson (ms ₂) | Pearson | 4 | 150-200 | 11 | 9 | 100 |
| ms_2 , a_1 , hl | VF36 | 3 | 100-150 | 5 | 2 | 40 |
| ms_{2}, a_{1}, hl | VF36 | Fresh | 150-200 | 5 | 3 | 60 |
| Pearson (ms ₂) | Pearson | Fresh | 150-200 | 5 | 5 | 250 |
| ms ₁₇ , a ₁ , c, d ₁ , l | Pearson | Fresh | 150-200 | 5 | 4 | 220 |

* Range observed in sample of two to five styles.

Table 1 gives representative findings from 8 of the 50 stored samples. The number of pollen tubes in column 4 represents the range found in the twoto five-style sample. The majority of the pollen tubes had grown the full length of the styles. Pollen lots older than 6 months produced some seedless fruits, and those older than 14 months failed to produce any fruits; yet pollen tube growth was observed in all styles regardless of pollen age. While staining and germination may predict growth in the style, such growth certainly does not measure fruit and seed setting capacity. It is clear from these simple tests that observing pollen tube growth in vivo also fails to serve as a reliable index of fruit or seed setting ability.

Comparable results have recently been reported by Nishiyama and Tsukuda (7) for x-irradiated tomato pollen, although responses in styles were not investigated. In their experiments, doses up to 10⁵ r did not reduce germination in vitro but did eliminate fruit and seed set. At lower levels of irradiation, seedless fruits were reported. Fruits with viable seeds were produced only at the lowest levels of irradiation.

The seedless fruits produced in our experiments characteristically contained aborted ovules of varying sizes. Those seeds which appeared normal in size germinated in soil and were 60 to 80 percent viable. However, the seedlings from the older samples of stored pollen produced a high proportion (40 to 50 percent) of mutant plants abnormal in appearance or in pollen production (8).

The ability of stored and irradiated pollen to produce pollen tubes which elongate both in the style and in sugar solutions but which do not produce seed adds to the evidence of Johri and Vasil (4) and Visser (3) that "pollen viability" tests, other than seed production itself, may be quite unreliable. The large proportion of mutant seed produced by aged pollen suggests damage to the nucleus. However, this does not necessarily mean that the nuclei are functionless in directing pollen tube growth or even incapable of entering into fertilization. A useful measure of seed setting ability of pollen will have to be sought with these possibilities in mind. Meanwhile, further studies of the pollen tube mitosis, fertilization, and embryo development with aged or irradiated pollen should add important knowledge to these phenomena.

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Visual Velocity Discrimination: Effects of Spatial and Temporal Cues

Abstract. Weber ratios were obtained for visual velocity discrimination under three topographic conditions with the same subjects and psychophysical procedures. The conditions differed regarding the presence of either temporal or spatial cues. these being correlated in magnitude with stimulus velocity. Systematic effects of the cues upon the level of velocity discrimination were noted.

While several investigators (1) have studied visual velocity discrimination, a consistent theoretical position has not emerged regarding the relation between spatial and temporal discrimination and visual velocity discrimination (2, 3). Attempts to analyze velocity discrimination into two parts, temporal discrimination and spatial discrimination, have resulted in divergent conclusions. J. F. Brown has suggested: "the velocity of moving objects is perceived directly and does not depend upon indirect judgments" (2). On the other hand, the position has been taken that some cognitive operation relating the perceived magnitude of a spatial displacement to the perceived duration of the displacement is necessary for a velocity judgment. The implications of this position have been observed by Boring who, in discussing perception of movement and time, notes that "both perceptions have been considered to be, in their essentials, independent of the properties of the particular organs of sense and thus almost wholly dependent upon the action of the central nervous system" (3).

A problem inherent in the measurement of velocity discrimination is that either spatial or temporal cues may be regularly related to the stimulus velocity, depending upon the kinds of displays adopted by the experimenter. The method used most frequently is one in

which the standard and comparison stimuli move in a field of equal and fixed spatial dimensions. Accordingly, the relative velocity of the comparison stimulus may be inferred from its relative duration in the movement field. R. H. Brown's review of the subject describes nine studies, eight of which employed viewing conditions which were essentially "isometric" in the foregoing sense (1). In the ninth study, both standard and comparison targets were presented together and initially superimposed. In this case, an angular offset occurs between the targets, and the target which is "ahead" at any moment is the one that is moving faster. Weber ratios obtained under the latter condition were substantially lower $(\Delta \omega / \omega = .00128)$ than the average for the other eight studies ($\Delta \omega / \omega = .1074$).

This large difference, while suggesting the influence of temporal and spatial cues upon velocity discrimination, cannot be attributed to these variables alone. The data were obtained by means of a variety of psychophysical procedures, with different subjects, and under unmatched overall conditions.

Our study was designed to permit comparison of Weber ratios gathered under three conditions, differing only with respect to the spatial or temporal cues which accompanied each stimulus presentation. The conditions common to all phases of the experiment were: psychophysical method, constant stimuli; stimulus object, spot of light 0.030 inch in diameter on the face of a cathode ray tube; velocities of the six standards, 20.06, 40.12, 80.25, 177.21, 256.35, and 512.71 minutes of visual angle per second; and subjects, two female college graduates with emmetropic vision. A trial consisted of a single traversal from left to right of the standard velocity stimulus followed within 4 to 5 seconds by a single traversal of one of the five comparison stimuli. "Faster" or "slower" responses were required. For one-half of the trials the order of standard and comparison was reversed. Blocks of 25 trials under each of the following conditions were presented in counterbalanced order:

Isometric. The standard and comparison stimuli traversed equal extents (343.2 minutes of visual angle), hence the duration of the stimulus transit varried inversely with the velocity.

Isochronal. The standard and comparison were in motion for equal durations (0.6 second). The extent of traverse varied directly with velocity.

Heterodimensional. The stimuli



Fig. 1. Weber ratio functions for both subjects under the heterodimensional, isometric, and isochronal conditions.

moved over extents and for durations which were "randomly" changed from presentation to presentation. In this condition velocity could not be successfully inferred from either the extents or the durations of the comparison stimuli.

Difference thresholds based on 100 trials for each standard were computed by an algebraic equivalent of the average z score method (4). The difference thresholds $(\Delta \omega)$ were converted to Weber ratios $(\Delta \omega / \omega)$ and plotted as a function of angular velocity (Fig. 1). Two other subjects had been tested under the same conditions in an earlier pilot study. The order of their Weber ratios as a function of stimulus conditions was the same as in Fig. 1 (5).

The hierarchy of Weber ratio functions for both subjects indicates thatat least for the range examined-discrimination is finest when a spatial cue is present, intermediate in the presence of a temporal cue, and poorest when neither a spatial nor a temporal cue is related to the stimulus velocity.

In view of the finding that both types of cues are effective in improving velocity discrimination, it appears reasonable to assume that the cue which is more effective is the one which can be more readily detected. This interpretation implies that within the ranges of spatial (12.04 to 307.63 minutes of visual angle) and temporal (0.67 to 17.16 seconds) values over which the stimuli were seen to move, spatial discrimination is relatively finer than temporal discrimination [that is, $(\Delta s/s) < (\Delta t/t)$]. This inference is consistent with the directly measured precision of visual spatial judgments (6) as compared with the precision of differences in temporal intervals (7).